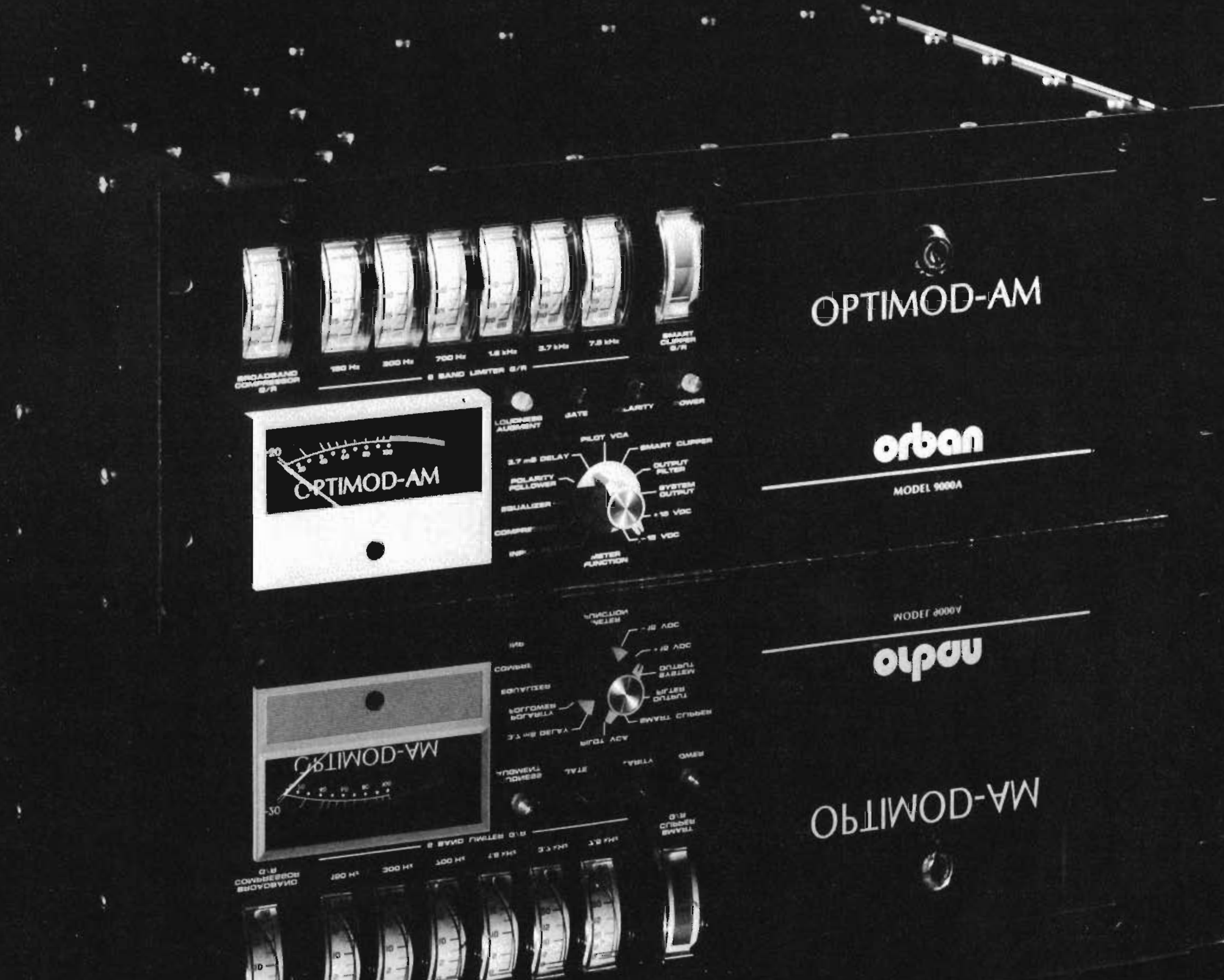
Operating Manual

OPTIMOD®-AM

Model 9000A/1



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Operating Manual

OPTIMOD®-AM

Model 9000A/1

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Call Toll Free: (800) 227-4498
In California (415) 957-1067

Orban Associates Inc. 645 Bryant Street San Francisco, CA 94107

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OPTIMOD-AM OPERATION AND MAINTENANCE MANUAL

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Section I

SYSTEM DESCRIPTION

INTRODUCTION

OPTIMOD-AM is a powerful system for obtaining the best possible quality from the AM broadcast medium. This medium includes the transmitter plus the listener's receiver, listening environment, and ear. OPTIMOD-AM is therefore configured to enable the station to pre-correct for certain unsatisfactory receiver characteristics, and to compensate for typical AM listening environments, like autos. Some receiver problems include extreme high frequency rolloff and moderate to severe bass rolloff; listening environments often contain high ambient noise which require considerable compression of program dynamic range to produce comfortably listenable sound. OPTIMOD-AM's built-in equalizer is capable of performing equalization which will accurately correct for the high frequency rolloff in an AM receiver which Orban/Broadcast's extensive research into the characteristics of AM receivers has defined as "typical". And OPTIMOD-AM's compressor and limiter circuits are capable of high degrees of dynamic range reduction with an unprecedented lack of side effects.

A receiver that is "typical" right now may well be "atypical" in future years. In addition, the use of extreme high frequency equalization makes tuning of the receiver more critical than such tuning with little or no equalization. For this reason, the equalization and other system parameters have been made completely adjustable; the system can be operated with extreme equalization, flat, or anywhere in between.

The completely-adjustable dynamic signal processing (including the Six-Band Limiter section and the "Smart Clipper" peak limiter) is uniquely suited to the task of conditioning a highly preemphasized signal so that it can be broadcast without objectionable distortion, loss of loudness, interference to other stations, or audible "action". Such "action" is often the indirect result of the large amount of high frequency energy which is rolled off at the receiver, but which may cause poorly designed audio processors to punch holes in the audio, to cause severe intermodulation distortion (such as splattered "esses"), and/or to produce other audibly unpleasant effects.

In addition to its unique equalization capabilities, OPTIMOD-AM has many other features not found on conventional audio processing equipment. Much of the systems concept is unique and revolutionary, and is subject to patent applications.

Because of OPTIMOD-AM's extreme versatility, it is very important that the sections of this manual regarding setup and adjustment be read and carefully understood. It will be seen that the OPTIMOD-AM system has many conceptual similarities to a conventional system consisting of a compressor, graphic equalizer, and peak limiter. This should help you install and adjust the system because of its familiar topology.

We have tried to design this manual as a tool to help you get the most out of OPTIMOD-AM, and to give you as much help as possible should something go wrong. Thus, we have purposely repeated much information in different sections.

WHEN YOU FIRST RECEIVE YOUR OPTIMOD-AM:

1) Read the **SYSTEM DESCRIPTION (Section 1)** to familiarize yourself with the basics of the device.

2) Then read **INSTALLATION (Section 2)** <u>thoroughly</u>, and install OPTIMOD-AM in the station.

3) If you want to get on the air <u>quickly</u>, the beginning of **SETUP AND ADJUSTMENTS (Section 3)** has abbreviated instructions to get you started.

4) To make the most of OPTIMOD-AM's special capabilities, it is important that you read and digest the full **SETUP AND ADJUSTMENTS** section soon after installation. This section was written so that both the Program Director and Chief Engineer can benefit.

IF TROUBLESHOOTING IS NECESSARY:

Refer to **Trouble Diagnosis and Correction** in the **MAINTENANCE** section for information on the most efficient way to diagnose and repair faults.

ASSUME NOTHING! IN PARTICULAR, DON'T ASSUME THAT OPTIMOD-AM's SUPERFICIAL SIMILARITY TO CONVENTIONAL SYSTEMS MEANS THAT IT CAN BE TREATED IDENTICALLY. BEST RESULTS CAN ONLY BE OBTAINED BY READING AND UNDERSTANDING THIS MANUAL.

SYSTEM DESCRIPTION

REFER TO THE FOLD-OUT BLOCK DIAGRAM
AT THE BACK OF THIS MANUAL.

The audio signal path through OPTIMOD-AM consists of seven basic cascaded sections. These are:

1) INPUT BUFFER AND CONDITIONING FILTERS
2) BROADBAND GATED COMPRESSOR/NOISE GATE
3) MAIN PROGRAM EQUALIZER
4) SIX-BAND LIMITER
5) POLARITY FOLLOWER
6) SMART CLIPPER
7) OUTPUT LOWPASS FILTER AND SAFETY CLIPPER.

A DESCRIPTION AND DISCUSSION OF EACH OF THE BLOCKS FOLLOWS.

1) Input Buffer And Conditioning Filter: The input buffer amplifier receives the signal from the phone line or STL and amplifies it to the point where the rest of the system is operated in the optimum part of its range. The INPUT LEVEL control determines the gain of the buffer, and thus the amount of gain reduction produced by the next section, the Broadband Compressor.

The input filter, which is bypassable with the INPUT FILTER IN/OUT switch performs three separate functions:

1) It highpass-filters the input signal at 100Hz at 18dB/octave;

2) It lowpass-filters the input signal at 11kHz at 36dB/octave;

3) It creates a mild preemphasis of approximately 10dB at 6kHz. (This preemphasis was chosen to minimize the audible action of the following Broadband Compressor by deemphasizing bass which might cause pumping, and to perform what we consider the minimum acceptable amount of high frequency preemphasis on the signal to improve crispness and intelligibility on typical contemporary AM receivers.)

(**NOTE:** For instructions for retuning the highpass filter and for defeating the preemphasis without losing the lowpass fuction, see **6.e** of the **INSTALLATION** section.)

2) Broadband Gated Compressor: The Broadband Compressor compensates for varying dynamics on records and for operator sloppiness so that subsequent sections are driven with optimum audio levels. In this way consistent sound is achieved despite normal production variations. The Broadband Compressor is not designed to produce significant augmentation of program density; such augmentation is produced far more effectively by the Six-Band Limiter following. Accordingly, the Broadband Compressor's attack time is moderate and its release time is slow.

In order to avoid audible noise pump-up (because of the slow release time), the gain of the Broadband Compressor is held constant if its input level falls below a user-adjustable GATING THRESHOLD level. The gating threshold level detector is bandlimited from 100 to 3000Hz to prevent false ungating on noise.

The amount of compression provided by the Broadband Compressor is adjusted with the INPUT LEVEL control; a 20dB range is available. The amount of compression produced is continuously indicated on the BROADBAND COMPRESSOR GAIN REDUCTION METER on the front panel. The INPUT LEVEL control should be set conservatively so that screaming D.J.'s and pegged console VU meters do not force the BROADBAND COMPRESSOR GAIN REDUCTION METER offscale.

3) Main Program Equalizer: The main Program Equalizer consists of three sections. The available curves provided by these sections have been carefully selected to readily enable effective correction of the frequency response limitations of conventional AM receivers. More than 30dB of equalization is available at 10kHz. Ordinarily, use of such large amounts of equalization would cause severe difficulties in the audio processing equipment following the equalizer. However, the audio processing in the OPTIMOD-AM has been specially designed to deal with such equalization. The Six-Band Limiter section acts as an unusually effective high frequency limiter; the program-controlled release time circuitry permits as much as 30dB compression of a given high frequency band without audible side effects. In addition, the "Smart Clipper" peak limiter is controlled by a psychoacoustical estimate of the audibility of clipping distortion. "Mud" caused by intermodulation products is reduced up to 30dB below 1.8kHz by sophisticated circuitry. Thus peaks and spikes caused by high frequency preemphasis can be clipped (typically up to 12dB), thus avoiding the pumping that would result if gain reduction were used instead of clipping.

A brief description of the three equalizer sections follows:

Bass Equalizer: The bass equalizer provides a peaking boost. This equalizer is "Parametric". This means that continuously variable control is provided over the amount of peak equalization (0 to 10dB), bandwidth ("Q"= 0.3 to 1.4), and tuning (maximum peak boost frequency variable from 80 to 120Hz).

5kHz Equalizer: This is a peaking equalizer with adjustable boost (0 to 20dB) and bandwidth ("Q"=1.0 to 2.2). Tuning is not adjustable. 5kHz is a very critical frequency, because this is the highest frequency which most AM radios can reproduce with appreciable loudness. Radios are typically down 20-30dB at this frequency. However, this is partially compensated by the fact that the ear is very sensitive to 5kHz.

10kHz Equalizer: This equalizer has a very special shape; it is quite unlike ordinary commercial program equalizers. It is a fourth-order equalizer (ordinary equalizers are second-order); this means its slopes are 12dB/octave instead of 6dB/octave. This selectivity means that this equalizer can provide a great deal of boost in the 10kHz region (up to 20dB) without excessive boost in the midrange, which would inevitably cause harshness and stridency.

4) Six-Band Limiter: Following the main equalizer, a set of six parallel filters divides the signal into frequency bands. The highest and lowest bands are highpass and lowpass respectively; the other bands are bandpass.

Since the average AM receiver is only flat to about 1.5-2kHz, the midrange is far more important in AM than in FM. Unlike a conventional triband processor, the six bands in OPTIMOD-AM can perform significant correction of midrange frequency balances, yielding a more consistent, intelligible, and pleasing sound with widely varying program material. The six bands are particularly useful in correcting intelligibility problems with low-grade speech, like telephone calls or actualities.

To permit large amounts of limiting without interaction and pumping, the filters have been designed with 12dB/octave slopes. When the filters' outputs are summed, the resulting output is typically flat ±0.75dB over the frequency range of the OPTIMOD-AM. Due to careful computer design of the filters, audible "holes" are not added to the frequency response under dynamic conditions.

Each filter is followed by its own limiter. Orban/Broadcast research has discovered that the characteristics of these limiters are extremely critical if proper frequency response and inaudible operation are to be maintained under dynamic program conditions. For this reason, none of the limiter characteristics are user-adjustable. The only user control affecting the Six-Band Limiter section is the DENSITY control, which controls the input drive to the entire section, thus determining the amount of compression produced under operating conditions.

The Six-Band Limiter section, because it operates in several frequency bands and exploits the "masking" effect, is capable of more compression without audible side-effects than either of the two broadband processing sections in the OPTIMOD-AM. We call it the "density augmentation" section because the individual limiters operate with fast release times and substantially improve the peak-to-average ratio of the signal without the pumping which would result if only one limiter were used for the entire frequency spectrum.

If you are familiar with other multiband audio processing systems, you should be aware that OPTIMOD-AM is fundamentally different in that its multiband section is primarily a limiter, not a compressor. Devices which attempt to perform a compression function with a multiband AGC run a severe risk of causing unnatural frequency balances if their input levels are not well-controlled. This is because certain bands may exhibit heavy gain reduction while others may exhibit little or no gain reduction. Those bands exhibiting heavy gain reduction will, of course, cause an effect similar to a graphic equalizer which is adjusted to severely dip its frequency response in said heavily-compressed bands. This, in turn, can overemphasize those frequencies which have so little energy at the input to the multiband compressor that they cause little or no gain reduction in their bands.

To control such potential problems, average levels into the Six-Band section are controlled by the slow Broadband Compressor so that excessive gain reduction never occurs in the Six-Band section. Note that the low frequency band only is gated by the same gating voltage which gates the Broadband Compressor. This is to avoid pumping up rumble and/or electrical or mechanical hum (from cart machine motors, for example).

5) Polarity Follower: In order to achieve maximum loudness, the Polarity Follower makes sure that asymmetrical program material always modulates the transmitter more highly in the positive than in the negative direction. Because the Six-Band Limiter tends to make peaks more symmetrical, input symmetry is not strictly preserved; however, voice remains sufficiently asymmetrical to fully utilize the legal 125% positive modulation limit currently permitted under FCC rules.

Orban/Broadcast research has developed a new type of polarity switcher which completely alleviates the problems found in earlier designs. In earlier designs, either a pop is produced on switching (with zero-crossing detection, which can only minimize, not suppress pops), or switching is delayed until a pause in the program is detected (which might take many seconds in the case of voice with a music "bed"). Because of our new "soft" switching technique, the polarity of the program can be reversed in approximately one second at any time, during any program material, without audible effects. In addition, the loudness improvement resulting from the polarity switching "fades in" in the course of the switching, rather than coming in suddenly and calling attention to itself. No user controls are provided or necessary; if the user wishes to defeat the function, instructions for doing so are provided in subsection **6.d** of **INSTALLATION (section 2).**

The operation of the Polarity Follower is indicated by the POLARITY LED on the front panel; the soft switching characteristic is easily seen. Sometimes during musical programming with inconsistent, slightly asymmetrical characteristics, the Polarity Follower will be observed to switch partially, and then to return to its initial state. This is entirely normal and inaudible.

6) "Smart Clipper" Peak Limiter: The "Smart Clipper" is a peak limiting circuit which employs both linear gain reduction and peak clipping. Unlike conventional peak limiters, which are controlled by the peak value of the output (by feedback), the "Smart Clipper" is controlled by a <u>psychoacoustical estimate</u> of the perceived distortion introduced by the clipping process. In addition, a distortion-cancelling circuit reduces clipping distortion in the frequency range from 0 to 1.8kHz up to 30dB.

The highly sophisticated control and distortion-cancellation circuitry employed by the "Smart Clipper" allows up to 12dB of clipping to occur without objectionable distortion. This in turn means that the very high peaks introduced by the extreme preemphasis can be controlled without loss of loudness, because they can be severely clipped without the usual distortion problems.

The "Smart Clipper" has four user adjustments. The first is an input attenuator called SMART CLIPPER DRIVE which determines, in conjunction with the CLIPPING control, the amount of gain reduction and/or clipping produced. The CLIPPING control determines the amount of perceived sound-quality <u>change</u> (usually a timbre change and/or added distortion) produced by the clipper. The control should be adjusted according to individual taste; there is a direct tradeoff between loudness and distortion. As the CLIPPING control is turned clockwise, more clipping and less gain reduction are produced for a given setting of the SMART CLIPPER DRIVE control.

The third control is called LOUDNESS AUGMENTATION. As it is turned progressively clockwise, it permits added clipping on certain material (like percussion) whose clipping-induced sound quality change is not perceived as distortion, but rather as loss of brightness or some similar perceptually acceptable change. The added clipping perceptually increases the loudness of such material. Since such material is usually naturally louder than its surroundings, the added clipping (which occurs instead of gain reduction) results in a less heavily-limited, "squashed" sound.

The fourth control affecting the operation of the "Smart Clipper" is the POSITIVE PEAK THRESHOLD control. This control adjusts the asymmetry of the system output by adjusting the clipping level on positive peaks, and leaving the clipping threshold of negative peaks fixed.

The "Smart Clipper" is an extremely powerful signal processing tool. It permits highly preemphasized program material to be broadcast with loudness comparable to non-preemphasized program material, and without audible "action" or other side effects. You should should experiment at length to determine how its power can best serve your individual format and sound.

7) Output Lowpass Filter, Safety Clipper, Transmitter Equalizer, And Output Amplifier: The clipping process occurring in the "Smart Clipper" causes the addition of harmonic energy above the permissible transmission bandwidth of the AM broadcast system. Because of the heavy clipping usually employed, harmonic energy can reach excessive (and potentially illegal) values, with potential for causing adjacent channel interference unless a lowpass filter is employed.

Therefore, a 30dB/octave lowpass filter is included in the system after the "Smart Clipper" output. Ordinarily, the cutoff frequency of this filter is 11kHz. (**NOTE:** Certain unusual situations may require the use of lower cutoff frequencies. Thus 6kHz and 8kHz filters are available as options. Optionally, two different filters may be selected by remote control for day or night operation.)

The lowpass filter is followed by a safety clipper which simultaneously clips overshoots induced by the lowpass filter and overshoots induced by the addition of the distortion-correction signal in the "Smart Clipper".

The clipping distortion cancellation employed tends to make asymmetrically-clipped material more symmetrical. Thus setting the main POSITIVE PEAK THRESH control at 125% may not result in consistent 125% peaks, depending on program material.

To fully utilize the 125% positive modulation capability of the better transmitters, a separate control adjusts the positive safety clipper threshold from 100% to 62% of the setting of the main POSITIVE PEAK THRESH control. The POSITIVE PEAK THRESH control can therefore be set higher than 125% (to produce many peaks at or above the 125% level); fine adjustment of the positive peak level is made with the SAFETY CLIPPER POSITIVE THRESH control.

Circuitry in the control section of the "Smart Clipper" prevents excessive clipping in the safety clipper which could otherwise cause distortion and/or splatter. Spectrum analysis in our laboratory using both severe program material and pink noise has verified that the output spectrum of the OPTIMOD-AM meets all interference requirements specified by the FCC, PROVIDED THAT THE TRANSMITTER ITSELF IS CLEAN AND FREE FROM SIGNIFICANT DISTORTION.

The safety clipper is followed by the OUTPUT ATTENUATOR control. This control is a 10-turn type with a built-in turns-counting dial. Thus, different adjustments for different transmitters can be made easily. Deterioration of modulator tubes can easily be observed by observing loss of modulation sensitivity in those transmitters employing open-loop modulators.

The output level of OPTIMOD-AM is highly stable. Therefore, if changes in the OUTPUT ATTENUATOR are required to produce correct modulation levels, then potential drift or deterioration in the transmitter plant should be investigated. Excessive line voltage variation is also a potential cause.

The OUTPUT ATTENUATOR drives a three-stage transmitter equalizer. This equalizer predistorts the shape of the final-clipped waveform so that the transmitter modulator will reproduce the intended shape. If the transmitter distorts the intended shape of the waveform, then overmodulation can occur.

The first two stages of the equalizer provide correction of the high frequency pulse response of the transmitter/antenna system. An adjustable shelving rolloff eliminates overshoot. Overshoot is further minimized (thus requiring minimum shelving rolloff) by means of a delay equalizer which corrects for nonlinear group delay.

Low frequency tilt is corrected by means of an equalizer which can introduce an adjustable amount of positive-slope tilt to the waveform. The positive-slope tilt cancels the transmitter tilt, permitting accurate reproduction of flat-topped waveforms.

Two sets of equalizer controls are provided. These can be switched by remote control for separate equalization of day and night systems. The system will always come up in "Day" mode on powerup. System status is indicated by green ("Day") and red ("Night") LED's which are visible when the access door on the right side of the OPTIMOD-AM front panel is opened.

The optional "Night" filter is switched by the same logic circuitry as the transmitter equalizer controls. If the "Night" filter option is not included, the "Day" filter will be in the circuit at all times, regardless of the logic state.

The transmitter equalizer is coupled to the output amplifier. The output amplifier is an active, balanced configuration capable of driving +20dBm into 600 ohms.

This concludes the **SYSTEM DESCRIPTION** section of this manual.

Section 2
INSTALLATION

1) Location: OPTIMOD-AM is ordinarily installed in the audio rack next to the transmitter. It can only be successfully installed at the studio if a phase-linear transmission link is available between the output of OPTIMOD-AM and the transmitter input. A composite STL (usually used for FM stereo) is one such link.

System reliability will be substantially improved if the location chosen is adequately ventilated, is not subject to large temperature variations (an ambient temperature of 70 degrees F is ideal), is not subject to high humidity which might cause condensation, and is not subject to vibration such as that caused by large blowers.

While OPTIMOD-AM is very well protected against RFI, a location with lower RF field intensity should always be chosen, all else being equal.

2) Audio Input: The audio input to OPTIMOD-AM is 600 ohm transformer-balanced and floating. Nominal input level ranges from -10dBm to +10dBm with the integral 20dB pad installed. However, if more sensitivity is required, this pad can be modified to produce 6dB loss. (See **6.b** below.)

If a phone line is employed to feed OPTIMOD-AM, it should be connected to the INPUT terminals on the rear-panel barrier strip of OPTIMOD-AM by means of two-conductor shielded cable (Belden 8451 or equivalent). The shield should be terminated at one end of the cable only. Be sure that the telephone company equipment is properly grounded to the station ground, which must, of course, be a very good earth ground. A 15kHz PHONE LINE MUST BE USED IF THE FULL AUDIBLE BENEFITS OF OPTIMOD-AM ARE TO BE ACHIEVED.

The high audio quality that OPTIMOD-AM delivers at the receiver makes increased demands upon the quality of the source material. We recommend that the entire audio plant be brought up to FM standards of distortion and noise, if this has not already been done. Considerable care should be taken in alignment of cartridge machines and turntables. Phono styli should be replaced as soon as an audible increase in distortion occurs, regardless of whether they still look good under a microscope. Audio headroom through the entire system should be checked to make sure that no clipping on live announcer (usually the weak spot in an audio system) occurs. The production studio should be brought up to similar high standards. If these things are done conscientiously, the result will be obviously improved airsound.

If an STL is used, the receiver should be connected to OPTIMOD-AM in the same way as the phone line would be connected. Since all compression occurs after the STL link, the signal-to-noise ratio of the STL is of substantial concern, and every effort should be made to get the best RF transmission path possible, to correctly align the transmitter and receiver antennas, and to make sure the electronics are properly tweaked up. In some cases, it may be necessary to add an STL protection limiter at the studio. If this is done, it should be adjusted so that gain reduction never occurs when normal levels are applied to the STL. Alternately, a compander-type noise reduction system (like Dolby or DBX) may be employed to increase the available dynamic range.

3) Audio Output: The output of OPTIMOD-AM is a transformerless balanced output capable of driving +20dBm into 600 ohms, which is the lowest permitted load impedance.

DO NOT GROUND EITHER SIDE OF THE OUTPUT.

If an unbalanced output is required, it should be taken from either output to circuit ground.

The output of OPTIMOD-AM is very tightly controlled with regard to overshoot, tilt, and ringing. In order to obtain maximum loudness, overshoot, tilt, and/or ringing must not be introduced by the connection between OPTIMOD-AM and the transmitter. This means that if OPTIMOD-AM is mounted at the studio, it cannot be connected to the transmitter through a standard telephone line, since this will exhibit all of the aberrations listed above. For the same reason, no lowpass filter may be used between OPTIMOD-AM and the transmitter. (OPTIMOD-AM's internal lowpass filter renders any such external filter unnecessary.)

A composite STL possesses the requisite characteristics, and can be used to carry the output of the OPTIMOD-AM to the transmitter. However, the output of a typical composite STL receiver is at the wrong level and impedance to directly drive a typical transmitter (which requires +10dBm into 600 ohms in most cases). Therefore, the transmitter must almost certainly be modified to make it compatible with the STL. If this is done, no permission from the FCC is necessary. However, at the time of your next next license renewal, you are required to file a description of the modifications performed (see FCC Rules, sections 73.43, 73.44).

Because use of a composite STL has so many ramifications, we recommend doing so only as a last resort, since installation of OPTIMOD-AM at the transmitter is vastly less complicated.

In installations where OPTIMOD-AM is installed at the transmitter, the output should be connected to the transmitter through double-conductor shielded cable with the shield grounded at one end only.

2

Before installation, we advise disconnecting the output cable from the OPTIMOD-AM, driving it with a good square wave generator (with low impedance output), and checking waveforms at the input stage of the transmitter modulator to make sure that overshoot and/or ringing have not been introduced by the transmitter's input transformer and/or by resonances between the input transformer and the capacitance of the input cable. If such problems are observed, it is sometimes possible to minimize them by placing a 300 ohm 5% 1/4 watt carbon resistor in series with each side of the input line to the transmitter. This may damp out ringing. In other cases, the transmitter's input transformer may have been chosen without regard for its transient response (particularly with older transmitters designed before the advent of "modern audio processing"), and the input transformer may have to be replaced with a better transformer or with an electronic differential amplifier.

This may seem fussy; however, EVERY dB OF OVERSHOOT IS A dB OF LOUDNESS LOST!

IMPORTANT

UNDER NO CIRCUMSTANCES SHOULD ADDITIONAL CLIPPING DEVICES, SUCH AS THE RCA "POWERMAX" OR THE HARRIS "MODULATION ENHANCER" BE EMPLOYED AFTER OPTIMOD-AM! THE ADDITIONAL DISTORTION INTRODUCED BY THESE DEVICES WILL TOTALLY VOID THE ADVANTAGES OF OPTIMOD-AM's "SMART CLIPPER"!

4) Power Requirements: OPTIMOD-AM will operate on either 115 volt or 230 volt AC ±15%, 50-60Hz. To switch voltages, see **5.a.F.**

The AC power cord is equipped with a 3-wire "U-Ground" plug. We do not advise cutting the grounding prong; if you wish to disconnect the chassis from the power line ground, use a 3-to-2 wire adapter.

5) Unpacking And Initial Checkout: You are now ready to proceed with unpacking and installation of your OPTIMOD-AM.

Sometime during the life of your OPTIMOD-AM, you may wish to re-ship or return it. Since it is expensive and heavy, it is advisable to ship it only in the original packing materials which have been carefully designed to protect it. For this reason, it is wise to mentally note the method of packing and to save all packing materials.

If you might be returning it:

-- Don't cut the grounding pin from the power cord (use the adapter provided if you must defeat the safety grounding provision);

-- Set the unit only on soft, clean surfaces to prevent damage to painted or plated surfaces (a folded newspaper will do);

-- Use the nylon-washered rack screws supplied to protect the panel from paint chipping.

Sage advice for repacking and reshipping your unit is contained in **Section 4 (MAINTENANCE), subsection 6.**

Various items are packed with OPTIMOD-AM:

(1) Line Cord
(4) 10-32x3/4" Rack Screws
(1) 3-wire AC Adapter
(1) Operating Manual
(1) Program Director's Manual
(1) 5/64" Allen Wrench (for front panel screws)
(1) Monitor Rolloff Filter Assembly (Orban MRF-1A)

IMPORTANT!

WE RECOMMEND THAT THE PROCEDURE BELOW BE FOLLOWED BEFORE PROCEEDING TO THE FOLLOWING **INITIALIZATION** SUBSECTION (#6). IF THIS IS DONE, FAILURE OF OPTIMOD-AM TO PASS THE TESTS BELOW WILL UNAMBIGUOUSLY INDICATE SHIPPING DAMAGE.

OTHERWISE, FAILURE TO CORRECTLY FOLLOW THE PROCEDURES IN **SUBSECTION 6** BELOW MIGHT ALSO ACCOUNT FOR PROBLEMS.

2

5.a) Physical Examination

A) Perform a general inspection of the perimeter of the unit to check for obvious damage.

DAMAGE CLAIMS MUST BE MADE BY YOU AGAINST THE CARRIER IMMEDIATELY UPON DISCOVERY.

B) Set the unit on a flat, soft surface. Remove the three hex-socket screws at the top of the front panel using the wrench provided. The front panel, which is hinged at the bottom, will then tilt downward and reveal the interior. Inspect for IC's or other loose parts which may have fallen out during shipment.

C) Remove the subpanel through which the controls protrude by twisting the four DZUS fasteners 1/4 turn counterclockwise. Tilt the panel to remove it. This reveals the "card cage".

Various components are mounted in sockets for servicing convenience. It is possible (but improbable) that a component could be dislodged by heavy vibration in shipment. The procedure below should reveal this.

IMPORTANT!

Because of alignment considerations, the various CA3080 and CA3019 chips are not interchangable among themselves. If two or more of these same-type IC's have become dislodged, the affected card may have to be returned for realignment. Check with the factory.

CAUTION

The #4 and #6 cards cannot be removed before the #3 and #5 cards respectively because of mechanical interference. Similarly, the #4 and #6 cards must be installed before the #3 and #5 cards respectively.

D) Starting at the left, using the card ejector tabs, remove the cards for examination in the order: 2,3,5,4,6,7,8,9. (The #1 card is the power supply regulator. It is permanently mounted to the rear chassis apron.) Examine all cards to make sure that all components are properly seated in their sockets. Check with particular care to make sure that none of the can-type IC's are held in their sockets by one row of leads only.

E) When the examination is completed, replace all cards in reverse order, then the subpanel. The subpanel, besides carrying knob identification and calibrations and holding the cards in place, also provides RF shielding for the cards. So all four DZUS fasteners should be engaged.

F) Without applying power to the line cord, turn the power switch on and check the position of the LINE VOLTAGE SELECTOR switch. All units are shipped with this switch in the "115 volt" position. Adjust the selector switch so that the appropriate voltage is indicated. Check the fuse, and replace with the following values if necessary:

115 VOLT: 1/2 amp SLO-BLO, 3AG-type;
230 VOLT: 1/4 amp SLO-BLO, 3AG-type.

G) The front panel may now be closed and fastened using the three hex-socket screws. Normally, all access required from now on can be achieved through the smaller access door (equipped with a single DZUS fastener).

5.b) Initial Electrical Checkout: Plug the power cord into a 115 volt outlet. The unit should spring to life. Check to make sure that the following conditions occur:

A) The green POWER LED is illuminated;
B) The red GATE LED is illuminated;
C) The yellow LOUDNESS AUGMENTATION LED is off;
D) The red POLARITY LED may be either on or off;
E) The VU meter reads "0" in all switch positions except for "+15" and "-15", where it should read approximately 95%;
F) The BROADBAND COMPRESSOR reads 20dB G/R
(Note: it will recover when audio is applied and the gating circuit "unfreezes" its gain);
G) The 150HZ BAND-LIMITER G/R METER reads either 0 or 20dB G/R (This will vary with individual units);
H) Each of the other five BAND-LIMITER GAIN REDUCTION meters reads "0";
I) The SMART CLIPPER GAIN REDUCTION meter is at the top of the green.

If anything is abnormal, the previous steps in **subsection 5** should be reviewed. A preliminary diagnosis should be made, and, if necessary, the factory should be consulted. (See title page for phone and Telex numbers, and address.)

If you wish to perform a more detailed preliminary checkout, refer to the attached "Final Factory Qualification Test Results" which, in conjunction with **Section 3 (SETUP AND ADJUSTMENTS), subsection 5 (PROOF OF PERFORMANCE)** provides a more thorough qualification procedure.

2

You are now ready to proceed with optional Initialization procedures described in **subsection 6** below.

IMPORTANT

OPTIMOD-AM is a major technological breakthrough in audio processing. It enables you to obtain a level of audio quality on AM that has heretofore been thought to be impossible. It fully exploits the limits of the standard AM channel. Its full capability may even exceed the limits of some AM transmitters and/or antennas.

Because OPTIMOD-AM is a much more powerful and complex processor than anything that has heretofore appeared on the market, it is important to:

MAKE NO ASSUMPTIONS!

FAMILIARIZE YOURSELF WITH THE FIRST THREE SECTIONS
OF THIS MANUAL BEFORE PUTTING YOUR OPTIMOD-AM ON THE AIR!

6) INITIALIZATION

This subsection describes a number of modifications which the user can make to OPTIMOD-AM to make it work better in his application. None of these procedures is required; if no modifications are desired, this subsection may be ignored.

6.a) Input Attenuator Pad: OPTIMOD-AM is shipped with a 20dB pad before the input transformer. This is appropriate for nominal line levels of -10 to +10dBm. If your telephone line levels are substantially lower than this, you may replace four resistors on the input filter board to obtain 6dB attenuation. (NOTE: A pad of at least 6dB is necessary to isolate the OPTIMOD-AM input transformer from the reactive components of the phone line impedance.)

The filter board is located inside the filter box mounted inside the rear panel, behind the barrier strip. In order to modify the pad, it is necessary to remove the back panel, and then remove the input shield box. (see **Section 4 (MAINTENANCE), subsection 4 (ACCESS)** for details on how to do this.)

To identify the resistors, refer to the **FILTER BOARD** assembly drawing (p. III-7) in the **ASSEMBLY DRAWING** section **(Appendix III).**

TABLE II-1: INPUT PAD RESISTOR VALUES

20 dB LOSS

R1,R4 = 750 ohm 1/2 watt 5% carbon composition
R2,R3 = 1.5 K ohm 1/2 watt 5% carbon composition

6 dB LOSS

R1,R4 = 1.8 K ohm 1/2 watt 5% carbon composition
R2,R3 = 220 ohm 1/2 watt 5% carbon composition

6.b) Output Lowpass Filter: Unless otherwise ordered, OPTIMOD-AM is shipped with an output filter with an 11kHz cutoff, strapped to operate in both the "Day" and "Night" modes. Certain circumstances may require a lower cutoff frequency. Such circumstances include unusual nighttime adjacent- or co-channel interference conditions, very narrowband antenna systems which misload the transmitter at high frequencies, and the use of certain transmitters which cannot take highly preemphasized audio without introducing splatter and distortion. It has been our experience that transmitters employing an "outphasing" modulation scheme seem particularly prone to this sort of behavior. If your station uses such a transmitter, its performance should be carefully investigated to make sure that significant out-of-band components are not introduced. If they are, first carefully realign the exciter following the manufacturer's instructions. If this does not cure the problem, contact the factory to obtain an 8kHz or 6kHz filter. This requires exchange of the entire #8 Card. Usually 8kHz is adequate to solve the problem, but will result in an audible loss of "air" and "transparency" compared to an 11kHz filter.

A factory option permits remote-controlled selection of two different filter frequencies for "Day" and "Night" use. Contact the factory for further details.

6.c) Defeating The Polarity Follower: (Refer to the SCHEMATIC and ASSEMBLY DRAWING for card #7 in **Appendix III.)**

a) Making sure that AC power is OFF, remove card #7 from the card rack behind the front panel. You will have to loosen 3 hex fasteners, then swing the front panel down, and then loosen 4 Dzus fasteners and remove the subpanel in order to gain access to the cards.

b) Following the instructions in **subsection 5** of the **MAINTENANCE** section, remove C702 from card #7. Set C702 safely aside, should you ever want to reactivate the function. Similarly, remove one lead (it doesn't matter which one) of the resistor (cell) side of IC703 from the board.

c) Solder a jumper in place where C702 used to be.

d) Clean residual flux from the board, and replace it in the card rack.

6.d) Retuning The Input Highpass And Lowpass Filters: Some broadcasters may wish to retune the 18dB/octave 100Hz highpass filter incorporated in the input conditioning filter in order to obtain more low bass energy. This should be done with substantial caution, because this bass will not be reproduced on smaller radios, and its addition can cause increased distortion and/or decreases in loudness.

If you still wish to retune the filters, follow these steps:

a) Determine the new cutoff frequency, F.

b) Calculate the ratio between 100 and F: R=100/F. (EXAMPLE: If F=80Hz, then R=1.25)

c) Three resistors, R304,305,306, must be replaced to retune the filter. Multiply the value of each resistor by R to obtain the new value of that resistor. (EXAMPLE: F=80Hz; R304=31.125K; R305=792.5K; R306=6.2375K)

d) Round off each calculated value to the nearest standard 1% value. (EXAMPLE: R304=30.9K; R305=787K; R306=6.19K)

e) Obtain RN55D-style (1/8 watt 1% metalfilm) resistors from a parts distributor.

f) Replace R304,305,306 on CARD 3 with the new resistors, conscientiously following the instructions in Section 4 (MAINTENANCE), **subsection 5.**

It is possible to defeat the preemphasis while still retaining the steep 11kHz lowpass characteristic. This may be desired if you find the preemphasis inappropriate for your format, yet you need the extra lowpass filtering because of tight occupied bandwidth restrictions (as in Canada). Retaining the lowpass filter will also prevent any possiblity of aliasing distortion in the BBD delay lines in the "Smart Clipper", and will prevent IM between in-band and out-of-band components in the clippers.

To defeat the preemphasis:

a) Remove C305, a 0.0047uF ±2% film capacitor, and discard.

b) Remove C306, a 0.0047uF ±2% film capacitor, and replace with a 0.019uF ±5% 50VDC (or greater) film capacitor. This value can usually be selected from an assortment of 0.018uF capacitors.

7) Mounting And Grounding The Chassis: OPTIMOD-AM requires 7" of vertical space in a standard 19" rack (four units). Refer to **subsection 1** above regarding optimum mounting location.

The chassis of OPTIMOD-AM must be very well grounded to minimize RFI. OPTIMOD-AM ordinarily picks up its chassis ground through the rack. It may be necessary to scrape the paint from the rack and/or the back of OPTIMOD-AM's mounting flanges in order to secure an adequate ground. Measure the resistance between the OPTIMOD-AM chassis and the rack; it should be less than 0.5 ohm. In addition, make sure that the rack itself is solidly grounded (preferably by means of a heavy copper braid or strap) to the station earth ground. DO NOT RELY ON THE POWER LINE GROUND!

The balanced input and output configuration makes ground loops most unlikely. The circuit and chassis grounds are connected together inside the OPTIMOD-AM chassis; if the devices driving and being driven by the OPTIMOD-AM are both balanced, and if the OPTIMOD-AM chassis is properly grounded, no difficulties should be encountered.

For the sake of RFI elimination, it is recommended that OPTIMOD-AM always be operated with all covers in place, and with the front doors closed.

After OPTIMOD-AM is correctly mounted, audio and power connections may be made as described in **2, 3,** and **4** above.

2

NOTE

IF HIGH FREQUENCY FEEDBACK IS ENCOUNTERED WHEN OPTIMOD-AM IS PUT ON THE AIR, THIS IS PROBABLY DUE TO RF RECTIFICATION'S OCCURING <u>BEFORE</u> THE OPTIMOD-AM INPUT. BECAUSE OF OPTIMOD-AM'S EXTREMELY HIGH GAIN AT HIGH FREQUENCIES, FEEDBACK CAN OCCUR EVEN IF RF RECTIFICATION IS SLIGHT. A 0.01 MFD CAPACITOR ACROSS THE OPTIMOD-AM INPUT LINE CAN OFTEN CURE THIS PROBLEM.

8) Use Of Reverberation: In the 1960's, the addition of artificial reverberation was touted as an easy method of achieving higher loudness in AM broadcasting. Given, the limitations of the audio processing equipment of that time, this was true: reverberation increased the signal density and average modulation without the pumping or other side effects that heavy limiting would cause if equivalent density were to be achieved by compression or limiting alone.

Reverberation, of course, exacted a price: decreased definition and intelligibility in many instances, because the reverb "smeared" the sound.

OPTIMOD-AM is capable of so much density augmentation by means of its six-band limiter and "Smart Clipper" that reverberation is neither necessary nor desirable to achieve high loudness and density. The advantage of OPTIMOD-AM's signal processing is that its processing <u>increases</u> definition and intelligibility, rather than "smearing" it at reverb does. For this reason, no provision for adding artificial reverb has been included in the OPTIMOD-AM system.

Interestingly, the density augmentation of OPTIMOD-AM makes any reverberation included in the source material more apparent to the ear, because the reverb decay is increased in loudness.

9) Transmitter Plant Considerations: The behavior of an FM station is more or less determined by the behavior of the exciter. Alas, this is not true in AM! The performance of an AM station is highly dependent upon the high-power sections of the transmitter, and upon the behavior of the antenna system.

OPTIMOD-AM is not a panacea; however, its transmitter equalizer can cure linear problems caused by the transmitter or antenna system. The transmitter equalizer cannot cure nonlinear problems, particularly those caused by inadequate power supplies, modulation transformers, or reactors. If any of these components saturate or otherwise fail to perform under heavy power demands, no amount of small-signal equalization will solve their problems.

9.a) The Transmitter: An AM transmitter is required to provide 150% of unmodulated carrier power when it is modulating 100%. This power must come from somewhere; this "somewhere" is the high voltage power supply. Such supplies are subject to two major problems:

1) Sag, which causes static carrier shift; and

2) Resonance, which causes dynamic carrier shift, or "bounce".

Sag is a result of inadequate steady-state regulation. It causes the carrier shift which is read on your modulation monitor. The FCC legally limits it to -5%; this corresponds to about 0.5dB, which is not a terribly significant loudness loss.

A more serious problem is dynamic carrier shift, or "bounce". This has been known to cause up to 3 dB loudness loss. It is usually caused by resonances in the LC filter network in the power supply. Any LC network has a resonant frequency; in order to achieve reasonable efficiency, the power supply filter network must be underdamped. Therefore, this resonance is excited by high modulation, and can cause overmodulation on the low-voltage peaks of the resonance.

Curing bounce is not at all straightforward because of the requirement that the power supply filter smooth the DC sufficiently to meet the FCC's -45dB noise requirement. One approach that has been employed recently is use of a 12-phase power supply. Upon rectification, the ripple component of the DC is down about -40dB without filtering; thus, a single-capacitor filter can be used, eliminating the filter inductor as a potential source of resonance with the capacitor.

Other sources of resonance include the modulation reactor and modulation transformer in conventional plate-modulated transmitters. Such transmitters will therefore not greatly benefit from a 12-phase power supply.

Recently, a new generation of transmitters employing switching modulation techniques has appeared; these transmitters control "bounce" far better than do older designs. One would expect transmitters employing "outphasing" modulation schemes to also benefit substantially from a tighter power supply.

2

The FCC permits positive peaks of up to 125% modulation. Many transmitters cannot achieve such modulation without substantial distortion, if at all. In such cases, the power supply can be beefed up. RF drive capability to the final power amplifier must sometimes be increased.

IT IS IMPORTANT NOT TO DRIVE THE TRANSMITTER BEYOND ITS LINEAR RANGE IN THE ATTEMPT TO ACHIEVE 125% POSITIVE MODULATION. THIS WILL NOT INCREASE LOUDNESS -- IT WILL ONLY ADD DISTORTION.

WARNING!

> Some older transmitters were underdesigned by today's standards, because "modern audio processing" techniques to increase average modulation had not yet been developed and the transmitters' designers assumed that average power demands on the modulator would be small by today's standards. If you have a transmitter designed before 1965, it should be carefully monitored to make sure that OPTIMOD-AM processing is not overheating the modulation transformer, the modulation reactor, or the power supply. The high frequency boost performed by OPTIMOD-AM can cause unusually high voltages in the final amplifier, which could cause arcing and/or component breakdown. (This latter problem has been found to be very rare, however). There is no hard-and-fast cure for such problems; they almost always require substantial modification of the transmitter with the addition of heavier-duty components and perhaps a whole new power supply for the modulator alone.

Much attention has been paid recently in the audio community to "Transient Intermodulation Distortion", or more correctly, "Slew-Induced Distortion" (SID) in feedback amplifiers. This distortion is caused by the amplifier in question's having a maximum available rate-of-change of its output waveform. It exhibits SID when musical waveforms try to force its output to change faster than this "slew rate limit".

The cause of this distortion is usually an open loop response which starts to roll off at a very low frequency. This rolloff is usually introduced after the input stage; thus the output of the input stage is forced by feedback to be highly preemphasized (to overcome the rolloff in the following stage). Because of this preemphasis, the input stage overloads easily. This input stage overload is the direct cause of SID.

It is not widely realized that certain AM transmitters are extremely prone to this type of distortion if they employ overall audio feedback around the transmitter (using rectified RF to supply the feedback signal). Because of the delays involved in the transmitter, it is necessary to roll off the open loop response at a very low frequency to make the feedback loop stable. This feedback improves the steady-state distortion measurements (SMPTE Intermodulation, and Total Harmonic Distortion); however, the conditions for severe SID exist. Such distortion is highly offensive to the ear; it is a plausible explanation for why some transmitters may measure good, but sound bad.

Because the output of OPTIMOD-AM is highly preemphasized, it can cause severe audible distortion in a transmitter with considerable SID. SID is therefore of substantial concern in an OPTIMOD-AM installation.

SID can be detected with the CCIF Intermodulation Test. This involves introducing to the input of the system being evaluated a pair of high frequency tones closely spaced in frequency. The level of the difference frequency which results from passing these tones through said system is then measured.

Curing SID in a transmitter is not straightforward. The only way to do it is to reduce the amount of overall feedback employed. Then try and compensate for the decreased feedback by decreasing the amount of high frequency rolloff, and by linearizing the modulator stage-by-stage. THD and/or SMPTE IM may well become poorer as a result of this process. However, the transmitter will probably sound better.

WARNING

MANY OF THE SUGGESTED PROCEDURES ABOVE INVOLVE MODIFICATIONS TO THE TRANSMITTER WHICH WILL NULLIFY ITS TYPE-ACCEPTANCE. BEFORE SUCH MODIFICATIONS ARE PERFORMED, THE ENGINEER SHOULD REFER TO PARTS 73.43 AND 73.44 OF THE FCC RULES REGARDING THE APPROPRIATE ADMINISTRATIVE PROCEDURES.

9.b) Antenna System: An AM antenna system, whether directional or non-directional, frequently exhibits two problems. These are:

1) Inadequate bandwidth; and/or,
2) Asymmetrical impedance.

Often, a system will exhibit both problems simultaneously.

An antenna with inadequate bandwidth couples RF energy into space with less and less efficiency at higher sideband frequencies within the ±15kHz bandwidth of the assigned channel. Instead, it reflects these higher frequency sideband components back into the transmitter or dissipates them in the tuning networks. This not only results in dull sound on the air (and nullifies OPTIMOD-AM's principal advantage: its ability to create a highly preemphasized signal without undesirable side effects); it also wastes energy, can cause distortion, and can shorten the life of transmitter components.

Asymmetrical impedance is simply the common point impedance's not being symmetrical on either side of the carrier frequency. This problem can cause transmitter misbehavior and on-air distortion when envelope detectors are used in receivers (as they universally are as this manual is written).

Neither problem is capable of easy solution. In most cases, unless the Chief Engineer is a knowledgeable antenna specialist, a reputable outside consultant should be employed to design correction networks for the system.

It should be noted that many antenna systems are perfectly adequate. However, if the transmitter sounds significantly brighter and/or cleaner into a dummy load than it does into your antenna, the antenna system should be evaluated and corrected if necessary.

9.c) Modulation Monitor And RF Amplifier: Field experience has shown that many AM modulation monitors (particularly of older design) indicate dynamic modulation inaccurately, although they may indicate sine wave modulation correctly. This is because the audio filter after the demodulator diode is not phase-linear, and exhibits overshoot and ringing. An incorrectly designed modulation monitor may indicate modulation as much as 3 dB higher than that actually occuring.

In addition, highly selective RF amplifiers have been known to suffer from similar problems. They can overshoot and ring if the passband filters are too sharp, thus causing the monitor to falsely indicate high modulation.

If your modulation monitor is not in agreement with an oscilloscope monitoring the RF envelope at the common point, do not assume that the monitor is indicating fast peaks that your eye cannot see. A more probable cause of the disparity is overshoot in the monitor or RF amplifier. If this problem is observed, we recommend that you replace your monitor with one of state-of-the-art design.

Note also that modulation percentages will vary in different parts of the radiated field of a directional antenna system. Depending on the location observed, actual modulation can be either lower or higher than modulation observed at the common point.

10) STUDIO AURAL MONITOR CONSIDERATIONS

10.a) Monitor Rolloff Network: A passive monitor rolloff network is included as part of the OPTIMOD-AM system. This is physically located in its own chassis, and is designed to be inserted between the AIR MONITOR output of the modulation monitor and the INPUT of the studio monitoring system. This rolloff network is needed to deemphasize the air monitor so that it is rolled off like a typical AM radio. If the rolloff network is not used, the output of the air monitor will sound shrill, strident, and unpleasant because the modulation monitor has a flat response, unlike virtually all real AM radios in the field.

The rolloff network is passive. It can be operated balanced or unbalanced. The input driving impedance can be either a voltage source (like an opamp output) or 600 ohms. The load impedance can be either 600 ohms or high impedance bridging. When operated between 600 ohm source and load impedances, the insertion loss at 50Hz is -7.4dB.

The slope of the rolloff network is 12dB/octave at high frequencies. Its extreme top end is therefore slightly "glamorous" compared with most AM radios, whose extreme high frequency response rolls off faster than 12 dB/octave. It should be noted that the rolloff network is not designed to be the final reference for adjustment of OPTIMOD-AM; it merely creates an easily listenable sound.

Figure 2-1 shows the frequency response of the rolloff network.

If you employ more conservative equalization than that contemplated by Orban engineering when the rolloff network was designed, the rolloff network may cause the "in-house" monitor to sound too dull. If this is the case, a graphic equalizer (or, for finest adjustability, a Parametric equalizer like the Orban 622) may be inserted in the monitor system before the monitor amplifier. This should be adjusted to make the D.J.'s happy. Because of this subjective "tuning" of the monitor system, it cannot, of course, be used as a reference for making adjustments of the OPTIMOD-AM Program Equalizer (see **section 3; subsection 3.c).**

2

If you use the Orban monitor rolloff network, install it as follows:

BALANCED INPUT; BALANCED OUTPUT:

INPUT:	4 and 1 (600 ohm source); 3 and 2 (voltage source)
OUTPUT:	7 and 8
S1:	BALANCED

UNBALANCED INPUT; BALANCED OUTPUT:

INPUT:	4(hot) and 1(ground) (600 ohms source); 5(hot) and 1(ground) (voltage source)
OUTPUT:	7 and 8(ground to circuit ground of amplifier)
S1:	UNBALANCED

BALANCED INPUT; UNBALANCED OUTPUT:

INPUT:	4 and 1 (600 ohm source); 5 and 1 (voltage source)
OUTPUT:	7 and 8(ground)
S1:	UNBALANCED

UNBALANCED INPUT; UNBALANCED OUTPUT:

INPUT:	4(hot) and 1(ground) (600 ohm source); 5(hot) and 1(ground) (voltage source)
OUTPUT:	7(hot) and 8(ground)
S1:	UNBALANCED

If termination is bridging (greater than 10K), TERMINATION switch should be ON.

If termination is matching (600 ohms), TERMINATION switch should be OFF.

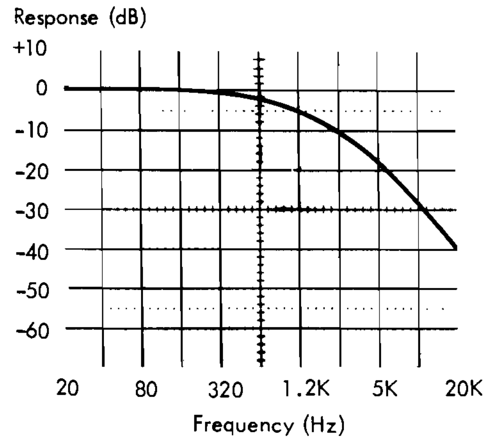

FIG. 2-2: FREQUENCY RESPONSE, "STANDARD" ROLLOFF NETWORK

10.b) Headphones: Highly processed audio always causes a problem with D.J. headphones. If the phones are fed directly from the air monitor, the headphone sound will be fatiguing and strident, and will tend to cause high frequency acoustic feedback if the D.J. uses high headphone gain. Therefore, if the D.J. must use the air monitor, the headphone amplifier should be driven from the output of the monitor rolloff filter (see **10.a)**.

Two other problems usually occur. The first is the polarity follower circuit. If this circuit changes the signal polarity while the D.J. is talking, the effect can be most disconcerting and upsetting to him. The second problem is that the output of OPTIMOD-AM is delayed approximately 4.2mS compared to the input. This delay is too short to cause an audible echo. However, it can create an "acoustic comb filter" effect when the delayed signal and the direct bone-conduction sound reach the D.J.'s ear simultaneously. This can cause a severe coloration of the voice quality that the D.J. hears, and can also be disconcerting and uncomfortable.

For these reasons, we recommend that D.J. phones be driven by an inexpensive compressor connected to the program line. This will avoid all the problems mentioned above. If the D.J. relies principally on his phones to determine whether the station is on the air, simple loss-of-carrier and loss-of-audio alarms should be added to the system. Such alarms could be configured to cut off audio from the D.J. phones in the case of an audio or carrier failure.

11) AM Stereo: OPTIMOD-AM is equipped with a connector on the rear apron of the chassis to accept a stereo adapter chassis for AM stereo. As this manual is written, the FCC has not decided which AM stereo system (if any) will be approved.

After such a system is approved by the FCC, requests for information about a stereo adapter chassis should be addressed to the Orban Associates, Inc. Marketing Department: (800) 227-4498; (in California (415) 957-1067).

12) OPTIONAL SPEECH INPUT PORT

If you have ordered the optional Speech Input Port, you have the ability to perform split voice/music processing. The Broadband Compressor and Six-Band

Limiter sections of OPTIMOD-AM sometimes create less than optimum results with certain types of low-quality speech with substantial background noise, like some noisy telephone conversations or sports remotes. In addition, they tend to "glamorize" announcer vocal quality. Some may like this effect; others feel that it sounds unnatural.

The solution to such problems lies in use of split voice/music processing. The front end of OPTIMOD-AM is employed only for music (or for music and high-quality voice). Voice is processed through its own equalization and "intelligent" gated compressor, both of which must be supplied by the customer. The output of said compressor is then introduced to the OPTIMOD-AM Speech Input Port, where it is mixed with the material processed by the OPTIMOD-AM input section. This mixing occurs at the input to the Polarity Follower; the only processing which the Speech Input receives is thus that performed by the Polarity Follower and "Smart Clipper".

Telemetry: The Speech Input Port provides a convenient input for subsonic telemetry tones. The Input Conditioning Filter following the main input cuts off at 18dB/oct below 100Hz. However, the response of the Speech Input transformer is essentially flat to 10Hz. Since the Speech Input is processed by the "Smart Clipper" and Polarity Follower, a certain amount of gain variation will be observed in normal operation. In addition, some intermodulation between the telemetry tones and the audio can occur. Normally, the telemetry receiver contains a limiter which renders it immune to considerable variations in tone level. However, if your telemetry system becomes upset by the level variations, or if audible IM occurs between the subsonic tones and program, the tones can be mixed into the program after the OPTIMOD-AM output. If this is done, be sure that the mixer has a frequency response flat from the lowest frequency telemetry tone to substantially above 11kHz. It is also important that this mixer be phase-linear in this frequency range to avoid distorting peak levels from the OPTIMOD-AM output.

Two-Tone EBS Tests: The Speech Input Port may also be effectively employed as an input for the two tones used in the EBS test. Fortunately, the two tones are sufficiently close in frequency to prevent the action of the Input Conditioning Filter, the Program Equalizer, and the Six-Band Limiter from seriously disturbing the relative balance between the tones if they are introduced into the main audio input of OPTIMOD-AM.

The 1980 version of the FCC Rules requires each tone to modulate the transmitter at least 40% by itself. No requirement for percentage modulation of the sum is specified. Ordinarily, at least 70% modulation will be produced by the tones if they are introduced to either input. If substantially less modulation is produced, it implies that: (1) the SMART CLIPPER DRIVE control (or, if the Speech Input is used, the external compressor OUTPUT ATTENUATOR control) is set to produce very low gain reduction in the "Smart Clipper", such that the tones produce no gain reduction in this section; or, (2) that the transmitter and/or antenna overshoot and/or bounce so severely (see **subsections 9** and **10,** this section) that the OUTPUT ATTENUATOR has been turned down to compensate for these overshoots on normal program material.

Note too that VU meters ordinarily read about 10dB lower than the peak level of program material. This means that if the two-tone signal is peaked at 0VU, it is actually about 10dB below peak program levels. If low modulation occurs, the VU meter may have to be pinned on tone to bring peak levels up to typical peak program levels.

If the transmitter and antenna system are well-behaved, the typical modulation level produced by a sine wave is about 2.5-3dB below 100% modulation (70-75% modulation). This reflects the fact that 2.5dB headroom is left between the output of the "Smart Clipper" and the final safety clipper to accomodate the distortion corrector signal and overshoots in the output lowpass filter, and that no overshoots or corrector signal are produced with pure sinewaves. (See **Section 5 (Principles of Operation), subsection 6).**

Ordering and Installing: The Speech Input Port is ordinarily ordered as a factory option. However, a field-retrofit kit is available for those who decide they need the option after they have lived with their OPTIMOD-AM's for a while. To order the retrofit kit, contact the Orban Marketing Department: (800) 227-4498; (in California (415) 957-1067).

The Speech Input Port appears on the rear-panel barrier strip. It is 600 ohms balanced and floating, RFI-suppressed. There is no gain control available. Thus, drive level must be adjusted by means of the OUTPUT ATTENUATOR of the gated compressor driving the port.

When adjusting this attenuator, be sure that the SMART CLIPPER GAIN REDUCTION METER is driven conservatively; under no circumstances should it be driven into the red section of the scale.

13) Remote Control Connections: Three terminals for remote control of "Day" and "Night" status are located on the rear-panel barrier strip. Switching can be effected by applying a pulse of 6-24V AC/DC between the appropriate terminal and "Common". If DC is used, connect the "+" polarity to the "Day" or "Night" terminal, and the "-" to "Common".

If you wish to use 48V, current limiting should be provided by connecting a 1K 2W ±10% carbon composition resistor in series with the "Common" terminal.

No local control of Day/Night status is provided.

Section 3

SETUP AND ADJUSTMENTS

0) Introduction

3

This section consists of five parts. The first is instructions on aligning the OPTIMOD-AM transmitter equalizer to your transmitter and antenna by instrument. The second is a condensed set of operating control setup instructions, designed to help you get on the air quickly. The third is a comprehensive discussion of the relationship between OPTIMOD-AM's setup controls and the sound produced on the air, written so that the Program Director, as well as the Chief Engineer, can use it. The fourth is a summary of typical problems and solutions. The fifth is detailed instructions on how to do a Proof Of Performance.

1) Transmitter Equalizer Setup Instructions

Fold down the small door in the right half of the OPTIMOD-AM front panel by loosening the single fastener at the top and swinging the door down on its hinges. This will expose the setup controls.

BEFORE ANY SUBJECTIVE AUDIO ADJUSTMENTS ARE MADE, IT IS NECESSARY TO ADJUST THE TRANSMITTER EQUALIZER TO MATCH OPTIMOD-AM TO YOUR TRANSMITTER/ANTENNA SYSTEM. The following instructions describe the correct procedure. If your system is changed at night (pattern change and/or transmitter change and/or transmitter power change), then the procedure should be repeated with the entire system in its normal nighttime mode. OPTIMOD-AM must also be switched to its "Night" mode by application of 6-24 V AC/DC to the "Night" and "Common" remote control screws on the rear-panel barrier strip.

a) OBTAIN THE FOLLOWING TEST EQUIPMENT: Audio frequency squarewave generator; oscilloscope with at least 5mHz vertical bandwidth.

b) Turn the OPTIMOD-AM OUTPUT ATTEN to 0.0. Be sure that the carrier is off.

c) Connect the HOT output of the squarewave generator to TP1 with RCA phono plug. TP1 protrudes from the subpanel containing the setup controls. Also connect the HOT output of the squarewave generator to the SYNC input of the scope. Clip the GROUND of the squarewave generator to a convenient place on the OPTIMOD-AM chassis.

d) Connect the vertical input of the scope to a convenient source of RF, such as the transmitter sampling loop. Adjust the scope so that it is synchronized by the square wave generator.

WARNING!

TO AVOID POSSIBLE OVERHEATING OF THE TRANSMITTER, THE FOLLOWING ADJUSTMENT SHOULD BE PERFORMED QUICKLY, AND 50% MODULATION SHOULD NOT BE EXCEEDED.

e) Adjust the square wave generator to 100Hz. Switch the TRANSMITTER EQUALIZER switch IN.

CAUTION

OPERATION OF THE TRANSMITTER EQUALIZER SWITCH CAN INTRODUCE A TRANSIENT AT THE OPTIMOD-AM OUTPUT WHICH MAY CAUSE OVERMODULATION OR MAY OVERLOAD THE TRANSMITTER. OPERATE THIS SWITCH ONLY WITH THE CARRIER OFF OR WITH OPTIMOD-AM TEMPORARILY DISCONNECTED FROM THE TRANSMITTER.

Adjust all of the six transmitter equalizer trimmer controls fully counterclockwise. Advance the output level of the square wave generator to produce roughly 3V p-p.

f) Turn on the carrier, and advance the OPTIMOD-AM OUTPUT ATTEN control until approximately 50% modulation is observed. Most transmitters will produce an RF envelope resembling fig. 3-1. Now adjust the LF TILT EQ trimmer control clockwise until the squarewave is as flat as possible. Fig. 3-2 shows a successful adjustment.

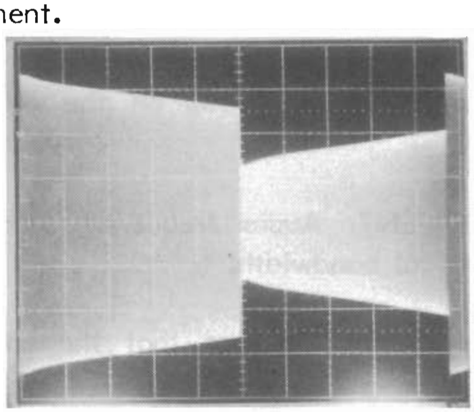

FIG. 3-1
LOW FREQUENCY SQUARE WAVE
WITHOUT TILT CORRECTION

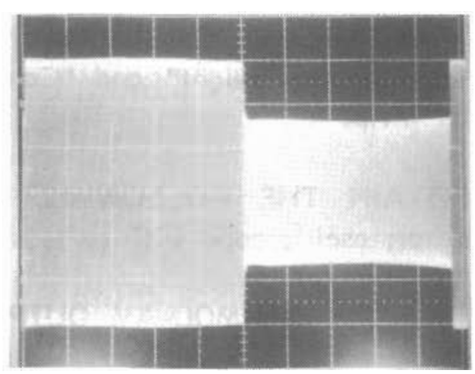

FIG. 3-2
LOW FREQUENCY SQUARE WAVE
WITH OPTIMUM TILT CORRECTION

If the range of the control is insufficient, this implies that transmitter bass response is inadequate and cannot be corrected without transmitter modification. In many cases, this modification is easy, and merely requires replacement of coupling capacitors with capacitors of larger value. In other cases, fundamental inadequacies in the input, interstage (if used), and/or modulation transformers (if used) are indicated.

Some transmitters cannot be fully corrected because the bass boost produced by the equalizer exaggerates power supply bounce problems (see **subsection 9** of **INSTALLATION)**. In many cases a compromise between full tilt correction and bounce may have to be achieved by careful experimentation with program material.

3

In other cases, the tilt correction may trip overload relays on program. It is often possible to readjust the trip point of these relays to avoid this problem. However, this must be done with the greatest care, since whether the transmitter is endangered is totally dependent upon its condition. ORBAN ASSOCIATES INC. ACCEPTS NO RESPONSIBILITY FOR TRANSMITTER FAILURES INTRODUCED BY SUCH READJUSTMENTS, OR BY OTHER CHARACTERISTICS OF ITS AUDIO PROCESSING (SUCH AS HIGH AVERAGE POWER OR BASS AND TREBLE PREEMPHASIS). The care and feeding of your transmitter requires application of sound engineering judgment: inadequate transmitters may fail, may have their tube life shortened, etc. Such transmitters are simply incapable of supplying the average power demands of OPTIMOD-AM processing regardless of transmitter equalization. These transmitters must be either repaired, modified, or replaced.

AS SOON AS THE ADJUSTMENT IS COMPLETE, REMOVE THE 100HZ SQUARE WAVE AND ALLOW THE TRANSMITTER TO COOL DOWN.

g) **High Frequency Adjustments:** Ordinarily, the high frequency square waves used for these adjustments place less demands on the transmitter than the low frequency adjustments just performed. If these high frequency adjustments are performed at 50% modulation or less, most transmitters will not be overstrained.

Modulate the transmitter to about 50% with a square wave in the region of 1 to 4kHz. The frequency should be chosen so that any ringing or overshoot has time to completely settle on each cycle of the square wave.

IF NO RINGING OR OVERSHOOT IS OBSERVED, THEN SIMPLY LEAVE THE HIGH FREQUENCY EQUALIZER CONTROLS FULLY COUNTERCLOCKWISE.

The H-F SHELF EQ and H-F DELAY EQ controls are adjusted interactively. Adjust the H-F SHELF EQ until any ringing is reduced to 50% (steady-state) modulation. That is, you will still have ringing, but no overshoot.

Now adjust the H-F DELAY EQ. You will observe that it further reduces the amplitude of the ringing on the leading edge of the square wave, and introduces a new ring on the trailing edge. The idea of this adjustment is to make the amplitude of the leading and trailing edge ringing equal. In addition, both should come to 50% modulation, but should go no further.

When you adjust the H-F DELAY EQ, this usually reduces the level of the ringing to below the 50% modulation point. You may then back off the H-F SHELF EQ until the ringing is once again at the 50% point. This adjustment unbalances the ringing at the leading and trailing edge of the square wave, so further readjustment of the H-F DELAY EQ control is then required.

By iterating between the two controls, you will finally get to a point where the ringing at both the leading and trailing edges of the square wave reaches 50%, and is exactly equal in level to the flat portion of the square wave. Figs. 3-3 and 3-4 illustrate a typical "before" and "after" condition. (Note that the waveform produced by your particular system may be quite different than our examples.)

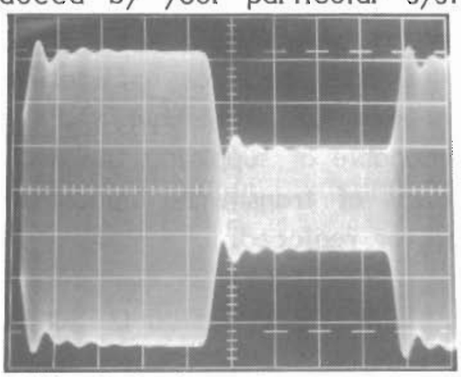

FIG. 3-3
HIGH FREQUENCY SQUARE WAVE
WITHOUT TILT CORRECTION

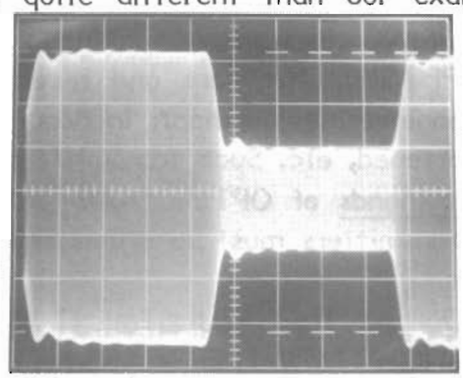

FIG. 3-4
HIGH FREQUENCY SQUARE WAVE
WITH OPTIMUM TILT CORRECTION

A final check should be made by sweeping the square wave generator up in frequency until the square wave turns into a sine wave and finally starts to roll off in amplitude. If any overshoot over the steady state (50% modulation) point is observed as you sweep, you will have to advance the H-F SHELF EQ control slightly more clockwise to eliminate it.

Finally, make a quick sweep between 100Hz and the point where the system frequency response is substantially rolled off. At no point should you exceed 50% modulation if you have performed the adjustments of all three TRANSMITTER EQ controls correctly.

TURN OFF THE CARRIER.

This concludes the adjustment of the TRANSMITTER EQ controls. Be sure you have repeated the procedure independently for both the "Day" and "Night" control sets if your system changes at night.

2) Initial Audio Processing Adjustments.

a) Below, you will find four diagrams of TYPICAL CONTROL SETTINGS for talk, conservative, moderate, and extreme processing. Conservative might be used by "beautiful music" or classical formats; moderate and extreme by MOR, AOR, or Top 40, depending on your market and competitive situation. Talk formats have special requirements; the optional Speech Input Port may be required (see **Section 2 (INSTALLATION), subsection 12).**

These settings are only starting points; **subsection 3** of **Section 3** below gives you enough information to "customize" them to create your own unique sound.

Now adjust all controls except for the INPUT ATTENUATOR and OUTPUT ATTENUATOR according to the TYPICAL CONTROL SETTINGS you have chosen.

b) Adjust the four mode switches as follows:

INPUT FILTER:	IN
EQUALIZER:	IN
XMTR EQ:	IN
OPERATE/TEST:	OPERATE

Drive the program line with typical levels. Adjust the INPUT ATTENUATOR until about 10dB gain reduction is indicated on the BROADBAND COMPRESSOR G/R meter. If this amount of gain reduction cannot be obtained, refer to **subsection 6.b** of the **INSTALLATION** section.

c) Under normal program conditions, considerable midrange gain reduction should be indicated on the BAND LIMITER G/R meters. The SMART CLIPPER G/R meter should be peaking somewhere in the vicinity of half-scale (this will vary widely with different types of program material). The GATE LED should light during pauses in the program, and the BROADBAND G/R meter should "freeze". The LOUDNESS AUGMENTATION LED should be flickering. And the POLARITY LED should turn on and off at seemingly random times as the dominant polarity of the input signal changes. (It is normal for this to happen infrequently). If these indications seem abnormal, check to see if you have correctly adjusted the controls

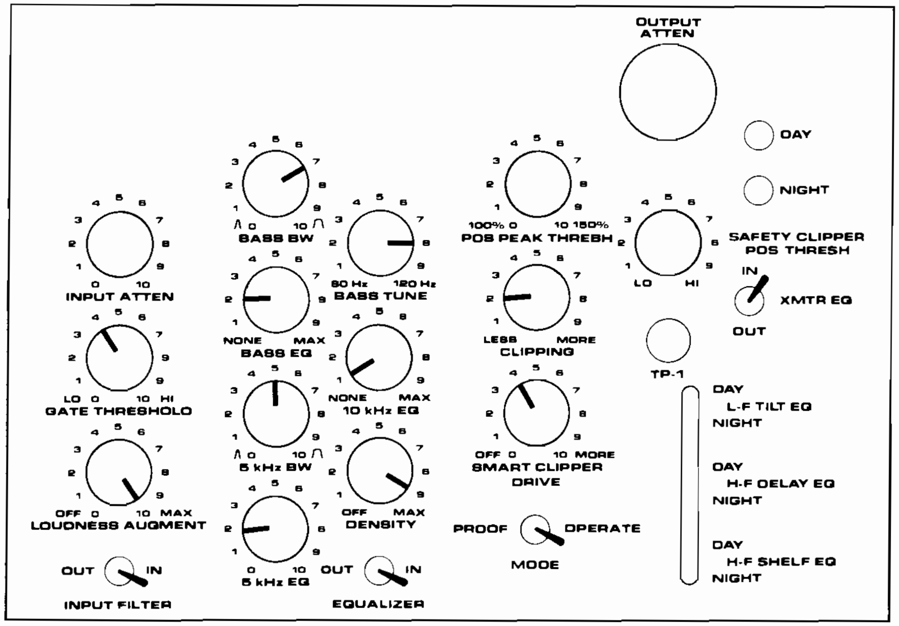

FIG. 3-5 "TALK" CONTROL SETTINGS

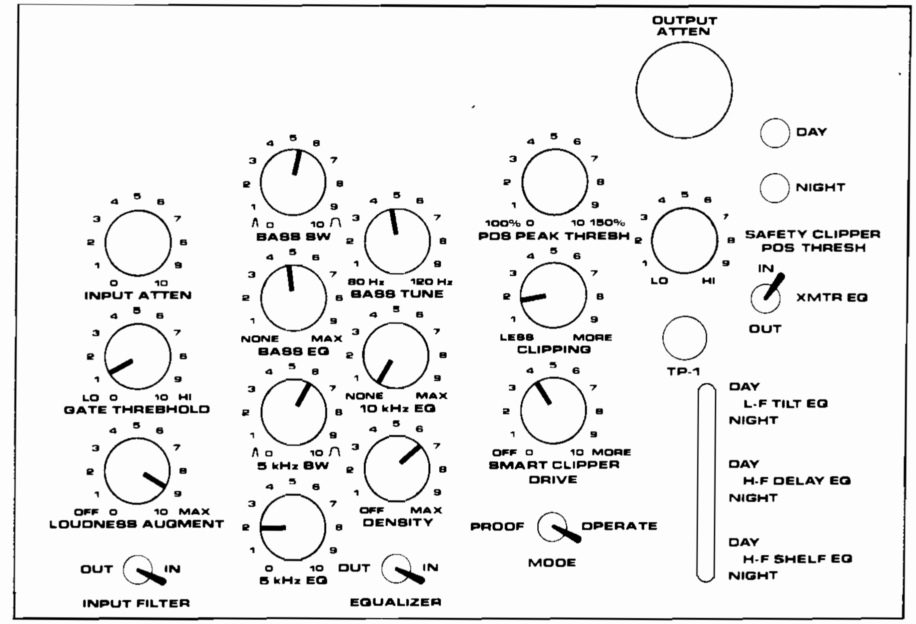

FIG. 3-6 "CONSERVATIVE" CONTROL SETTINGS

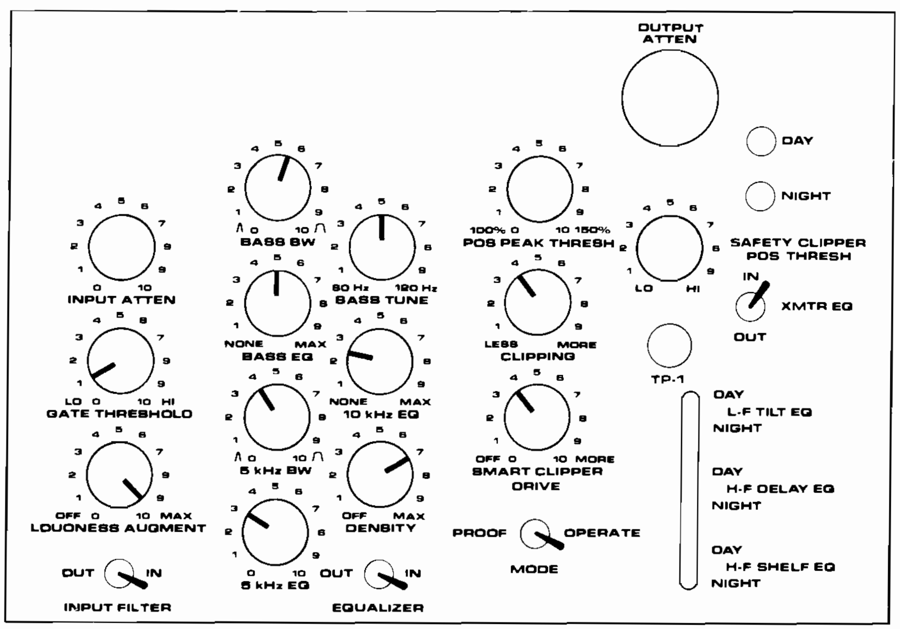

FIG. 3-7 "MODERATE" CONTROL SETTINGS

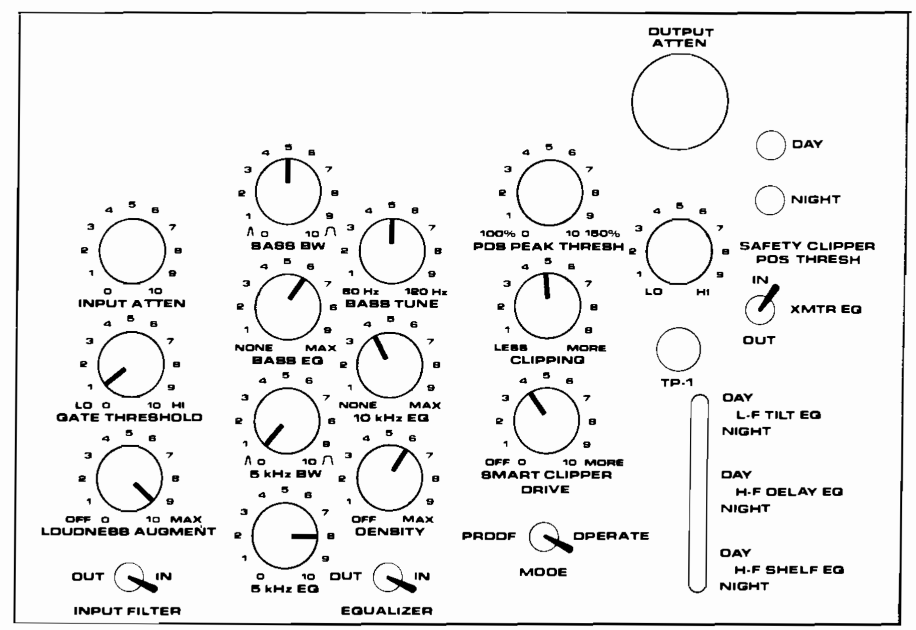

FIG. 3-8 "EXTREME" CONTROL SETTINGS

according to the TYPICAL CONTROL SETTINGS sheet. If not, a malfunction in the OPTIMOD-AM internal circuitry, or an installation problem should be suspected.

d) If your transmitter is capable of 125% positive modulation, adjust the POSITIVE PEAK THRESHOLD control to 150%, and adjust the SAFETY CLIPPER POSITIVE THRESH control to approximately 7. The SAFETY CLIPPER POSITIVE THRESH control should be used to adjust positive modulation! (See **subsection 7** of **Section I -- SYSTEM DESCRIPTION** -- for an explanation.)

If your transmitter can only produce symmetrical modulation without distortion, adjust the SAFETY CLIPPER POS THRESH control to "10", and adjust the main POS PEAK THRESH control to approximately "2" (corresponding to 100% positive modulation -- a bit of tolerance was left in this control so that "0" is usually slightly less than 100% positive modulation). In this symmetrical case, you will adjust positive modulation with the main POS PEAK THRESH control.

3

e) Turn the OUTPUT ATTENUATOR CONTROL to "0".

f) Turn on the carrier. Advance the OUTPUT ATTENUATOR control until substantial modulation is observed.

g) Using your modulation monitor, check modulation symmetry. If negative peaks are modulating higher than positive peaks, reverse the polarity of the OPTIMOD-AM output cable.

h) Advance the OUTPUT ATTENUATOR control until desired modulation levels are achieved. If all is well, the meter (when reading negative peaks) will usually "hang" close to 100% at all times except during pauses. IF THE TRANSMITTER IS OBSERVED TO COMPRESS PEAKS IN THE POSITIVE DIRECTION, DO NOT ATTEMPT TO MODULATE FULLY TO 125% POSITIVE. This will only cause distortion. Note too that the distortion of transmitters and receivers tends to increase radically when negative modulation of more than 85% is attempted. In the case of receivers, the major cause of this distortion is cheaply-designed envelope detectors whose diodes are not correctly biased. Serious consideration should be given to the possibility of modulating 86% negative, and trading off about 1.5dB loudness loss (compared to 100% negative) for substantially cleaner sound on most receivers.

i) Check audio quality with an AM radio, or with the modulation monitor aural output with the monitor rolloff network in place (see **10.a** in the **INSTALLATION** section). If distortion or other problems are observed, refer to **9** in the **INSTALLATION** section.

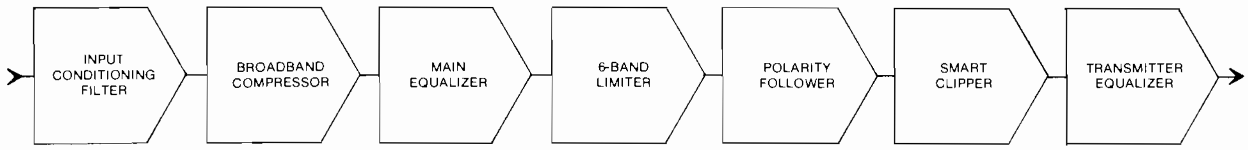

FIG. 3-9 (BLOCK DIAGRAM)

3) TAILORING OPTIMOD-AM'S SOUND TO YOUR REQUIREMENTS

This section is written for both Program Directors and Chief Engineers, with the hope that it will ease their way towards getting good sound.

3.a) The Basics: A perfectly-designed audio processor would allow you to trade off three fundamental factors. Each could be improved at the expense of the others. These factors are:

1) LOUDNESS
2) BRIGHTNESS
3) DISTORTION

Historically, a fourth, non-fundamental factor has always entered into consideration. This factor is the presence of processing artifacts, generated by imperfect psychoacoustical design of the audio processor. These artifacts are the audible side-effects of audio processing, including "pumping", "breathing", "hole-punching", and "noise pull-up". OPTIMOD-AM has reduced these artifacts to an unprecedented minimum by revolutionary circuit and system design. You are therefore free to play-off loudness against brightness against distortion without worrying that you will be limited by unwanted side-effects unrelated to the basic limitations of the AM radio medium.

The technical details of how Orban achieved this reduction in artifacts are probably not important to you -- but it is important that you understand the setup controls, and how they relate to the fundamental tradeoffs, and to your air sound. Only in this way will all of OPTIMOD-AM's potential be available to you.

3.b) Where To Start: Start by

1) Identifying your competition, and listening to them analytically, and by;

2) Developing a set of "reference radios" with which you are familiar, and which are similar to those used by a majority of your audience. Too often, just one radio (usually the PD's car radio) is used. But it is important to use at least two car radios (a radio with lots of high-frequency rolloff, like Blaupunkt or some earlier Delcos, and one with more highs, like Philco-Ford or Chrysler). At least one table radio is required. (At this writing we have no specific

recommendation. Our former recommendation -- the Radio Shack MTA-7 -- has been discontinued and replaced with the MTA-8 which has inferior sound and is not recommended. The best we can recommend is the use of one of the large Japanese radio/cassette recorder combinations.) You also need a pocket transistor radio.

Having a number of different reference radios is important because of the vast and distressing differences in performance of AM sets. The only similarity among current radios seems to be considerable high frequency rolloff. Bass performance is completely unpredictable.

3

Identifying the competition's sound is important, too. Stations in some markets tend to use large amounts of high frequency equalization to overcome the large amounts of rolloff in most radios; other markets tend to be more conservative. The ideal is to sound dramatically better than the competition, without being so stunningly different that your audience might become alienated. It's best to proceed in medium-sized steps rather than in one giant leap! In particular, if your market is not engaged in a "loudness war", you can use less processing, and trade loudness for reduced distortion, more brightness, and greater apparent fidelity. On the other hand, if a "loudness war" exists, OPTIMOD-AM can be a lethal weapon when properly set up.

If your competition already has OPTIMOD-AM, then it is up to you to use the utmost taste and judgement in setting your processor up. If two or more OPTIMOD-AM stations get into a loudness battle (presuming RF plants of equivalent quality) then the loser can be each station as listeners are driven to FM because of fatigue due to overprocessing. Don't lose your perspective: loudness isn't everything! With taste and care, OPTIMOD-AM can make AM into a quality medium which can seriously compete with FM's on smaller radios and in cars.

Note that the sound from the off-air monitor system in your station is usually totally unrelated to your air sound -- because your monitor is not rolled off like a real AM radio. A special monitor rolloff network is included with each OPTIMOD-AM. This network is designed to roll off the aural monitor output of your modulation monitor to make it sound more like a real AM radio. If you use bright, aggressive equalization then use of this rolloff network will make the OPTIMOD-AM processed signal sound right on your air monitor. You can't accurately judge the OPTIMOD-AM processed signal on a flat monitor -- it will sound shrill and unpleasant unless very little equalization is used. (If you use a moderate amount of equalization, the rolloff network may make the monitor sound too dull. In this case your engineering staff can use an equalizer to tailor the monitor sound to your taste.)

We assume that those people listening on wideband, high fidelity AM tuners are an insignificant portion of your audience. Indeed, most AM sections of stereo receivers are just as highly rolled off as smaller radios are. This is good, because it lets you perform high frequency boosting with the knowledge that it will benefit virtually every radio in the field.

There is, however, a wide range in the amount of high frequency rolloff employed by radio manufacturers. Some of the Japanese sets were produced to be compatible with the European market (where station carrier frequencies are closer together than they are in the U.S., rendering wideband broadcasting impossible and increasing interference between stations if wideband reception is attempted). These sets produce very muffled sound. At the other extreme, some sets from American manufacturers like G.E. were designed specifically for the U.S. market, and have far more highs than their Japanese counterparts. It is therefore vital to obtain a compromise between shrillness on the wideband sets, and a dull, muffled quality on the narrowband sets.

3.c) EQUALIZATION: THE FIRST PRIORITY

The built-in, fully-adjustable program equalizer in your OPTIMOD-AM was designed after exhaustive research into the characteristics of various randomly selected AM radios in the "car", "table", and "pocket portable" categories. The OPTIMOD-AM equalizer enables you to come up with high frequency equalization curves appropriate to all these radios very efficiently. There are only six equalization controls, only three of which affect the highs. Yet far more effective curves can be obtained than you could get with any conventional graphic equalizer. We have found the "Moderate" settings shown in Fig. 3-7 above to be most nearly "universal" as of this writing. This may change in future years if AM stereo results in wider-band radios than those commonly produced today (1980). For the moment, we recommend that you start with these settings and experiment until your personal tastes are satisfied. After you make a change, listen for a while -- make sure that your sound is good with different voices, with different kinds of music within your format, with commercials, and with low-quality material like telephone and shortwave. And make sure the sound is good on all your reference radios -- don't fall into the trap of overequalizing for the narrowband sets.

3.c.A) On High Frequency Equalization: The effect of high frequency boost is very different on wideband than on narrowband radios. Many narrowband radios cut off frequencies around 10kHz so completely that these frequencies cannot be heard or detected, even slightly. Conversely, wider-band radios have sufficient response around 10kHz so that the presence of highly boosted material in the 10kHz region is easily perceived as a sense of "air" or "transparency" which is usually totally missing from AM reception. OPTIMOD-AM can provide sufficient boost (using mostly the 10kHz EQ control) to provide this sense of transparency on the wider-band sets.

The narrowband sets must have a presence boost at 5kHz in order to sound even halfway decent. Yet this 5kHz presence boost must not be so excessive that it results in strident, fatiguing sound on wider-band radios. This tradeoff between equalization for narrowband and wider-band radios is by far the trickiest aspect of high frequency equalization. We have spent a great deal of time coming up with curves that sound good on a wide variety of radios. This is why we strongly recommend that you start with our suggested curves. As you experiment, always keep the wideband/narrowband tradeoff in mind. If you use too little 5kHz boost, you can get a very "open", smooth sound on wider-band sets -- but no punch on narrowband sets. Conversely, too much 5kHz boost causes unpleasant stridency on wider-band radios. And too much 10kHz boost can cause problems with distortion, loudness loss, and tuning ease.

3

Tuning ease is important. The more high frequency boosting you do, the more carefully the listener will have to tune his radio. On the other hand, the brighter and closer to high fidelity will be the sound quality he receives. Each station must use its own careful judgement here; experimenting by tuning your reference radios will help you make this judgement accurately. Typical 1980 auto radios are sufficiently wideband so that a good compromise between brightness and tuning ease is achievable. Unfortunately, Delco sets from the mid-1970's sound dull with any practical amount of high frequency boost -- this dullness must be lived with.

"Beautiful music" and classical stations will usually operate with the INPUT CONDITIONING FILTER out, and will perform all equalization with the main equalizer controls. Stations using these formats must avoid fatiguing listeners with over-equalization! In particular, this equalization technique is the best way to achieve "silky" strings without "edge".

On Low Frequency Equalization: A certain amount of low frequency boost must be used along with the high frequency boost in order to obtain a balanced sound. The watchword is: BE CONSERVATIVE! Use the bassiest of your auto radios (all of which usually have a peaky midbass when you listen through the standard dashboard speaker) as a "worst case" reference. Do not boost the bass so far that your reference radio becomes muddy or boomy. A correct bass boost will cause your table radio to have only moderate bass, and your pocket radio to sound thin and tinny.

Because bass equalization is so dependent on individual taste, we have made the bass equalizer fully-parametric. This means that you have control over three parameters:

1) the frequency at which the largest boost occurs;
2) the amount of boost at that frequency; and,
3) the bandwidth -- the number of frequencies on either side of the largest-boost frequency which are also affected by the boost.

Use of a narrow bandwidth, a low boost frequency, and a relatively large boost can give a very "punchy", "kicky" sound in a car, or on a radio with significant bass response. It can also cost you loudness (bass frequencies take lots of modulation without giving you proportionate loudness), and can result in thin sound on radios with only moderate bass response. A smaller amount of boost, a medium boost frequency, and a moderate bandwidth usually give a better compromise.

Bass boost can also endanger some inadequately designed older transmitters, and can cause others to misbehave (further compromising loudness) even if they don't actually fail.

Formats (like disco) whose lifeblood is bass will probably sound better with the input conditioning highpass filter tuned below the stock 100Hz curve (or even entirely bypassed). This may also be desirable if a significant portion of your audience is listening to deluxe auto radios with high powered amplifiers and big rear-deck speakers. Instructions for retuning the filter are found in **6.d** of **Section 2.**

3.d) LOOKING AT THE REST OF OPTIMOD-AM

We have started with the specific: the OPTIMOD-AM program equalizer. This is because the equalizer is the single most important factor affecting the sound of your station. However, to understand how OPTIMOD-AM can control your loudness, distortion, density, and dynamic range, it's essential to learn more about the rest of the OPTIMOD-AM system.

3.d.A) Broadband Compressor

Gain is ridden on the raw sound from the program line by the OPTIMOD-AM Broadband Compressor. This is designed to control average levels, and to compensate for a reasonable amount of operator error. It is specifically not designed to substantially increase the short-term program density: this task (which helps increase loudness) is better performed by the Six-Band Limiter and "Smart Clipper" sections which follow.

The Broadband Compressor has a 20dB range. This is plenty to handle any reasonable operation; only gross sloppiness on the part of the board operator will result in exceeding its range. However, be warned that the habit of some D.J.'s of peaking the music low and hitting the pin of the VU meter on voice will result in improper on-air balances. OPTIMOD-AM maintains an impression of short-term dynamic range; this is one of the keys to its preservation of musical quality and to its lack of processing artifacts. In the case of the D.J. who pegs the meter, OPTIMOD-AM "sees" exactly what's happening; a very loud sound (voice) surrounded by much softer sounds (music). It therefore maintains this impression on the air. The cure is simple: peak voice and music closer together.

**IF IT SOUNDS RIGHT ON THE PROGRAM LINE,
IT WILL SOUND RIGHT ON THE AIR!**

The Broadband Compressor is gated; its gain will "freeze" if the level coming into OPTIMOD-AM goes below a level that you can select with the GATING THRESHOLD control. The adjustment of this control depends heavily on your format. If you use mostly high-quality program material, you will want to set it low. If there is considerable noisy material like telephone conversations, shortwave broadcasts, sports remotes, and the like, then the threshold should be set higher so that noise is not "pumped up" during pauses.

If you observe soft passages in music fading away, then the GATING THRESHOLD control is probably set too high (or the operator is peaking too low). If background noise is heard to rise slowly during pauses, then the control is set too low. For most formats, this control should be set fully counterclockwise.

3.d.B) Six-Band Limiter: The program equalizer that we discussed initially follows the Broadband Compressor. After the equalizer comes the Six-Band Limiter.

The Six-Band Limiter has two main tasks:

1) It increases loudness by increasing the density of the program; and,

2) It corrects the frequency balance of substandard program material automatically, helping give the highly sought-after "uniform sound" without critical manual re-equalization of every piece of program material in the production studio.

By "density", we mean how uniform the loudness is. Programs with large amounts of dynamic range are not dense; very highly compressed programs are generally much denser. The trick in audio processing is to increase program density without introducing unpleasant side effects.

We recommend that the Six-Band Limiter be driven fairly hard. Only in this way will its advantages be fully utilized. It can compress short-term dynamic range with fewer audible side-effects than any other section of OPTIMOD-AM. If it is driven too hard, the only bad effects we've been able to observe are an apparent increase in background noise, and an unnatural sound on voice (excessively loud breath sounds, for example).

"Beautiful music" and classical formats may wish to use the six-band section as a substitute for broadband compression. This can be done by adjusting the Broadband Compressor so that no gain reduction is produced during normal programming. Careful control of input levels is required for a "beautiful music" format; this is easily achieved in automated facilities. In classical formats, considerable dynamic range will be preserved, and no processing will be audible.

3.d.C) Smart Clipper: The "Smart Clipper" is a complex collection of circuits which performs essentially the same function as an old-style peak limiter but with vastly improved performance. It's a fast level controller which reduces the level of audio peaks which would otherwise overmodulate the transmitter -- with minimum degradation of program material surrounding the peaks. The peak limiting function will always produce some distortion (in the engineering sense) if competitive loudness is created. This "distortion" may or may not be noticeable to the ear. The "Smart Clipper" is "programmed" to simulate the way the human mind perceives distortion. It therefore lets you adjust the amount of distortion produced by the peak limiting process to a level which is just below perceptibility. This results in maximum loudness and minimum processing artifacts.

Let us repeat what was stated earlier:

THERE IS A DIRECT TRADEOFF
BETWEEN LOUDNESS, BRIGHTNESS, AND DISTORTION.

On Loudness Compromises: You can increase loudness in several ways:

1) Increase the action of the Six-Band Limiter;

2) Increase the amount of gain reduction produced by the "Smart Clipper";
3) Increase the amount of clipping (and therefore, distortion) produced by the "Smart Clipper"; and
4) Reduce the amount of equalization at very high and very low frequencies.

Traditionally, (4) has been considered very important. However, the "Smart Clipper" control circuitry is so sophisticated that very large amounts of high frequency boost do not result in serious loudness compromises. Usually the high frequency boost becomes unpleasant to listen to before significant loudness is lost.

When judging comparative loudness between stations, please note that this will vary according to the frequency response of the radio used, and according to the accuracy with which the radio is tuned. Narrowband radios will usually get very much louder if tuned off center while a highly equalized signal is being received. This means that your auto radio pushbuttons must be carefully adjusted to make meaningful loudness comparisons. In addition, a highly equalized sound (like that produced by OPTIMOD-AM when optimally adjusted) may sound less loud than an unequalized signal on a narrowband radio, yet sound substantially louder on a wider band radio than the same unequalized signal, since the latter radio reproduces more of the frequency range in which the highly-equalized signal concentrates its energy, and to which the ear is most sensitive.

The point is this: loudness is a very complex psychoacoustic phenomenon. It is impossible to say that one station is louder than another unless it is consistently louder on many different receivers and with many different types of program material.

NOTE

> Many modulation monitors and/or RF amplifiers will indicate higher modulation than the transmitter is actually producing. This forces the engineer to turn down the volume, and can cost up to 3dB of loudness! It is very important to be sure that your modulation monitor is accurately calibrated using test tones, and that it does not exhibit "overshoot" on program material.

Several newer monitors are specifically designed for accurate pulse response without overshoot. Any of these monitors will enable you to obtain the highest loudness achievable from your specific transmitter and antenna system. If the monitor is used remotely, be sure that the RF amp doesn't overshoot: overshoots in RF amps have been observed to be as high as 3dB also!

We presume that the Six-Band Limiter is being driven as hard as you feel sounds good. You are then left with the task of adjusting the "Smart Clipper".

This task is somewhat complicated because there are three controls to deal with. We will explain each.

1) Smart Clipper Drive: This controls how much level the "Smart Clipper" must eliminate in order to prevent overmodulation. The "Smart Clipper" can control this level either by clipping (which can cause audible distortion when used to excess), or by gain reduction (which can cause pumping when overdone). As this control is set higher, the danger of audible side effects increases, but you get more loudness.

2) Clipping: This control affects how much level control is produced by gain reduction, and how much by clipping. It should be advanced clockwise until the amount of distortion produced by the processing becomes excessive, and then backed off slightly. The more clipping that is used, the harder the "Smart Clipper" can be driven without processing artifacts caused by gain reduction (pumping, etc.), and therefore the louder the on-air sound. It is thus important to carefully and critically adjust the CLIPPING control just below the point where clipping distortion begins to be disturbing if maximum loudness is to be obtained. Usually a live announcer is the most sensitive test for audible "fuzziness". Use your medium bandwidth reference radio for this test; the station monitoring system will reveal distortion you could never hear on the average radio. If you use the station monitoring system, you will therefore set the control too conservatively, and get lower loudness.

But beware the "distorted radio" phenomenon: particularly close to the transmitter, many radios produce excessive distortion all by themselves, and aren't truly reflecting what's being transmitted. If the station monitor (with rolloff) sounds clean but your radio is distorted -- don't trust the radio! This is a traditional problem with managers too -- if the GM's auto radio is distorted, he may think there's something wrong with the station, or your ears. So watch out!

3) Loudness Augmentation: OPTIMOD-AM contains a circuit that subjectively "unsquashes" heavily limited sound by permitting increased clipping on certain sounds which are naturally louder than their surroundings (like snare drum shots or dense, loud music). This "Loudness Augmentation" circuit creates a subjective loudness increase of 2-3dB on such sounds. Its effect is adjustable with the LOUDNESS AUGMENTATION control. We recommend that this control always be adjusted fully clockwise (for maximum action), unless you find the volume expansion effect to be objectionable for some reason. Experiment with the control to hear what it does; we have yet to discover program material which is, in our opinion, affected adversely by the circuit.

4) SUMMARY

The signal going through OPTIMOD-AM passes through four major sections:

1) The BROADBAND COMPRESSOR, which rides gain;
2) The PROGRAM EQUALIZER, which compensates for receiver rolloffs and optimizes the frequency balance of the airsound;
3) The SIX-BAND LIMITER, which increases density and corrects program material with improper frequency balance or presence problems; and,
4) The "SMART CLIPPER", which controls peaks without the usual peak-limiter side effects.

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4.a) TO INCREASE LOUDNESS:

1) Turn the DENSITY control up. This drives the Six-Band Limiter harder;
2) Turn the SMART CLIPPER DRIVE control up. This increases the amount of peak limiting;
3) Turn the CLIPPING control up. This provides more clipping, but also increases distortion;
4) Turn the LOUDNESS AUGMENTATION control fully up;
5) Use less BASS EQ;
6) Test the transmitter and antenna to make sure that:
   a) "overshoot", "tilt", "ringing", and "bounce" are insignificant (or that the first three are being properly corrected by the OPTIMOD-AM transmitter equalizer circuit);
   b) OPTIMOD-AM is connected to the transmitter through a circuit path that does not introduce any of the problems in (a) (such as a transformer);
   c) the modulation monitor is correctly calibrated, and does not exhibit ringing or overshoot;
   d) the transmitter is capable of 100% negative and 125% positive modulation without significant distortion;
   e) the antenna and ground systems are intact, and licensed field strengths are being generated at rated antenna current.

4.b) TO DECREASE DISTORTION:

1) Turn the CLIPPING control down and/or;
2) Turn the SMART CLIPPER DRIVE control down;
3) Check the transmitter plant as described in (6) above to make sure the transmitter itself isn't generating distortion;
4) Make sure that the audio before OPTIMOD-AM is immaculately clean. OPTIMOD-AM will reveal flaws that older processing equipment hid behind a curtain of mud.
5) Reduce the amount of high frequency boost. This will make receivers easier to tune, and will make distorted program material less obvious.

4.c) TO INCREASE INTELLIGIBILITY ON NARROWBAND CAR RADIOS:

1) Advance the 5kHz EQ control;
2) Use broader settings of the 5kHz BANDWIDTH control.

4.c) TO INCREASE "DEFINITION" ON WIDER-BAND RADIOS:

1) Advance the 10kHz EQ control.

4.d) TO MAKE TUNING BROADER AND LESS CRITICAL:

1) Reduce the 10kHz EQ control. If this is insufficient...
2) Somewhat reduce the 5kHz EQ control.

4.f) TO MAKE PROCESSING LESS AUDIBLE:

1) Use less gain reduction in all sections;
2) Work the Six-Band Limiter as hard as possible; use less gain reduction in the "Smart Clipper";
3) Use more clipping in the "Smart Clipper" by advancing the CLIPPING control;
4) Make the "Smart Clipper" do as little gain reduction as possible by advancing the LOUDNESS AUGMENTATION control;
5) Reduce the BASS EQ.

4.g) TO MAKE THE BASS MORE "MELLOW":

1) Use center BASS TUNING and broad BASS BANDWIDTH.

4.h) TO MAKE BASS MORE "PUNCHY":

1) Use center to low BASS TUNING and narrower BASS BANDWIDTH.

4.i) TO REDUCE NOISE:

1) Use less compression overall;
2) Set the GATE THRESHOLD higher (if the gate is not turning on during pauses);
3) Use Dolby or DBX noise reduction when recording on tape or cart;
4) Use a dynamic noise filter in the program line before OPTIMOD-AM.

4.j) TO REDUCE SIBILANCE:

1) Use less 5kHz EQ;
2) Use a de-esser (like the Orban 526A) in the microphone channel.

4.k) TO INCREASE LOUDNESS OF LIMITED BANDWIDTH PROGRAM (LIKE TELEPHONE OR SHORTWAVE)

1) Use an external sharp-cutoff lowpass filter on these sources to remove high frequency noise without affecting program content.

5) PROOF OF PERFORMANCE

Doing a Proof of Performance (assuming the 1980 version of the FCC Rules and Regulations) requires adjusting four switches to put OPTIMOD-AM into the "Proof" mode:

1) TRANSMITTER EQ SWITCH: OUT. This eliminates any high frequency rolloff induced by the H-F SHELF EQ.

NOTE

Except in the most unfavorable cases where the H-F SHELF EQ has been adjusted considerably clockwise from its end stop, the TRANSMITTER EQUALIZATION will ordinarily not disturb the overall frequency response sufficiently to cause problems in a PROOF. In fact, the L-F TILT EQ will tend to correct any bass rolloff problems. In most installations, defeating the transmitter equalizer for a proof is thus optional.

2) INPUT FILTER SWITCH: OUT. This restores the input amplifier to a flat response condition;

3) EQUALIZER: OUT. This bypasses the equalizer, restoring flat response; and

4) PROOF/OPERATE SWITCH: PROOF. This has five functions:

a) it bypasses the Six-Band Limiter section and defeats gain reduction in this section;

b) it defeats gain reduction in the Broadband Compressor and "Smart Clipper" sections, both of which remain in the circuit;

c) it forces the "Smart Clipper" into 10dB gain reduction to optimize signal-to-noise ratios through the system;

d) it defeats all clipping;

e) it ungates the Broadband Compressor and 150Hz Band Limiter to permit them to release to maximum gain.

OPTIMOD-AM is a very complex system which can be set up in a wide variety of ways. Because of the variations in gain through the system which occur when the DENSITY and SMART CLIPPER DRIVE controls are adjusted for different tastes, it is not possible to design the system gains such that OPTIMOD-AM performs optimally in the Proof mode for any arbitrary setting of these controls and for any arbitrary adjustment of the main program equalizer. It is therefore necessary to temporarily readjust these controls when a Proof is performed.

The following step-by-step instructions assure that standard levels are applied to the BBD delay lines in the OPTIMOD-AM in the Proof situation. These standard levels guarantee an optimum compromise between noise and distortion, and assure that no significant noise is added by other parts of the OPTIMOD-AM circuitry.

Please understand that these inconveniences are due entirely to the fact that an AM Proof is a highly artificial test situation which assumes flat frequency response from both station audio chain and receiver, and fails to take into account the fact that contemporary receivers are highly rolled-off. Great engineering effort was expended in assuring that the operating levels inside OPTIMOD-AM yield an optimum combination of low noise and sufficient headroom under normal operating conditions. The complications which may be imposed by a Proof situation do not reflect the realities of how OPTIMOD-AM sounds.

PERFORMING A PROOF

1) Connect a 1kHz oscillator through the most commonly used console input. With console gain controls in normal operating positions, adjust the output level of the oscillator until normal operating level (+4 or +8dBm, depending on your standard) is produced at the console output.

2) RECORD ALL OPTIMOD-AM CONTROL SETTINGS, SO THEY CAN BE RESTORED WHEN THE PROOF IS COMPLETE!

3) Switch the OPTIMOD-AM INPUT CONDITIONING FILTER, TRANSMITTER EQUALIZER, and PROGRAM EQUALIZER out by means of switches provided behind the swing-down door in the OPTIMOD-AM front panel.

4) Adjust the INPUT ATTENUATOR until approximately 5dB broadband gain reduction is indicated on the BROADBAND G/R METER. While the input transformer is mu-metal shielded, a sufficiently high-level 60Hz magnetic field exists in most locations to induce some subaudible hum into the transformer. If the INPUT LEVEL control is set to less than 12:00, this induced hum typically will not affect the measured noise level.

5) Switch the OPTIMOD-AM PROOF/OPERATE switch to PROOF.

6) Adjust the SMART CLIPPER DRIVE to 10:30. This assures that no noise will be contributed by earlier circuitry, and that all noise will be contributed by the BBD delay lines in the Smart Clipper. It is the noise and distortion performance of these delay lines which determine the noise and distortion of the entire OPTIMOD-AM.

7) Adjust the ten-turn OUTPUT ATTENUATOR control full clockwise.

8) The following procedure establishes a standard level through the BBD delay lines. Disconnect the OPTIMOD-AM output from the transmitter temporarily. Make sure that the output is not loaded by a resistor, transformer, or other load. Connect a dBm meter between either side of the OPTIMOD-AM output and ground. Adjust the DENSITY control until the output (in dBm) is the same as that indicated in Part I of your FINAL TEST SHEET. If you have lost this sheet, use +14.5dBm. (The DENSITY control will be fairly close to full clockwise.)

9) Now reconnect the transmitter to the OPTIMOD-AM output. Turn the OUTPUT ATTENUATOR to 0. Turn on the carrier, and adjust the OUTPUT ATTENUATOR until 99% negative modulation is observed.

With the OUTPUT ATTENUATOR full clockwise, at least +14dBm into 600 ohms will be available to drive the transmitter. This should be more than sufficient to drive any transmitter to full 100% modulation. However, if a pad is employed between the OPTIMOD-AM output and the transmitter, this pad may have to be bypassed to obtain 100% modulation.

OPTIMOD-AM is now set up to produce an optimum compromise between noise and distortion for performance measurements. Noise in the band between 20 and 30,000Hz will typically measure 60dB below the 1kHz level produced by the preceding adjustments. Total Harmonic Distortion will typically range from 0.2% at low frequencies to 0.5-0.6% at 5kHz. This distortion will be predominantly second-harmonic. At 7.5kHz, very little THD will be produced because all harmonics are removed by the output filter of OPTIMOD-AM. The THD will decrease as levels through OPTIMOD-AM are decreased.

While these noise and distortion figures are not negligible, they are nevertheless sufficiently low to leave plenty of "error budget" for deviations in the console, phone lines (or STL), and transmitter. No problems should be encountered in meeting Proof standards unless gross misbehavior exists in some other part of the system, such that said part is exhausting virtually the entire error budget itself.

This concludes the **SETUP AND ADJUSTMENTS** section of this manual.

Section 4

MAINTENANCE

General: OPTIMOD-AM's circuitry is all solid-state, and therefore does not require periodic readjustment. It has been carefully adjusted and inspected at the factory by skilled technicians using special test equipment and procedures.

The user is advised that it is unwise to attempt any readjustment of the calibration controls on the PC boards in a field situation. The average user is not likely to have the necessary equipment or experience to successfully calibrate the unit in the field. However, if the user has no choice, APPENDIX I provides complete calibration instructions.

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(Calibration controls are defined as those controls which are not accessible from the front of OPTIMOD-AM after the access door is opened. These calibration controls are trimpots located on the PC boards. They are usually accessed by removing the PC card on which they are mounted, and then plugging the card into a card extender.)

Routine Maintenance Procedure: OPTIMOD-AM should be inspected periodically to make sure that all the meters and indicators seem to be behaving normally. In addition to aiding setup, these meters will often indicate failures in the system which might otherwise go unnoticed.

Some potential failure modes will not be indicated on the meters. However, a practiced ear will often pick up subtle failures in the control circuitry that are not otherwise indicated. If OPTIMOD-AM begins to sound different, if it begins to pump, or if it begins to create distortion, this probably indicates that something is wrong. Of course, all other potential causes of such audible problems elsewhere in the audio chain must also be checked.

It is also wise to occasionally check for corrosion, particularly in the area of connections, and for conditions which may affect the chassis' ability to dissipate heat normally.

The only other routine maintenance necessary is keeping the unit free of dust and dirt. We recommend that the outside of the chassis be periodically cleaned with a mild household detergent: stronger solvents may damage the paint, silk-screened lettering, and/or plastic parts. Open the front panel periodically, and vacuum out any dust or dirt which has leaked inside the chassis.

TROUBLE DIAGNOSIS AND CORRECTION

Many problems experienced in the field can be resolved or conclusively diagnosed without necessity for factory service. Even if the repair cannot be done in the field, the information provided by the diagnostic routines below can speed the work of the factory service department in making the repair. Please perform these routines and make notes if you observe anything exceptional or unusual.

1) Use systematic troubleshooting techniques to positively determine that the problem is in fact being caused by OPTIMOD-AM, and not by other equipment. If a standby processor is available, it should be substituted for the supposedly faulty OPTIMOD-AM to see if the problem vanishes. If a standby processor is not available, audio quality at the OPTIMOD-AM audio input terminals should be checked with a high-quality monitor system. Note that even slight distortion can be seriously exaggerated by "heavy" processing, and that this sort of processing can only be successful if the input audio is extremely clean. A relatively minor problem which develops in the station's audio chain or STL can therefore be magnified by the action of OPTIMOD-AM, even if OPTIMOD-AM is in no way defective.

If the audio is clean going into OPTIMOD-AM, problems can still arise in the transmitter or antenna system. (Some of these potential problems are discussed in **Part 9** of the **Installation** section.) If a standby transmitter is available, it should be substituted to see if the problem vanishes. If no standby transmitter is available, positive trouble diagnosis is more difficult. In this case, we suggest that you audition the audio at the OPTIMOD-AM output terminals with a high-quality monitor system. Try to ascertain whether the problem observed "on-air" can still be heard when you listen to the OPTIMOD-AM output alone. You should use some high-frequency rolloff so that your ear is not deceived by the highly preemphasized sound. (We suggest that less rolloff than that provided by the supplied monitor rolloff filter be used to avoid masking possible high frequency problems.)

Loss of modulation control can be checked by observing the OPTIMOD-AM output terminals with a DC-coupled scope, and checking to make sure that the output envelope is "tight".

NOTE

> The transmitter equalizer will upset the peak levels at the output because these have been "predistorted" by the equalizer for transmitter errors. The oscilloscope check is thus only meaningful with the transmitter equalizer OUT.

Changes in or deterioration of grounding and/or exterior lead dress can sometimes cause RFI or hum problems to appear in a good OPTIMOD-AM.

If it seems impossible to conclusively isolate the problem to OPTIMOD-AM, yet no other definite cause is found, then duplicating the Factory Final Test and Qualification Procedure may help diagnose a problem. Your Final Test and Qualification sheet contains the measurements that were originally made by the factory technician who tested your unit. The sheet describes all test conditions. Using the same test conditions, you should be able to closely duplicate the factory results if OPTIMOD-AM is operating normally.

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2) If the fault has been positively isolated to OPTIMOD-AM, then the **Problem Localization Routine** described below should be performed to identify the faulty PC card.

PROBLEM LOCALIZATION ROUTINE

General Principles: The most powerful and general technique for localizing a problem within OPTIMOD-AM is signal tracing. This simply means that the signal is observed at various points as it passes from OPTIMOD-AM's input to its output. If the signal is normal at some point "A" in the circuit, and is abnormal at a point "B" further towards the output, then the problem clearly lies in circuitry between points "A" and "B".

Power Supply Tests: The power supply feeds all cards, and problems with the power supply may affect many OPTIMOD-AM circuits simultaneously. For this reason, the first step in any troubleshooting procedure is to check the power supply for normal output. Gross changes in power supply voltage can be detected with the "+15VDC" and "-15VDC" positions on the VU meter. Normal readings are 0VU $\pm$0.5VU.

If either "+" or "-" power supply output is significantly low, it could indicate a defect in the supply itself. But it is more likely to indicate a shorted IC or capacitor somewhere in the circuit that is overloading the supply and causing it to current-limit.

The power supply is electronically protected against excessive current demand by other parts of the circuitry. If a failure causes a high current demand on the power supply, its output voltage will drop as far as necessary to reduce output current to approximately 0.75A. If the power supply voltage is observed to be abnormally low, unplug each circuit card in turn and check if the power supply recovers by observing the "-15VDC" meter position. (The negative regulator tracks the +15V supply. So the -15V supply will go down if the +15V supply does, even if the -15V supply is completely normal. A normal "-15VDC" reading thus assures a normal "+15VDC" reading.) If recovery occurs, then troubleshoot the unplugged board. Ordinarily, the defective component will become very hot, and is easily detected by touch. (Wet your finger first to avoid burns!)

If all cards are removed and an undervoltage problem does not disappear, examine the chassis wiring before suspecting the supply itself. (A wiring problem will be indicated by an ohmmeter's indicating very low resistance between the "+15V" or "-15V" power busses with AC power OFF.)

Even if power supply voltages appear normal on the VU meter, subtle problems such as hum, noise, or oscillation may still exist with the supply. To check for this, measure the regulated DC with a well-calibrated DVM, AC ATVM (with 20-20,000Hz bandpass filter), and oscilloscope. Voltages should be +15.00V ±0.075V, -15.00V ±0.375V. Ripple must be less than 2mV rms, 20-20,000Hz. There must be no high frequency oscillation.

VU Meter Technique: If the audio at the OPTIMOD-AM output goes dead, loses or gains significant level, or becomes grossly distorted, then the VU meter provides a means for fast signal tracing. Note, however, that problems other than gross gain changes or total failure to pass signal may not be detected by the meter alone.

The VU meter has been configured to permit examination of the audio signal as it passes through OPTIMOD-AM from input to output. The Block Diagram at the rear of this manual indicates the exact points monitored by the meter. Switch through the first nine VU meter functions to see where the signal disappears (or the VU meter pegs, implying that a defective IC opamp has latched up to the power supply rail.)

The only point monitored which is not actually in the audio path is "Pilot VCA".

If the signal is abnormal at this point, it means that the "Smart Clipper" control circuitry cannot be operating correctly, as this circuitry relies upon the output of VCA1 to develop the "Smart Clipper" gain control signal by feedback.

Further signal tracing and systematic identification of faulty cards is aided by **Part 1 (Simplified System Description),** and particularly by the Block Diagram.

Servicing on the "component replacement" level requires more profound understanding of OPTIMOD-AM circuit operation, which is provided by **Part 5 (SYSTEM DESCRIPTION)** and **Part 6 (CIRCUIT DESCRIPTION).** If the technician wishes to troubleshoot OPTIMOD-AM 9000A at the component level, he should first use **Part 5** to help track down the fault to a given subsystem, and then refer to **Part 6** for an extremely detailed explanation of the circuitry at the component level.

4

USER ACCESS

Routine Access

The first part of this section describes how to access those parts of OPTIMOD-AM ordinarily involved in setup, adjustment, or alignment. (The second part provides information on the disassembly techniques necessary to access the balance of the circuitry.)

a) User Adjustments: To access the user adjustments, open the small access door by turning the single DZUS fastener on the door one-quarter turn counterclockwise. Or if the optional lock is fitted, turn the key one-quarter turn clockwise. This will reveal all user-adjustable controls.

b) Line Fuse, Power Switch, and Line Voltage Selector: These are accessed by swinging down the entire front panel, which is hinged at the bottom. To avoid damage, this should be done only with the small access door locked. Using the 5/64" hex wrench supplied, remove the three hex-socket screws at the top of the front panel and carefully swing the panel out and down.

c) Circuit Cards: First, swing the front panel down (see **b).** You must then remove the subpanel by first loosening four DZUS fasteners by turning each one-quarter turn counterclockwise with a long 3/16" or 1/4" slotted-blade screwdriver. Taking care not to stress the flat cable beneath it, tilt the top of the subpanel outward and leftward to clear the upper chassis lip and the door support bail at the right. The PC cards may now be removed from their slots.

CAUTION!

THE #4 AND #6 CARDS CANNOT BE REMOVED BEFORE THE #3 AND #5 CARDS BECAUSE OF MECHANICAL INTERFERENCE. SIMILARLY, THE #4 AND #6 CARDS MUST BE INSTALLED BEFORE THE #3 AND #5 CARDS RESPECTIVELY.

**** This procedure is directly reversible with cautions:

-- The subpanel should always be replaced to protect the cards from RFI.

-- DZUS fasteners turn only 1/4-turn. Don't force them, lest they be damaged in a way that is very time-consuming to repair.

Service Access

General Cautions: These apply to all the procedures described below.

-- For best RFI protection, replace all screws and tighten normally to achieve firm contact

-- If screws are lost, replace them with screws of the same length, since longer screws may cause mechanical interference or internal short circuits.

-- Most screws used in OPTIMOD-AM are binding head to achieve secure fastening without lockwashers. If a pan head screw is substituted, use an internal star lockwasher to retain this security.

-- Plating on all screws is Cadmium type II. Almost any other plating is acceptable unless corrosive atmosphere is present.

a) Cover Removal: Removing the top or bottom covers is tedious because thirty screws must be removed. (The large number of screws is necessary to achieve an RF-tight seal.) Luckily, most service access can be achieved without removing either cover! Specific instructions for doing this are found below.

If you wish to remove either cover, simply remove all thirty screws.

**** This procedure is directly reversible with cautions:

-- When replacing a cover, align it as closely as possible with the corresponding holes, and start all screws. After all screws have been started, tighten all screws to normal tightness, "inland" screws first.

b) Access To Area Behind Rear Panel: If the covers are still in place, they needn't be removed.

Remove eight screws holding the top cover to the flange of the rear panel. Remove the corresponding eight screws from the bottom cover. The rear panel will remain solidly in place.

Set the chassis, bottom cover down, on a pad on a table. Allow 6" (15cm) between the rear panel of the chassis and the table edge. Unplug the power cord.

Now remove three vertically-spaced groups of three screws on the rear panel. Two groups are found on the extreme left and right of the rear panel respectively. The third group is found about one-third of the way from the right edge of the rear panel.

4

VERY carefully and slowly, pull the rear panel about 3/4" (2cm) toward you, and tilt the top edge down until the rear panel is horizontal and resting on the table.

CAUTION

Watch for snags in the internal wiring, and for any stress on the ceramic feedthrough capacitors on the divider wall or input filter box. These capacitors are very fragile and difficult to replace.

**** This procedure is directly reversible with cautions:

-- When positioning the rear panel over the corresponding holes, make sure that no wires are pinched under the flanges. Start, but do not tighten all nine screws. Observe the areas where the flanges on the rear panel meet the flanges on the side panels. Adjust the rear panel so that the flanges line up in order to provide a flat mounting surface for the cover when tightened.

c) Access To RF Filter Card: First open the rear panel (procedure **b** above).

Remove the four screws holding the Input Filter Box to the rear panel. **VERY** carefully and slowly, tilt the metal box back to vertical, taking care to avoid snagging the internal wiring and stressing the ceramic feedthrough capacitors.

This will reveal the internal circuit card, which is attached to the rear panel by four #4-40 screws. While this card can be removed for component replacement, it is easier (though less workmanly) to clip out the defective component from the topside and to install its replacement by tack-soldering to the old leads.

**** This procedure is directly reversible with cautions:

-- If components have been replaced, make sure that reassembly will not result in crushing of the component against the rear panel.

-- Tilt the box back to horizontal (so it rests against the rear panel) very slowly and carefully. Watch for wire snags and dress wires appropriately. Make sure that no wires are crushed under the flange.

d) Access To Unregulated Power Supply Chamber: If the covers are not already removed, remove the five cover screws which attach the top cover to the flange of the side panel. Remove the corresponding five screws from the bottom cover.

Open the front panel.

Remove the shoulder screw that attaches the door-support bail to the left chassis wall. Note that there is a nylon washer between the bail and chassis wall to prevent scraping.

Turn the chassis so that the left wall is facing you. Remove the left rack flange by removing the six unrecessed screws.

Remove the three screws that attach the rear panel to the main (steel) side panel.

Remove the remaining six screws and gently lift off the side panel by pulling outward.

**** This procedure is directly reversible with cautions:

-- Position the steel side panel and start, but do not tighten, all nine screws. Observe the areas where the flanges meet the rear panel and internal bulkhead, and align the flanges so that the covers will seat on a flat mounting surface.

e) Removal Of Card #1 (The DC Regulator) From Rear Panel And Power Transistor Replacement: Because the removal procedure is complex, this card was designed to permit many servicing operations to be performed without removing the card from the chassis.

The plastic transistors and some capacitors are socketed in very tiny sockets pressed into the card. IC's are conventionally socketed. Many unsocketed components can be replaced from the topside by tack-soldering the new component to the lead stubs of an old clipped-out component.

If the card must be removed, do it as follows:

CAUTION

> The rear panel serves as a heat dissipator for the power transistors. Proper contact is necessary to insure sufficient transistor cooling. Please follow instructions carefully.

4

Remove the four press-fit plastic plugs on the power transistor covers with a pair of chain-noise pliers. This will reveal the transistor mounting screws. Remove the four screws holding the power transistors.

VERY carefully and slowly pull each transistor from its socket. If, as you do this, the silicone rubber insulator tends to stick to the panel, release it from the panel such that it sticks to the bottom of the transistor instead. After you remove each transistor, press its insulator back in close contact with it pending reinstallation.

NOTE

> These insulators form themselves to the bottom surface of each transistor. Since they take a "set", they should not be interchanged or reversed. If you have to replace a power transistor, you may re-use the insulator if it is in good condition. With care, it will re-form itself as necessary. Otherwise, use a conventional mica insulator and white silicone heat-conducting compound.

Open the rear panel (procedure **b)**. With the transistors removed, it is possible to release the circuit card from its plastic post mounts by squeezing the tangs in each of the four corners to permit pulling the card off the posts.

**** This procedure is directly reversible with cautions:

-- See the discussion above regarding heat-conduction insulators

-- The screws mounting the transistors should be tightened evenly. For best thermal contact, tighten each screw a small amount, alternating between screws. Tighten securely, but not enough to damage the threads in the sockets.

-- Note that there must be a split lockwasher under each screwhead to accomodate thermal cycling.

-- The Thermalloy (TM) plastic cover does not attach in a conventional or readily obvious way. It rides on the circumference of the special split lockwasher and does not (and should not) become captured under the head of the screw. Consequently, the cover may be slightly loose even after screws are tightened securely. This is normal, and should not (and cannot) be corrected.

-- Be sure to reinstall the press-fit plugs that cover the screwheads.

FACTORY ASSISTANCE

Orban Associates, Inc., maintains a Customer Service Department to help Orban product users who experience difficulties. Orban Customer Service is supplied at two levels. The first is telephone consultation. Often, a problem is due to misunderstanding, or is relatively simple and can be fixed by the customer aided by phone advice from the factory. Telephone consultation should always be the first step in any factory service transaction. Units will be accepted for factory service (the second level) only after consultation, and only after a Return Authorization (RA) code number has been provided by phone or letter. The RA number flags the returned unit for priority treatment when it arrives on our dock, and ties it to the appropriate information file.

The purpose of this formality is to save both the customer and the factory time and trouble by attempting to weed out problems which are caused by equipment other than OPTIMOD-AM, misapplication, or environment, and to identify those problems that lend themselves to quick field repair.

Before calling Customer Service, be prepared to give the model number (9000A) and serial number of your unit. If the unit is in its warranty period and the Registration Card was never returned, we will also need the name of the dealer from which the unit was bought, the invoice number, and the invoice date.

Be prepared to accurately describe the the problem. What is the complaint? Is it constant or intermittent? If it is intermittent, can it be correlated to environmental conditions like line voltage, temperature, humidity, electrical storms, vibration, etc? Do problems only occur with certain program material (live voice, very bright music, music with heavy bass transients, etc.)? What about source: cart, disc, reel-to-reel, live microphone?

Be prepared to describe any unusual observations made during the **Problem Localization Routine** you performed using the instructions above.

Then, contact the Customer Service Department by telephone, letter, or Telex (see title page for numbers). A Customer Service Engineer is ordinarily available during local business hours, Monday through Friday. The Customer Service Engineer will do everything practical to help correct the fault and have your OPTIMOD-AM up and running again as quickly as possible.

In many cases, field repairs can be effected by merely exchanging a single PC card, rather than by returning the entire OPTIMOD-AM chassis for repair. The factory ordinarily maintains a small number of "loaner cards". One of these may be provided as a spare PC card for use while the customer's card is being repaired at the factory. In most cases, factory service of defective cards is preferable to field service by the customer because the factory maintains a supply of exact-replacement spare parts, and has the experienced technicians and special test fixtures necessary to assure that the repaired card meets factory specifications in all respects. Instructions for packing and shipping cards or the complete chassis are found at the end of this Appendix.

Selecting And Ordering Replacement Parts

Nearly all parts used in OPTIMOD-AM have been very carefully chosen to make best use of both major and subtle characteristics. For this reason, parts should always be replaced with exact duplicates as indicated on the Parts List. It is very risky to make "close-equivalent" substitutions because of the possibility of materially altering performance and/or compliance with FCC requirements. The Factory is ordinarily able to supply any replacement part rapidly at an uncommonly reasonable price.

Specifically, such parts include all FET's and precision metal-film resistors, almost all capacitors, trimmer resistors, and integrated circuits, most transistors, and certain diodes.

Certain cards contain potted modules which, if diagnosed as defective, must be replaced as a unit. Ordinarily, this requires return of the entire card to the factory.

Certain parts are selected by the factory to tighter than normal specifications in order to obtain circuit performance which meets our exacting standards. Such parts are footnoted in the Parts Lists.

Certain parts, if replaced, require partial recalibration which may or may not be practical in the field. The recalibration requirements are outlined in the appropriate section of **Part 6 (Circuit Description)** and/or **Appendix I (Alignment).**

Service in areas involving selected parts or recalibration is best referred to the factory, which, as a result of training, experience, availability of special equipment, and availability of exact replacement parts, is generally far better qualified to perform repairs efficiently and correctly.

Ordering Parts From The Factory: If parts are ordered from the factory, we require all of the following information:

-- The Orban part number, if ascertainable from the Parts List
-- The Reference Designator (e.g., R503)
-- A brief description of the part
-- And, from the serial label on the rear of the unit
  - the exact Model Number
  - the Serial Number
  - the "M" number, if any

Troubleshooting IC Opamps

IC opamps are operated such that the characteristics of their associated circuits are essentially independent of IC characteristics and dependent only on external feedback components. The feedback forces the voltage at the "-" input terminal to be extremely close to the voltage at the "+" input terminal. Therefore, if the technician measures more than a few millivolts between these two terminals, the IC is probably bad.

Exceptions are IC's used without feedback (as comparators) and IC's whose outputs have been saturated due to excessive input voltage because of a defect in an earlier stage. However, if an IC's "+" input is more positive than its "-" input, yet the output of the IC is sitting at -14 volts, this almost certainly indicates that it is bad. The same holds if the above polarities are reversed. Because the characteristics of OPTIMOD-AM are essentially independent of IC opamp characteristics, an opamp can usually replaced without need for recalibration.

NOTE

CA3080's AND CA3019's EMPLOYED IN THE VCA's ARE NOT OPAMPS. IF THEY ARE REPLACED, RECALIBRATION IS ABSOLUTELY NECESSARY.

A defective opamp may appear to work, yet it may have extreme temperature sensitivity. If parameters appear to drift excessively, freeze-spray may aid in diagnosing the problem. Freeze-spray is also invaluable in tracking down intermittent problems. But, use sparingly, because it can cause resistive short circuits due to moisture condensation on cold surfaces.

4

Replacement Of Components On Printed Circuit Cards

It is important to use the correct technique for replacing components mounted on PC cards. Failure to do so may result in circuit damage and/or intermittent problems.

Many components, if replaced, will cause a change in calibration which will require returning the affected circuit card to the factory for recalibration. Also, some components are selected for characteristics which are not indicated by the manufacturer's part number. Most of these components are listed as "selected" on the parts list, but not all. In addition, the selection criteria are not generally described. It is therefore almost always wiser to return the defective card to the factory for service.

Most circuit cards used in OPTIMOD-AM are of the double-sided plated-through variety. This means that there are traces on both sides of the card, and that the through-holes contain a metallic plating in order to conduct current through the card. Because of the plated-through holes, solder often creeps 1/16" up into the hole, requiring a sophisticated technique of component removal to prevent serious damage to the card.

If the technician has no practical experience with the elegant and demanding technique of removing components from double-sided PC cards without card damage, it is wiser to cut each of the leads of an offending component from its body while the leads are still soldered into the card. The component is then discarded, and each lead is heated independently and pulled out of the card with a pair of long nose pliers. Each hole may then be cleared of solder by carefully heating with a low-wattage soldering iron and sucking out the remaining solder with a spring-activated desoldering tool. THIS METHOD IS THE ONLY SATISFACTORY METHOD OF CLEARING A PLATED-THROUGH HOLE OF SOLDER IN THE FIELD!

The new component may now be installed by following the directions below starting with step (4).

Otherwise, use the following technique to replace a component:

1) Use a 30 watt soldering iron to melt the solder on the solder side (underneath) of the PC card. Do not use a soldering gun or a high-wattage iron! As soon as the solder is molten, vacuum it away with a spring-actuated desoldering tool like the Edsyn "Soldapullt". AVOID OVERHEATING THE CARD; overheating will almost surely damage the card by causing the conductive foil to separate from the card base.

Even with care, you are likely to blister the enamel solder-mask coating on the card, which, in most cases, is no cause for concern. The coating exists mainly to prevent moisture from condensing between the traces and to simplify wave-soldering.

2) Repeat step (1) until each lead to be removed has been cleared of solder and freed.

3) Now release the component by gently wiggling each of the leads to break solder webs. Then lift the component out.

4) Bend the leads of the replacement component until they will fit easily into the appropriate PC card holes. Using a good brand of rosin-core solder, solder each lead to the bottom side of the card with a 30 watt soldering iron. Make sure that the joint is smooth and shiny. If no damage has been done to the plated-through hole, soldering of the topside pad is not necessary. However, if the removal procedure did not progress smoothly, it would be prudent to solder each lead at the topside as well in order to avoid potential intermittent problems.

5) Cut each lead of the replacement component close to the solder (underneath) side of the PC card with a pair of diagonal cutters.

6) Remove all residual flux with a cotton swab moistened with a solvent like 1,1,1 trichloroethane, naptha, or 99% isopropyl alcohol. The first two solvents are usually available in supermarkets under the brand name "Energine" fire-proof spot remover and regular spot remover, respectively. The alcohol, which is less effective, is usually available in drug stores. Rubbing alcohol is highly diluted with water and is ineffective.

It is good policy to make sure that this defluxing operation has actually removed the flux and has not just smeared it so that it is less visible. While most rosin fluxes are not corrosive, they can slowly absorb moisture and become sufficiently conductive to cause progressive deterioration of performance.

Shipping Instructions

Circuit Cards: A circuit card is best shipped in the special Orban Associates shipping carton used to supply loaner cards. If you wish to ship a card without this carton, cut two pieces of 1" or thicker soft foam to 6.5" x 9" (17cm x 23cm) or larger. Sandwich the card between the two foam pieces, and ship the foam "sandwich" in a rigid cardboard carton.

A "JIFFY-BAG" OR SIMILAR SOFT MAILING BAG DOES NOT PROVIDE SUFFICIENT PROTECTION FOR THE CARD, AND MUST NOT BE USED!

Shipping The Complete Chassis: If the original packing material is available, it should be used. Otherwise, a sturdy, double-wall carton of at least 200 pounds bursting test and no smaller than 22" x 15" x 12" (56 x 38 x 31 cm) should be employed.

OPTIMOD-AM should be packed so that there is at least 2" of packing material protecting every point. A plastic wrap or bag around the chassis will protect the finish. Cushioning material such as Air-Cap, Bubble-Pak, foam "popcorn", or thick fibre blankets are acceptable. Folded newspaper is not suitable. Blanket-type materials should be tightly wrapped around OPTIMOD-AM and taped in place to prevent the unit from shifting out of its packing and contacting the walls of the carton.

The carton should be packed evenly and fully with the packing material filling all voids such that the unit cannot shift in the carton. Test for this by closing but not sealing the carton and shaking vigorously. If the unit can be felt or heard to move, use more packing. The carton should be well-sealed with 3" (8 cm) reinforced fibreglass or polyester sealing tape applied across the top and bottom of the carton in an "H" pattern. Narrower or parcel-post type tapes will not stand the stresses applied to commercial shipments.

The package should be marked with the name of the shipper, and the words in red: DELICATE INSTRUMENTS, FRAGILE!. Even so, the freight people will throw the box around as if it were filled with junk. The survival of the unit depends almost solely on the care taken in packing!

After a formal Return Authorization (RA) number is obtained from the factory, units should be shipped to the Service Manager at the address shown on the title page.

YOUR RETURN AUTHORIZATION NUMBER MUST BE SHOWN ON THE LABEL, OR THE PACKAGE WILL NOT BE ACCEPTED!

INSURE YOUR SHIPMENTS APPROPRIATELY!

SHIP PREPAID -- DO NOT SHIP COLLECT!

DO NOT SHIP PARCEL POST!

Section 5

PRINCIPLES OF OPERATION

The purpose of this section of the manual is to provide the technician with a moderately detailed overview of the operation of the OPTIMOD-AM system. This section should be particularly useful in tracing a fault to a given subsystem. Usually a fault can be repaired merely by replacing a bad card with a good one, and having the defective card repaired at the Orban factory. Each card is numbered. Reference will be made in each section to the number of the card on which the described circuitry is located. If the technician wishes to troubleshoot the OPTIMOD-AM on the component level, he should first use this section to help track down the fault, and then refer to the subsequent **CIRCUIT DESCRIPTION** section for an extremely detailed explanation of the circuitry on a component level.

REFER TO THE BLOCK DIAGRAM IN THE BACK OF THIS MANUAL.

For reference purposes, the explanation will be broken down into the following logical sections, which follow the signal flow:

1) INPUT SECTION
   a) input amplifier (card #3)
   b) input conditioning filter (card #3)
   c) gating detector (card #3)

2) BROADBAND COMPRESSOR
   a) voltage-controlled amplifier (card #3)
   b) control circuitry (card #3)

3) MAIN EQUALIZER
   a) bass equalizer (card #5)
   b) 5kHz equalizer (card #5)
   c) 10kHz equalizer (card #5)

4) SIX-BAND LIMITER
   a) crossover filters (card #5)
   b) limiters (card #4 and card #2) and summing amplifier (card #7)

5) POLARITY FOLLOWER
   a) polarity controller (card #7)
   b) polarity detector (card #7)
   c) polarity switching shaper (card #7)

6) SMART CLIPPER
   a) pilot system
      A) VCA I and clipper (card #7)
      B) distortion-scaling VCA (card #7)
      C) third-octave filters and analog dividers (card #6)
      D) analog "OR" (card #9)
      E) control-voltage integrator with delayed release (card #9)
   b) delay system
      A) clock (card #9)
      B) 3.7 mS BBD delay (card #9)
   c) main audio path
      A) slave VCA (card #9)
      B) clipper and 1.8kHz lowpass filter (card #9)
      C) 450 microsecond delay line and clipper (card #9)
      D) distortion corrector subtractor (card #9)

7) OUTPUT SECTION
   a) phase-linear lowpass filter (card #8)
   b) safety clipper (card #8)
   c) transmitter equalizer (card #8)
   d) output line amplifier (card #8)
   e) remote control and logic (card #8)

8) POWER SUPPLY
   a) unregulated ±24 volt supply (on chassis)
   b) +15 volt regulator (card #1 (on chassis))
   c) -15 volt regulator (card #1 (on chassis))
   d) clipper bias supplies (card #7)
   e) ±1 volt comparator reference supplies (card #3)
   f) miscellaneous supplies derived from ±15 volt supplies by means of diode drops (found locally as needed)
      A) +14 volt supply
      B) +12.6 volt supply
      C) -6 volt supply

1.a) Input Amplifier: (On Card #3)

The audio is applied to a balanced 600 ohm pad with 20dB of nominal loss. Instructions for restrapping the pad for 6dB loss are provided in **Section 2, subsection 6.A.** Following the pad, the signal is stepped up with a transformer and applied to the input amplifier through the INPUT ATTENUATOR control. The output of the input amplifier can be disconnected from the following circuitry and connected to a stereo adapter chassis for sum-and-difference (or other linear combination) limiting of AM stereo audio.

1.b) Input Conditioning Filter: (On Card #3)

The input amplifier drives a complex filter which conditions the signal by removing frequency components outside the range which can be reproduced by a consumer AM radio. The filter also applies a mild high frequency preemphasis reaching a peak of about 10dB at 6kHz. The signal first encounters a 100Hz 18dB/octave highpass filter. The next three opamps combine the preemphasis function with a 30dB/octave 11kHz lowpass filter characterized by 1dB of ripple in the passband (excluding the effects of the preemphasis). The input filter can be entirely bypassed by means of a switch which sends either its output or the output of the input amplifier to subsequent circuitry.

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1.c) Gating Detector: (On Card #3)

The output of the highpass filter is routed to a variable gain bandpass amplifier which rolls the signal off at 6dB/octave below 300Hz and above 3kHz to filter out noise. The output of this amplifier is peak-detected. The peak-detected output is applied to a comparator. If the input signal level exceeds the level set by the GATE THRESHOLD control then the output of the comparator goes HIGH; otherwise, it is LOW and defeats the release time circuits in the following broadband and 150Hz limiters.

2.a) Voltage-Controlled Amplifier -- Broadband Compressor: (On Card #3)

(**NOTE:** The following is a general description of the VCA's used in the OPTIMOD-AM system, and will therefore be referenced later in the text.)

The voltage-controlled amplifier employs a two-quadrant transconductance multiplier in the feedback loop of a high-gain FET-input operational amplifier. A diode bridge is used to linearize the multiplier, thereby cancelling distortion.

The multiplier's overload point is constant with respect to its input level. This is why it is used in the divider mode: the purpose of a compressor is to provide a constant level output. In the divider mode, the input of the multiplier is connected to the output of the VCA; thus dynamic range is maximized.

2.b) Control Circuitry — Broadband Compressor: (On Card #3)

(**NOTE:** The control circuitry employed in the broadband compressor is similar to that employed in the limiters in the 6-band section. This section will therefore be referenced later in the text.)

The gain of the compressor is controlled by applying its output to a 711C dual comparator IC which produces an error signal if the compressor input attempts to exceed a given positive or negative reference voltage. Said voltages are ± 1 volt and are generated on card #3 (see **8.e**). The output of the comparator charges a pair of integrating capacitors through a diode network which provides delayed release to reduce low frequency distortion due to ripple on the gain-control voltage.

The control voltage on the high-ripple capacitor is fed back into a proprietary modular circuit which produces desirable program-controlled release time characteristics which minimize audible "pumping" and/or "holes" in the program. The smoothed control voltage on the other integrating capacitor is buffered by a FET-input opamp, whose output feeds the stereo adapter link and which also feeds an exponential current source. The output of the exponential current source is used to control the gain of the VCA, thus closing the control feedback loop and making the output of said FET-opamp buffer amplifier proportional to the gain reduction in dB. Since the voltage on the integrating capacitor is proportional to the logarithm of the gain of the VCA, the attack and release time characteristics are essentially independent of the amount of gain reduction already occuring (except for characteristics intentionally programmed into the release-time module). The output of said buffer amplifier also drives a gain reduction meter which is linearly calibrated in dB gain reduction.

Gain reduction is defeated for proofs by grounding the "strobe" terminals of the comparators, thus disabling them.

3) MAIN EQUALIZER — GENERAL: (ON CARD #5)

The main equalizer is a three-frequency series/parallel topology. It is quite different from conventional program equalizers in that it is specifically designed to compensate for the frequency response inadequacies of consumer AM receivers.

The bass (100Hz) and high frequency (10kHz) equalizers are connected in parallel because their frequency ranges are far enough apart to avoid significant phase interaction. The midrange (5kHz) equalizer is placed in series with the two previous equalizers.

All of the equalizers are peaking equalizers with boost (but no cut) available. They each employ a differential configuration. That is, peak boost is accomplished by adding the output of a bandpass filter to the unequalized signal. The bass and midrange equalizers use second-order (6dB/octave slopes) filters; the high frequency equalizer employs a fourth-order (12dB/octave slopes) filter.

The main equalizer can be entirely bypassed for proofs by operation of the EQUALIZER IN/OUT switch.

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3.a) Bass Equalizer: (On Card #5)

The bass equalizer is a "quasi-parametric" configuration offering control over frequency of peak equalization (80-120Hz), amount of equalization (0-10dB), and bandwidth of equalization ("Q"=0.3-1.4). Adjustment of the frequency changes the fractional bandwidth, as does adjustment of the amount of boost. Otherwise, the controls are non-interacting. The equalizer employs a dual-amplifier quasi-parametric bandpass resonator whose output is summed with the unequalized signal.

3.b) 5kHz (Midrange) Equalizer: (On Card #5)

The 5kHz equalizer follows the other equalizers. It uses a quasi-parametric bandpass resonator identical in topology to the bass resonator **3.a.** However no control over tuning frequency is provided because of the critical relationship between the midrange and high frequency equalizer characteristics which can result in stridency if peaking frequencies are incorrectly chosen. It is capable of 0-20dB peak boost, and a "Q" range of 1.0 to 2.2.

3.c) 10kHz (High Frequency) Equalizer: (On Card #5)

The high frequency equalizer employs a specially shaped fourth-order bandpass resonator consisting of two opamps in cascade. The output of this resonator can be added to the unequalized signal to produce a smooth curve with slopes approaching 12dB/octave. Careful design has eliminated dips in the frequency response due to phase cancellations for any degree of equalization. This equalizer has much higher selectivity than second-order types, and can effectively equalize the steep high frequency rolloff caused by narrowband IF's in consumer AM receivers. It is capable of 0-20dB peak boost.

4) SIX-BAND LIMITER — GENERAL:

The Six-Band Limiter performs most of the density augmentation in OPTIMOD-AM because independent processing of each frequency band masks interactions inherent in wideband limiters. The signal is divided into six bands by an active crossover network. The output of each of the six filters drives its own limiter with extremely carefully chosen characteristics. The outputs of the six limiters are then combined and used to drive subsequent processing sections. When the PROOF/OPERATE switch is in the PROOF position, the Six-Band Limiter is bypassed. Gain reduction is also defeated by strobing the 711C IC comparators so that no gain reduction is indicated on the six individual band gain reduction meters when the Six-Band section is defeated.

4.a) Crossover Filters: (On Card #5)

There are six crossover filters, all with 12dB/octave skirts. To avoid phase cancellations, the polarity of adjacent filters must alternate. Thus the filter characteristics are as follows:

1) 150Hz lowpass inverting;
2) 300Hz bandpass non-inverting;
3) 700Hz bandpass inverting;
4) 1.6kHz bandpass non-inverting;
5) 3.7kHz bandpass inverting;
6) 7.5kHz highpass non-inverting.

4.b) Limiters And Summing Amplifier:

(300Hz, 1.6kHz, and 7.5kHz Limiters On Card #4; 150Hz, 700Hz, And 3.7kHz Limiters On Card #2; Summing Amplifier On Card #7)

The topology of each limiter is substantially identical to the topology of the broadband compressor; the reader is referred back to **subsection 2.**

There are few additional comments necessary. The thresholds, attack times, release times, and gains of the limiters have been carefully chosen to provide natural, uncolored sound. All these characteristics are programmed by four external fixed resistors per limiter; all other circuitry is identical. The four bottom bands have a potential gain reduction range of 20dB; the top two limiters have a potential range of 30dB so that extreme high frequency preemphasis from the equalizer stages can be controlled without overload of the limiters.

The summing amplifier adds the outputs of the six limiters to obtain a signal typically flat ± 0.75dB when no gain reduction is employed. The filters have been carefully designed to avoid unwanted dips in the frequency response of the sum when the limiters are operating normally with varying amounts of gain reduction. The summing amplifier is a conventional opamp "virtual ground" inverting mixer.

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5) POLARITY FOLLOWER — GENERAL: (ON CARD #7)

The purpose of the polarity follower is to present asymmetrical program material to the "Smart Clipper" circuit with consistent polarity so that the side of the waveform with the highest peak level will modulate the transmitter consistently in the positive direction. To do this, it is necessary to detect whether or not the polarity is correct. If it is wrong, it must be reversed without audible effect on the program (except for a slight increase in loudness as the improvement is detected and acted upon by the "Smart Clipper".)

5.a) Polarity Controller: (On Card #7)

The polarity is switched by means of a first-order allpass network which is swept in approximately one second through the entire frequency range covered by OPTIMOD-AM. This allpass network is realized with a differential amplifier.

The phase response of the network varies from 0 degrees at a low frequency to 180 degrees at a higher frequency. At some intermediate frequency the phase shift is 90 degrees. This 90 degree point can be varied from substantially below to substantially above the frequency range covered by OPTIMOD-AM by varying the illumination of the photoresistor associated with the allpass network. If the 90 degree point is moved at an optimum speed as a function of its instantaneous frequency, then it can be swept throughout its range in about a second without causing audible phase modulation of any program material. The circuitry which drives the LED illuminating said photoresistor has been carefully designed to provide such optimum shaping of the sweep.

The sweep shaper starts with a ramp generator. The ramp is shaped by a diode-resistor network with three breakpoints, and is finally applied to an exponential converter which provides an exponential current drive for the LED. A front panel LED in series with the control LED indicates that the circuit is performing properly.

5.b) Polarity Detector: (On Card #7)

The polarity detector follows the polarity switcher. Therefore, all it has to do is determine if the polarity is wrong or right. If it is right, nothing happens. If it is wrong, a flip-flop changes state and forces the polarity switcher into its opposite state, thus correcting the polarity.

The negative half of the polarity switcher output is peak-detected with slightly higher than unity gain. The DC peak-detected signal is compared to the positive-going half of the waveform by a comparator. If the positive-going half of the waveform exceeds the amplified negative-going half, the polarity is considered wrong and the comparator produces an output pulse which charges a capacitor. If a few such pulses are produced fast enough, then said capacitor becomes sufficiently charged to fire a second comparator with hysteresis. Said capacitor's discharge time is stretched to greater than one second so that the polarity switcher has time to switch polarity before another error indication occurs. Said second comparator clocks a CMOS D-type divide-by-two flip-flop each time its output goes positive, thus changing the state of the flip-flop. The output of the flip-flop determines the state of the polarity switcher through the interface circuitry described in **5.a.**

6) "SMART CLIPPER" (U.S. PATENT #4,208,548) — GENERAL: (ON CARDS 6, 7, AND 9)

The "Smart Clipper" is a peak limiting circuit which employs both linear gain reduction and peak clipping. By subtracting the output of the clipper from its input, the distortion component introduced by the clipping process is derived. This distortion component is then employed in three distinct ways to control the gain of the Voltage-Controlled Amplifier (VCA) preceeding the clipper, thus determining the amount of clipping:

i) Above approximately 1.8kHz, the distortion component is frequency-divided into psychoacoustical "critical bands" one-third octave wide by means of parallel bandpass filters. The clipper input is also divided into such bands. Arithmetic divider circuits then compute the ratio between the distortion component in each band and the undistorted energy in the band. This provides an estimate of whether or not the distortion component in each critical band above 1.8kHz is "masked" by the undistorted signal (see **6.a)**. If the distortion component is not masked, feedback circuitry forces the VCA prior to the clipper to reduce its gain. Thus clipping is reduced until the distortion is masked.

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ii) Clipping distortion below 1.8kHz is dealt with differently (see **6.d)**. The distortion component is lowpass-filtered at 1.8kHz with a linear-phase lowpass filter. The output of said lowpass filter is then subtracted from the clipped signal, which has been delayed to compensate for the delay in the lowpass filter. Thus clipper-induced distortion below 1.8kHz is cancelled. This dramatically reduces the "mud" and "grit" caused by the severe intermodulation distortion which usually results from heavy clipping. It is particularly effective on voice.

iii) The distortion-cancellation process in (ii) above disturbs peak levels because the distortion-cancelling component adds to the clipped waveform. To absolutely control peak levels at the output of the OPTIMOD-AM, a safety clipper must therefore follow the output of the "Smart Clipper" (see **7.b)**. Approximately 2.5dB of "headroom" is left between the peak level at the output of the "Smart Clipper" (with distortion correction disabled) and the clipping threshold of the safety clipper. This allows the distortion-correction signal and filter overshoots to be accomodated without forcing excessive, interference-producing clipping in the safety clipper. To further protect against excessive clipping in the safety clipper, the output of a 1.8kHz lowpass filter is also used to control the gain of the VCA preceeding the clipper. If the distortion-cancelling component (i.e., the output of the 1.8kHz filter) becomes so large that it would tend to cause excessive clipping by the safety filter, the gain of the VCA (and thus the amount of clipping) is reduced to a safe value.

The net effect of these three control approaches is that extremely large amounts of peak limiting can be performed by the "Smart Clipper" without audible ill effects. When a large amount of high frequency boost is employed, it is not unusual to see 12dB of clipping alone. Ordinarily this much clipping would produce totally unacceptable amounts of intermodulation distortion. However, by using the distortion-cancelling scheme described in (ii) above, the distortion is cancelled in the frequency band which is typically flat in a consumer AM receiver, and acceptable distortion performance is produced.

The attack and release time characteristics of the linear gain reduction section of the "Smart Clipper" also contribute to its high performance. Gain reduction is controlled by a "pilot system" which does not pass program, but serves only to derive a gain control voltage which controls a VCA. The audio to this VCA is delayed 3.7 milliseconds with a Bucket-Brigade delay line. Thus the attack time of the circuit is negative; gain reduction settles to its required value before the program material initiating the gain reduction reaches the VCA.

The control voltage integrator employs a very "intelligent" program-controlled release time circuit. The basic release time is very fast (about 30mS) to avoid "holes" and loss of solidity. However, pumping is avoided by slowing down the release time as necessary when the program material lacks transients.

Orban research has discovered that the ear tolerates the addition of clipping distortion to varying degrees with different program material. Therefore, merely measuring the extent to which the clipping distortion components are masked by the undistorted signal is insufficient; we must also estimate how much masking is needed to produce an esthetically acceptable sound. Only in this way will maximum loudness be obtained for all program material.

In general, "dense", bright material tolerates clipping better than material in which low frequencies are dominant, or which is so simple that only a few frequency components predominate. For example, male voice is very sensitive to clipping distortion; bright rock music can be heavily clipped without ill effect.

Orban has developed a proprietary digital filter circuit which effectively estimates how much "extra" clipping can be tolerated by a given piece of program material. The output of this circuit is a control voltage which effectively adjusts the CLIPPING control automatically on a moment-to-moment basis.

6.a) Pilot System — General:

The input to the "Smart Clipper" is applied to a Voltage-Controlled Amplifier (VCA1), whose gain is controlled by feedback. The output of VCA1 is clipped. The output of the clipper is subtracted from its input; this signal is the distortion added by the clipping process.

The distortion signal is passed through four contiguous third-octave filters with center frequencies of 2.5, 3.2, 4.0, and 5.0kHz. The undistorted input to VCA1 is passed through four filters identical to the first four filters. Four analog dividers determine the ratio between the distortion signal and the undistorted signal in each band, thus scaling the magnitude of the distortion signal in each band according to an estimate of its psychoacoustic audibility. The outputs of the dividers are applied to an analog "Or" threshold detector. Said detector produces an output pulse if the output of any of the four dividers is greater than a set threshold. Said output pulse is used to charge a complex integrator with delayed, program-controlled release time. The voltage on said integrator determines the gain of VCA1. The effect of this closing of the control loop is to reduce the gain of VCA1 until the clipping distortion produced has a constant and consistent audibility. It should be noted that some such audible distortion may be acceptable to the ear; other such distortion may be highly offensive. "Audibility" simply means that the distortion is detectable when compared directly to the unclipped program.

Two refinements must be mentioned. The first is a circuit which scales the amount of audible clipping distortion by an estimate of the esthetic acceptability of such distortion. The distortion signal is passed through a VCA (VCA3). The gain of VCA3 is controlled by a proprietary circuit driven from the output of the broadband compressor, thus scaling the distortion signal seen by the pilot circuit. This in turn scales the amount of distortion which the pilot circuit permits the clipper to create.

The second refinement is a ninth (1.8kHz lowpass) filter in addition to the eight third-octave filters. The output of the 1.8kHz lowpass filter corresponds to the amplitude of the distortion-cancelling signal added to the clipped signal (see **6.c.B**). Its output is also applied to the analog "Or" threshold detector (see **6.a.D**), and assures that the distortion correction signal is not excessively clipped by the final safety clipper in the OPTIMOD-AM system.

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6.a.A) Pilot VCA And Clipper: (On Card #7)

The VCA's employed in the "Smart Clipper" are multipliers rather than dividers (like the VCA's employed in the broadband and Six-Band Limiters). However, the basic VCA circuitry is quite similar. It employs an Operational Transconductance Amplifier linearized by a diode bridge (see **2.a**) and buffered by an opamp. The technique for voltage-controlling the gain is substantially different than that used in the divider-type VCA's discussed in **2.a.**

The actual clipped signal is not required from this section of the circuit; only the difference between the clipped and unclipped signals is needed. Said difference is derived by a differential clipper, synthesized with a single opamp.

6.a.B) Distortion-Scaling VCA (VCA3): (On Card #7)

The output of the differential clipper is scaled by a VCA which is configured as a multiplier, and which is almost identical to the VCA described in **6.a.A** except for a different choice of bias voltages. Further details will be supplied in the **CIRCUIT DESCRIPTION** section. The gain of this VCA is controlled by a voltage derived by a proprietary modular circuit. This circuit uses hybrid digital/analog techniques to derive an estimate of the esthetic acceptability of a given amount of audible clipping distortion. It is driven by the output of the broadband compressor to avoid uncertainties in its behavior due to equalization changes and the action of the six-band compressor. We have chosen to call this circuit a "Loudness Augmentation" circuit. Its action is inhibited by a gating circuit which detects the presence of low frequency energy in the signal and only permits increases in clipping when low frequency energy is present. If such gating were not employed, clipping on sibilance (although clean at the OPTIMOD-AM output) could produce distortion in receivers. The amount of loudness augmentation employed is externally adjustable to any degree desired within the range of the LOUDNESS AUGMENTATION control.

6.a.C) Third-Octave Filters And Analog Dividers: (On Card #6)

The third-octave filters are fourth-order types (see **Appendix II** for filter shape). They are designed for 0.5dB ripple in the passband. These filters are realized by cascading two active RC two-pole sections, and then by taking overall negative feedback around the filters to minimize their sensitivity to component variations.

The output of the filter connected to the undistorted signal drives a simple active peak detector which derives a DC control voltage for the analog divider. The analog divider is similar to the divider-type VCA described in **2.a.** Because of its relaxed performance requirements, however, it does not employ diode-bridge linearization. The diode bridge is replaced by a series RC network; thus, its DC output is self-centering. Instead of a transistor-type control-current source, an opamp is used in a circuit similar to that employed in the multiplier-type VCA **6.a.A.**

The AC input port of the analog divider is driven by the output of the third-octave filter connected to the distortion signal. Thus the divider scales the filtered distortion signal by the amount of undistorted signal in a given third-octave band.

6.a.D) Analog "OR" Threshold Detector: (On Card #9)

The outputs of each of the four dividers and the 1.8kHz lowpass filter are connected to their own pair of diodes. These diodes are bussed together at a threshold detector. If any of the said outputs rises above approximately 1.6 volts, it will cause one of its associated diodes to conduct, ultimately forcing an output current from the threshold detector to flow into the integrating capacitors described in **6.a.E.** To assure system stability, the voltage/current conversion gain is relatively low, which makes the attack time rather long -- in the order of 3 milliseconds. A delay line is incorporated to compensate for this (see **6.b.B).** Further circuit details will be found in the **CIRCUIT DESCRIPTION** section.

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6.a.E) Control Voltage Integrator: (On Card #9)

The control voltage integrator in the "Smart Clipper" employs an extremely short basic release time -- approximately 30mS. To avoid excessive ripple on the control voltage line, delayed release is employed in the form of the nonlinear diode smoothing network already described in **2.b.**

The release time is program-controlled by means of a proprietary module to prevent pumping. After a sharp transient, the release time is speeded up; if the program is relatively smooth, the release time is made slower.

The PROOF mode does two main things. First, it forces the VCA's in the "Smart Clipper" into approximately 10dB gain reduction to maximize the signal-to-noise performance of the OPTIMOD-AM system (which is determined primarily by the S/N ratio of the BBD delay lines). Second, it inhibits the release time circuit in order to stabilize the 10dB gain reduction condition.

6.b) DELAY SYSTEM — GENERAL:

The OPTIMOD-AM employs two separate Bucket-Brigade delay lines. These two delay lines have entirely independent functions which will be described in more detail below.

The two delay lines are realized by two halves of a single SAD-1024 BBD delay line package which employs NMOS technology. The delay time of the longer delay is exactly eight times the delay time of the shorter delay.

Special techniques are employed to linearize the BBD and obtain maximum performance from it. Nevertheless the entire system performance of the OPTIMOD-AM in the proof mode is limited by the performance of the BBD's. This performance is considerably better than that practically required by the AM broadcast system or legally required by the FCC. In no instance will the audible performance of the OPTIMOD-AM be affected by the measured limitations of the BBD's. Nevertheless, the measured performance is not as good as systems employing no delay. This is a perfect example of the inability of customary specifications to correlate with the listening qualities of a complex signal processing device like OPTIMOD-AM. Although the BBD's cause the device to have mediocre specifications by contemporary standards, they vastly improve its listening quality!

6.b.A) Clock: (On Card #9)

Each half of the BBD requires two square-wave clocking signals 180 degrees out-of-phase. This requirement is satisfied by the use of a CD4049UB inverting buffer operated as a 1100kHz oscillator. The output of said oscillator is divided down by a chain of D-type flipflops to provide clocking frequencies of approximately 550kHz for the shorter delay and 69kHz for the longer delay. Each flipflop has both true and complement outputs to supply the required two-phase clocking signals. Special shielding precautions have been taken to assure that these RF signals are kept away from the rest of the circuitry.

6.b.B) 3.7 Millisecond Delay Line: (On Card #9)

The purpose of the 3.7mS (long) delay is to delay the audio applied to VCA2 (the "slave" VCA operated by the same control voltage as VCA1 in the pilot system -- see **6.a.A).** Because the audio is delayed, the gain of VCA2 is fully settled before the transient initiating gain reduction passes through the VCA. Thus excessive clipping and distortion due to the relatively long attack time of the pilot system are avoided.

The output of the BBD contains high frequency "garbage" consisting of the clock frequency, its harmonics, and upper sidebands of the clock. These must be filtered from the signal without time-domain distortion of the waveform. To accomplish this, a fourth-order Chebychev lowpass filter is employed with phase correction. This filter is realized with a single opamp. The output of the lowpass filter is applied to an inverting bandpass filter. Twice the output of said bandpass filter is added to the output of the lowpass filter. It can be shown that this produces an allpass response, with flat magnitude response but phase response that varies from 0 degrees at some low frequency to 360 degrees at some higher frequency. The phase response is chosen such that it adds delay as needed to the basic lowpass filter to approximate a constant time delay (equivalent to a linear phase response) within the lowpass filter's 11kHz bandwidth.

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6.c) MAIN AUDIO PATH -- GENERAL:

So far, the sections of the "Smart Clipper" circuitry which have been described deal with control of the system. The only exception is the 3.7mS delay line, which passes program audio.

This section describes the remaining part of the "Smart Clipper" which passes and controls the program audio. Said part is broken into two major subsections. The first is VCA2 -- the slave VCA whose gain follows the gain of VCA1 in the pilot system **6.a.A.** The second is the intermodulation distortion cancelling circuit, which includes a 450uS BBD delay line, a clipper, a phase-linear 1.8kHz lowpass filter, and a subtractor.

6.c.A) Slave VCA (VCA2): (On Card #9)

The slave VCA is a multiplier-mode VCA that is virtually identical to VCA1 (see **6.a.A)**. VCA2's gain-control node is connected to VCA1's gain control node, so the gains of the two VCA's track. However, the audio applied to VCA2 arrives 3.7mS after the audio applied to VCA1, due to the use of a delay line (see **6.b.B)**. The gain of VCA2 is therefore fully reduced before the transient initiating gain reduction is applied to the signal port of VCA2, and distortion-producing overshoots are eliminated. This feature gives the "Smart Clipper" a negative attack time.

6.c.B) Clipper And 1.8kHz Lowpass Filter: (On Card #9)

VCA2 is followed by a clipper. The levels feeding this clipper are carefully adjusted to match the levels feeding the clipper following VCA1 in the pilot system (see **6.a.A)**. The phase-linear lowpass filter following the 3.7mS delay line (see **6.b.B)** introduces very little time-domain distortion into the delayed waveform. Therefore, the clipper at the output of VCA2 produces a distortion spectrum very similar to the distortion spectrum produced by the clipper following VCA1.

The distortion spectrum derived from the clipper following VCA1 is used to control the gain of VCA1, and thus the gain of VCA2. Only spectral components above 2kHz are used in the masking estimation. This is because spectral components below 1.8kHz contained in the distortion produced by the clipper following VCA2 are derived by a phase-linear lowpass filter, and then subtracted from the clipped waveform in order to cancel distortion below 1.8kHz.

The 1.8kHz lowpass filter is basically a third-order type. Its output is applied to a second-order bandpass filter. Twice the output of said bandpass filter is subtracted from the output of the lowpass filter. It can be shown that this yields an allpass response: the amplitude response is flat, but the phase response changes as a function of frequency. The characteristics of this phase response have been carefully chosen to add time delay to certain frequencies such that the overall time delay of the 1.8kHz lowpass plus the allpass filter is approximately 450 microseconds from 0 to 1.8kHz.

6.c.C) 450 Microsecond Delay Line And Clipper: (On Card #9)

We are going to subtract the distortion below 1.8kHz from the clipped signal. We must therefore compensate for the time delay in the 1.8kHz phase-linear lowpass filter by introducing a 450uS delay in the clipped signal. We do this with the other half of the BBD delay line (see **6.b**).

Because the bandwidth of the 450uS delay line is limited by the Nyquist Sampling Theorem, we do not delay the clipped signal directly since it contains large amounts of added high frequency energy due to clipping. Instead, we delay the unclipped signal, and clip it after the delay line with yet a third clipper. The drive to this clipper is carefully controlled so that its output is substantially identical to the other two matched clippers--just delayed. A passive LC phase-linear lowpass filter is employed after the 450uS BBD to remove the clock and upper sidebands. Because the clock frequency is so high, this filter can be a third-order minimum-phase type with a very gentle rolloff and linear phase; a separate phase corrector is not required to maintain accurate reproduction of the waveform (which would be distorted if the lowpass filter did not have constant delay).

The output of this third clipper is the appropriately delayed clipped signal. The clipping distortion below 1.8kHz can therefore be cancelled simply by subtracting the output of the 1.8kHz lowpass filter from this waveform. The output of the 1.8kHz lowpass filter can be considered a "smoothing function", in that it adds peak amplitude to the clipped signal in order to greatly reduce perceived distortion.

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6.c.D) Subtractor: (On Card #9)

The subtraction functions occur in a simple inverting summing amplifier realized with an opamp. This summer has three inputs:

1) the output of the 450uS delayed clipper;
2) the output of the 1.8kHz third-order lowpass filter; and
3) the output of the 1.8kHz phase corrector.

The 1.8kHz third-order lowpass filter is inverting, as is the bandpass filter in the phase corrector. Thus the desired subtractions are performed in the summing amplifier because sign inversion occurs in the filters.

The output of the subtractor is considered the output of the "Smart Clipper" section of the OPTIMOD-AM. This signal is used to drive the output section, described below.

7) OUTPUT SECTION — GENERAL:

The output section interfaces the OPTIMOD-AM with the transmitter. It consists of a lowpass filter to remove excess high frequency energy added by the clipping process, as well as a safety clipper, a transmitter equalizer, and an active balanced output amplifier.

7.a) Phase-Linear Lowpass Filter(s): (On Card #8)

The large amounts of clipping (typically 12dB) occurring in the "Smart Clipper" result in the addition of high frequency energy due to the sharp "edges" clipping adds to the waveform. In order to avoid creating interference to adjacent channels, and to satisfy FCC requirements that energy above 15kHz be attenuated better than 25dB below 100% modulation, this energy must be filtered from the output of OPTIMOD-AM.

This filtering is accomplished with a fifth-order Chebychev lowpass filter with a passband ripple of 1dB and a cutoff frequency of 11kHz. If unusual adjacent channel interference requirements must be met, or if the transmitter splatters on high energy, high frequency audio due to inadequate design, then the optional 8kHz or 6kHz filters may be used. In addition, an optional second filter is available (for nighttime use) which can be automatically switched by remote control. If any of these options seem necessary, the factory should be consulted.

The overshoots occurring in this filter are minimized by the use of an allpass phase corrector preceding the filter itself. The ripple in any of the filters is designed to complement the ripple in the fourth-order filter after the 3.7mS delay line (see **6.b.B**) such that the frequency response within the "proof of performance" passband (100-5000Hz) is maintained approximately $\pm$0.5dB.

7.b) Safety Clipper: (On Card #8)

A safety clipper is introduced after the 11kHz lowpass filter. This clipper has two distinct functions. First, it compensates for any overshoot in the safety filter. Second, it clips excess amplitude in the smoothing voltage added by the "Smart Clipper" to cancel distortion below 1.8kHz. You should recall that excessive clipping of the smoothing voltage in the safety clipper is avoided by employing the output of a 1.8kHz lowpass filter as one of the inputs to the analog "or" in the "Smart Clipper" pilot system (see **6.a.D).**

Because the addition of the smoothing voltage changes the amount of asymmetry in asymmetrically-clipped program, the positive threshold of the safety clipper is adjustable from 62% to 100% of the positive threshold of the main clipper by means of the SAFETY CLIPPER POSITIVE THRESHOLD control. This way, the positive threshold of the main clipper can be adjusted to some value higher than 125% (like 150%) to assure that frequent 125% peaks will be produced even after the smoothing voltage is added to the main signal. Then the SAFETY CLIPPER POSITIVE THRESHOLD CONTROL is used to precisely set the positive peak threshold at the OPTIMOD-AM output.

Of course the safety clipper adds a certain amount of high frequency energy when it clips. However, the amount added is not sufficient to cause any interference problems.

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7.c) Transmitter Equalizer: (On Card #8)

The transmitter equalizer consists of three stages. The first provides a 2.5dB shelving rolloff whose initial frequency of operation is adjustable from approximately 500Hz to beyond the passband of the OPTIMOD-AM system. This shelving rolloff will reduce or eliminate high frequency overshoot in a vast majority of antenna/transmitter systems with such difficulty. It is created differentially by subtracting the output of an adjustable highpass filter from the main signal.

The second stage is an adjustable first-order allpass network. If the transmitter modulator has a non-constant group delay, this allpass network can add delay as necessary to make the delay more constant, thus improving the pulse response. The allpass network is realized in a standard differential bridge form.

The third stage is the tilt equalizer. This adds a carefully shaped signal (generated within the module) to the main signal. The sum of the two causes low frequency square waves to have a positive tilt. The amount of tilt is adjusted to exactly cancel the normal negative tilt characteristic of many transmitters at low frequencies.

Switching between "Day" and "Night" modes is effected by means of JFET's which switch the appropriate trimmer controls in or out of the circuit as required.

7.d) Output Line Amplifier: (On Card #8)

The third (TILT EQ) section of the transmitter equalizer employs the first section of the output amplifier as its summing amplifier (see previous paragraph). In addition, the entire transmitter equalizer can be bypassed by means of the XMTR EQ switch. The output amplifier has a gain of -5 and the ability to drive +26dBm into 150 ohms due to a discrete complementary symmetry output stage. This stage drives a similar amplifier with a gain of -1. The two amplifiers thus provide signals of equal and opposite polarity which are normally used in a bridge configuration to drive 600 ohm loads with peak levels up to +26dBm.

Obviously, neither side of the output should be shorted to ground, or its associated amplifier will be shorted-circuited through the RFI suppression network/output pad. While the amplifiers are protected against shorts, these should be avoided as a matter of good practice.

Both amplifiers are wideband, DC-coupled devices, and therefore add no tilt or phase shift to the accurately controlled output of the transmitter equalizer. A single amplifier can drive +26dBm into 150 ohms. From the point of view of output voltage swing, this is equal to +20dBm into 600 ohms. The two amplifiers in bridged configuration result in doubled output voltage swing, and can thus deliver a full +26dBm into 600 ohms. This level is attenuated in the output pad/RF filter, such that the actual output drive capability is +20dBm.

No output transformer is employed. However, LC RF filters are inserted in both output lines to suppress any potential RF interference. It should be pointed out once again that the potential gain of OPTIMOD-AM at high frequencies is very high. The input and output of the device should be rigorously shielded from each other. Relatively small amounts of RF rectification before the OPTIMOD-AM input can result in high frequency feedback due to the large high frequency gain after the rectification point. Any mysterious ringing or feedback problems should be investigated from this point of view.

7.e) Remote Control And Logic: (On Card #8)

"Day" and "Night" modes may be selected by application of a pulse of voltage from 6 to 24 V AC/DC to the remote control lines. These lines drive optoisolators which switch the state of a CMOS bistable. Logic levels are ON=0 volts, and OFF=-15 volts. The output of one of the gates in the bistable drives the "Day" switching FET's directly; it is also applied to a NAND gate operated as an inverter to drive the "Night" FET's. In addition, a NAND gate connected as an inverter buffers the high impedance control line from the DAY/NIGHT LED indicators, which are switched by a transistor in a current-steering configuration.

8) POWER SUPPLY -- GENERAL:

The power supply provides basic DC voltages to operate the rest of the system. The basic power supply creates ±15 volt highly regulated supplies. From these supplies, many other voltages are derived on various cards.

8.a) Unregulated Supply: (On Chassis)

The unregulated supply is designed to produce a nominal ±24 volts. This relatively high voltage enables the OPTIMOD-AM to operate properly even if the line goes as low as 90 volts AC. The power transformer is rated at 1 amp, and is switchable for 115 or 230 volt AC operation, 50-60Hz by means of a slide switch behind the tilt-down front panel.

Power supply RF suppression is employed on the AC line. In addition, VHF RF filtering is inserted in the lines between the unregulated DC supply and the main regulators.

8.b) +15 Volt Regulator: (On Card #1 (On Chassis))

The +15 volt regulator is capable of delivering 1 amp of highly smoothed, regulated current. It is fully current limited. In addition, a fast-blow fuse and 16 volt zener diode provide positive overvoltage protection for the rest of the circuitry, should the regulator fail.

The regulator employs a 723C voltage regulator IC with an external series-pass transistor which is heat-sunk to the OPTIMOD-AM chassis.

8.c) -15 Volt Regulator: (On Card #1 (On Chassis))

The -15 volt regulator employs a IC opamp with current-boosted output stage to track the +15 volt regulator with a gain of -1. Like the +15 volt output, this output is current limited, and is overvoltage protected with a fuse and zener. If the +15 volt supply fails, the -15 volt supply will attempt to track. However, its current limiting circuit should prevent its fuse from blowing. Thus, if its fuse is blown, the -15 supply is probably defective.

The -15 volt series pass transistor is capable of 1 amp output current, and is heat-sunk to the OPTIMOD-AM chassis.

8.d) Clipper Bias Supplies: (On Card #7)

The OPTIMOD-AM employs several shunt clippers in its audio processing section (see **6.a.A, 6.a.B, 6.a.C,** and **7.b).** A low impedance bias source must be provided for these clippers -- a source into which the clippers "dump" excess peaks without affecting said bias voltage. This bias source is provided by the output of two opamps. The first opamp is connected as a voltage follower, and supplies a fixed bias of approximately +2.0 volts.

IMPORTANT!

> In the internal circuitry of OPTIMOD-AM, a positive-going signal corresponds to <u>negative</u> modulation; a negative-going signal corresponds to <u>positive</u> modulation.

Thus the +2.0 volt source is <u>fixed</u>, and is temperature-compensated with a diode identical to the ones used in the clipper circuits. In this way the threshold of clipping is made temperature-independent. The negative source (-2.0 volts for 100% positive peaks) is connected as an inverting amplifier. It is driven from the +2.0 volt source. Its gain is variable from -1.0 to -1.5 by means of the user-adjustable POSITIVE PEAK THRESHOLD control. This permits the positive threshold of clipping to be continuously varied between 100% and 150% modulation.

8.e) 1 Volt Comparator Reference Supplies: (On Card #3)

The OPTIMOD-AM employs seven 711C dual comparator IC's as error detectors. One is used in the broadband compressor (see **2.b)**; six are used in the six-band limiter (see **4.b)**. For convenience, all of these comparators use the same reference voltages which define the threshold of compression. These voltages are nominally ±1 volt, and are derived by a pair of opamps connected as voltage followers "amplifying" the outputs of a pair of resistive voltage dividers. The accuracy of these voltages is thus dependent upon the highly regulated ±15 volt supplies.

8.f) Miscellaneous Loosely-Regulated Supplies: (Found Locally)

A number of less critical voltages are derived by means of diode voltage drops. This technique is an economical way of decoupling locally generated noise from the power busses.

8.f.A) +14 Volts: The +14 volt supply is actually a number of local supplies created for noise decoupling purposes. The +15 bus is dropped by one forward diode drop (about 0.6 volt), and is decoupled with one or more capacitors to local ground.

8.f.B) +12.6 Volts: This voltage is created by dropping the +15 volt bus with three series forward diode drops. It is primarily used to power the 711C dual comparator IC's, which require +12 and -6 volt supplies.

8.f.C) -6 Volts: This is derived by dropping the -15 volt supply through a 9 volt zener. It is used to power the 711C dual comparator IC's.

This concludes the **PRINCIPLES OF OPERATION** section of this manual.

Section 6

CIRCUIT DESCRIPTION

BEFORE EMBARKING ON THIS SECTION, READ **SECTION 1 (SYSTEM DESCRIPTION);** THEN, **SECTION 5 (PRINCIPLES OF OPERATION).**

The following section provides an extremely detailed description of the circuitry used in the OPTIMOD-AM at the component level.

Orban Associates Inc. prefers that the OPTIMOD-AM be serviced by exchanging defective boards with loaner boards, so that the defective board(s) can be accurately serviced at the factory using our special expertise and test equipment.

We are aware that some situations may demand that the user service the equipment himself. For this reason, and for purposes of reference, we include this section.

To save space, comments relating to systems operation will not be repeated in this section. Such systems principles are found in **Section 5 (PRINCIPLES OF OPERATION).** This section should be used with the **PRINCIPLES OF OPERATION** section by noting that both sections use identical paragraph reference designators. These designators are indexed in the outline at the beginning of the **PRINCIPLES OF OPERATION** section on page 5-1.

REFER TO THE BLOCK DIAGRAM AND SCHEMATICS, WHICH FOLD OUT FROM THE LAST SECTION OF THIS MANUAL.

IN ORDER TO AID TROUBLESHOOTING, APPENDIX II PROVIDES GRAPHS OF THE EXPECTED FREQUENCY RESPONSE OF EACH IMPORTANT FILTER INCLUDED IN THE OPTIMOD-AM CIRCUITRY.

1.a) Input Amplifier: (On Card #3)

The input signal enters the RF filter chamber, and is there applied to a balanced 600 ohm 20dB pad R1, R2, R3, R4. From there it is applied to a

600:50000 ohm transformer T301 yielding 19.2dB voltage gain. T301 is loaded by the INPUT ATTENUATOR control R301. The wiper of R301 is applied to a 20.8dB non-inverting buffer amplifier IC301, R302, R303, C301. This buffer amplifier employs a low-noise JFET-input IC opamp.

1.b) Input Conditioning Filter: (On Card #3)

The input conditioning filter consists of four cascaded sections. The first is a third-order Chebychev highpass filter with 100Hz cutoff and 0.5dB nominal passband ripple. This is a unity-gain positive feedback filter consisting of IC302A, C302, C303, C304, R304, R306, R305.

The second section consists of a passive RC lowpass ladder, C305, C306, R307, R308, R309, feeding a negative feedback active "bridged-tee" section IC302B, C307, C308, R310, R312, R311. This section combines the first part of a sharp 11kHz lowpass filter with a gentle preemphasis of approximately 10dB at 6kHz.

The third and fourth sections complete the lowpass filter. These are medium and high-Q second-order lowpass sections in the "multiple negative feedback" configuration. The medium-Q section includes IC303A, C309, C310, R313, R314, R315. The high-Q section includes IC303B, C311, C312, R316, R317, R318.

1.c) Gating Detector: (On Card #3)

The gating detector consists of a peak detector followed by a comparator. IC opamps are employed for both functions.

The signal enters and is lowpass filtered at 3kHz at 6dB/octave by C313, R319. The output of this filter is amplified by non-inverting amplifier IC304A, C314, R320, R321. The gain of this amplifier is variable from 0dB to 40dB by means of the GATE THRESHOLD control, R321.

The output of IC304A is connected to a passive positive peak detector CR301, C315, R322. The voltage across C315 is a DC voltage representing the approximate peak level of the input signal. This DC voltage is applied to a comparator IC304B. If the output of the peak detector is below +3.1 volts, the output of IC304B is negative. This illuminates the front-panel GATE LED CR105, and also inhibits release in the broadband compressor **2.b** and the 150Hz band compressor **4.b.** If the output of the peak detector rises above +3.1 volts, the output of IC304B goes positive and normal release occurs in the compressors.

NOTE: THE FOLLOWING MATERIAL REGARDING THE BROADBAND COMPRESSOR **(2.a** and **2.b)** IS APPLICABLE TO MANY OTHER OPTIMOD-AM CIRCUITS AS WELL, AND WILL BE REFERENCED IN FUTURE SECTIONS.

2.a) Broadband Compressor VCA: (On Card #3)

The broadband compressor VCA is a two-quadrant divider. The division function is realized by placing a two-quadrant multiplier in the feedback loop of an opamp.

The basic multiplier is a CA3080 Operational Transconductance Amplifier, IC306. This device has a bipolar differential input and level shifting circuitry to produce a bipolar current source output. The current source feeding the CA3080's differential input stage is a current mirror; thus, the operating current of the input stage can be controlled by controlling the amount of current flowing through the current mirror. The control input is pin 5.

The transconductance (gain) of the input stage (and thus of the entire CA3080) is directly proportional to the input stage operating current. Therefore the gain of the CA3080 is directly proportional to the current flowing through pin 5. This current is supplied by an exponential voltage-to-current converter, which is simply a bipolar PNP transistor in a CA3096 transistor array IC308. The collector current in this transistor is an almost perfect exponential function of its base-to-emitter voltage. The scaling factor of the converter is stabilized by using a matched PNP transistor in conjunction with opamp IC309B to force a reference current through the matched transistor. The base of said transistor is grounded; its emitter is connected to the emitter of the current source transistor. Thus (assuming perfectly matched transistors) the same current will flow through both transistors if the base of the current source transistor is also grounded. The reference current is determined by the VCA GAIN CAL control R366.

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IC309B is stabilized against high frequency oscillations by C318. R328 limits the amount of current that can flow into pin 5 of IC306 by saturating the current source transistor for high currents, thus limiting the gain of the VCA and protecting IC306 from damage.

The input/output transfer curve of the CA3080 is non-linear like any bipolar differential pair. It is also temperature-sensitive. By predistorting the input signal to IC306, it is possible to simultaneously linearize its transfer characteristic and make said characteristic temperature-independent. This linearization is performed with a CA3019 diode bridge IC307. A constant current is forced through the bridge by means of R332 and R333. IC307 is the bottom leg of a voltage divider; R334 is the top leg. The impedance of R334 is much greater than the dynamic impedance of IC307; thus, R334 approximates a current source. It can be shown that the non-linear dynamic impedance of IC307 causes the signal to be predistorted correctly, provided IC306 and IC307 are at the same temperature.

The top of R334 is thus the input of the two-quadarant multiplier; its output is the current source output of IC306. This current source output can be injected directly into the summing junction of an opamp, IC305. A low noise JFET-input opamp is employed to eliminate any dependence of output quiescent point on offset or bias currents. The audio input to the entire divider is introduced to the summing junction through R326,316. The voltage gain of the entire divider is inversely proportional to the multiplier gain (i.e. the current flowing into pin 5 of IC306). The output of the divider is the output of IC305.

The divider is frequency compensated to prevent oscillations by C317. This compensation is necessary in addition to the internal compensation in IC305.

Offsets in either IC306 or IC307 can give rise to substantial second-harmonic distortion. Thus an offset-null circuit R330, R331, R329 is provided to introduce a few millivolts of DC to pin 2 of IC306. The correct adjustment of this control will not necessarily minimize DC level shifts with changes in control current and/or absolute DC offsets. Therefore the output of IC305 will normally have up to ±2 volts of DC offset because the DC bias point of IC305 is controlled by the DC transfer characteristic of IC306, which may shift somewhat as the gain-control current is changed. C319 prevents passing these shifts to later parts of the circuitry. Excessive DC shift with control current variation (which could cause thumping as in old vacuum-tube limiters) is controlled by factory-selecting the CA3080's. Fortunately, the characteristics of a given CA3080 are very stable with time; thus rebalancing or other adjustments are never required once initial DC level-shift stability is determined.

2.b) Compressor Control Circuits: (On Card #3)

The compressor gain is controlled by a feedback loop. The output of the VCA is attenuated in voltage divider R344, R345. The output of said voltage divider is compared against a stable ±1 volt reference voltage in dual comparator IC311. The gain of said voltage divider is chosen to divide the desired peak output level of the VCA down to ±1 volt; the gain of said voltage divider thus determines the threshold of compression.

Every time the voltage at the input to IC311 attempts to rise above ±1 volt, IC311 produces a positive-going pulse of approximately +4 volts peak. This pulse is level-shifted through C322, CR304, R341 and turns on a NPN transistor in the CA3096 transistor array IC308. The collector output of said transistor is a current. This current (and thus the attack time) is determined by the value of R340. The current discharges two integrating capacitors C320, C321 arranged in a non-linear recovery time (i.e. delayed release) circuit. This circuit operates as follows:

Whenever a discharge pulse occurs, it discharges both C320 and C321 to equal negative voltages through matched diode-connected transistors in the CA3096 array IC308. The only source of charging current for either capacitor is the line connected to the release time module. After a discharge pulse, C321 immediately begins to charge through the release time module towards its quiescent voltage of zero volts, representing maximum VCA gain. C320 can only charge through CR303 and R339. R339 provides only a slow charge because of its high resistance. Thus release is essentially delayed until C321 charges sufficiently to turn on CR303. In this way, potential sawtooth ripple on the control voltage on C320 is eliminated. This ripple, if permitted, could cause distortion by modulating the audio in the VCA.

The release time module is a proprietary circuit which adjusts the release time of the compressor according to the prior history of the program. After a sharp transient which requires a large gain change, the release time is speeded up. If the program material contains no sharp peaks, the release time is slowed down. Thus "pumping" and "holes" are simultaneously prevented.

Release is inhibited by applying greater than -10 volts to the gate of N-channel JFET Q301, thus pinching Q301 OFF, and preventing C321 from charging through R342. When the voltage on the GATE line goes HIGH (greater than +10 volts), the gate of Q301 is disconnected from the line by reverse-biasing CR323. Q301 is then turned ON through R343.

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From a "black box" point of view, the module may be considered as a resistor from C321 to ground. The value of this imaginary resistor is constantly changing as a function of the program. The module also has trim input to assure that the quiescent voltage on C321 is zero volts.

Because the module is proprietary, further circuit details will not be supplied. A failure of the module requires that a new module be ordered from the factory. If the module is replaced, R346 may have to be readjusted to zero the gain reduction meter.

The control voltage developed on C320 is buffered by a unity-gain FET-input buffer opamp IC310. The output of this opamp drives the exponential voltage/current converter circuit through voltage divider R335, R336. (see (2.a)). Because of said exponential converter, the output voltage of IC310 represents the logarithm of the gain of the VCA. Thus its output is linear in decibels, and can directly drive a linear-scale gain reduction meter. In addition, its output is made available to drive a slave VCA in an optional stereo adapter chassis. Assuming that the stereo chassis and main chassis both handle linear combinations of the left and right signals, this interconnection forces the gain of the stereo signal to follow the gain of the signal handled by the main chassis.

3.a) Low-Frequency Equalizer: (On Card #5)

The low frequency equalizer creates peak boost by summing the output of a second-order "quasi-parametric" bandpass resonator IC502A, R518, R517, R515, R516, R514, R513, R512, R511, R510, C506, C505 with the input signal of said resonator in summing amplifier IC503A. The amount of equalization is determined by the resonator's input attenuator R510. The operation of the resonator can only be justified mathematically and will not be further discussed. Because of the multiple feedback loops, repair of the resonator is usually a cut-and-try affair in which IC502B is first checked. Then each of the passive components is tested with an impedance bridge. Passive component failure is extremely unlikely due to the lack of stress on the passive components. Normal frequency response of the resonator at the output of IC502A is a bell-shaped curve centered at approximately 100Hz. The normal gain of the resonator from the wiper of R510 to the output of IC502A at the frequency of maximum gain is 6.02dB.

3.b) 5kHz Equalizer: (On Card #5)

The 5kHz equalizer provides peak boost by summing the output of a second-order bandpass filter with said filter's input. Summation occurs in IC504A when S501 is IN; otherwise IC504A is fed by the input signal to the entire main equalizer through R533 and all equalization is defeated.

The topology of the 5kHz resonator is identical to the topology of the low frequency responator (see **3.a)** with the exception that the EQUALIZATION control R527 is placed at the output of the resonator rather than at its input. Thus all comments in **3.a** regarding service apply equally here.

3.c) 10kHz Equalizer: (On Card #5)

The 10kHz equalizer is a fourth-order peaking equalizer. Peak boost with slopes approaching 12dB/octave is generated by summing the output of a special fourth-order network with said network's input in summing amplifier IC503A. Said network consists of two second-order networks in cascade.

The first second-order network IC501A, R501, R502, R503, R509, R508, R504, C502, C501 is characterized by a notching response. Its gain at very low frequencies is -5.93dB.

The second second-order network IC501B, R505, R506, R507, C504, C503 is a high-Q bandpass filter. Its nominal peak gain is 11.3dB.

Both second-order filters are characterized by a large amount of interaction between their various components. Thus the service hints found in **3.a** apply equally to these filters. However note that each of the second-order sections can be measured separately when their performance is evaluated during maintenance as there is no interaction between sections. To measure the second section (IC501B and associated components), lift the end of R505 driven by the output of IC501A and drive it with a low-impedance (600 ohms or less) signal generator.

4.a) Crossover Filters--Six-Band Limiter: (On Card #5)

The crossover filters for the six-band limiter consist of the following:

A) 150Hz inverting second-order multiple-feedback lowpass filter
B) 300Hz non-inverting fourth-order bandpass filter
C) 700Hz inverting fourth-order bandpass filter
D) 1.6kHz non-inverting fourth-order bandpass filter
E) 3.7kHz inverting fourth-order bandpass filter
F) 7.5kHz non-inverting second-order unity-gain positive-feedback highpass filter.

All filters are chosen to add smoothly under both test and operational conditions. All filters are highly selective with 12dB/octave slopes.

All filters are built with second-order sections of the type found in any modern text on active filter design (see for example--Wong and Ott: Function Circuits. McGraw-Hill, New York, 1976, chapter 6). Some filters are of the "multiple feedback" type, and are basically negative-feedback filters. Others are of the "Sallen and Key" type, and are positive feedback filters. The two types are mixed as necessary to achieve desired inverting (negative feedback) or non-inverting (positive feedback) responses.

The inverting bandpass sections (C and E) employ overall negative feedback via R547,562 in order to couple the two second-order sections together, thus reducing the sensitivity of filter parameters to changes in component values or opamp drifts.

As in any filter, the resistor and capacitor values within the second-order sections all interact. The best way to troubleshoot a filter is to first check the opamp. If the opamp is good, use an impedance bridge to test each of the precision resistors and capacitors in turn until the bad component is found. Because the passive components are highly understressed, failures are very improbable.

4.b) Limiters And Summing Amplifier--Six-Band Limiter:

(300Hz, 1.6kHz, And 7.5kHz Limiters On Card #4; 150Hz, 700Hz, And 3.7kHz Limiters On Card #2; Summing Amplifier On Card #7)

The six band-limiters are virtually identical to the broadband compressor (see

2.a and **2.b.** The following differences should be noted:

1) R2()4's value has been chosen in each band-limiter to produce an optimum attack time;

2) R2()6's value has been chosen in each band-limiter to produce an optimum compression threshold;

3) R2()0's value has been chosen in each band-limiter to produce an optimum release time;

4) R2()1's value has been chosen in each band-limiter to produce an optimum range of compression (This is 20dB (R2()1=150K) in bands A,B,C,and D, and is 30dB (R2()1=470K) in bands E and F)

5) Only band A (150Hz) is gated.

The band-limiters use the same ±1 volt reference voltage source as the broadband compressor. The +12 and -6 volt power supplies for the 711C dual comparator IC's are generated locally in cards 2 and 4.

The outputs of the band-limiters are summed in a simple inverting summing opamp IC701A. The feedback resistor R702 of IC701A varies the gain of the entire amplifier, and thus controls the drive to the polarity follower.

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The entire six-band section can be bypassed by means of S701A, which can connect the input of IC701A to the output of the main equalizer output amplifier IC504A.

An auxiliary speech input is optionally available. This is transformer coupled to the outside world. The secondary of the optional transformer connects to the summing junction of IC701A through a 51K resistor.

5.a) Polarity Controller: (On Card #7)

The polarity controller is a first-order allpass section. Its frequency response is flat; its phase response changes from 0 to 180 degrees as frequency is increased.

The circuit subtracts the output of lowpass filter IC703, C702 from said filter's input. It can be shown that when the ratio between the input and output gains is correct, an allpass function is produced.

In the case of the IC702 circuit, 25.6dB of gain is produced between the output of IC701A and the output of IC702. This assures that the voltage across IC703 is small, and that negligible distortion is produced by the photoresistor.

The frequency at which the phase shift equals 90 degrees is determined by the RC time constant of C702 and by the photoresistor in IC703. By changing the illumination on said photoresistor, the 90 degree frequency is swept through the audible range in approximately one second, thus varying the polarity from non-inverting to inverting (or vice-versa) in a smooth and continuous manner.

The gain of the polarity controller is unity at all times. Its frequency response is essentially flat from 30 to 15,000Hz.

5.b) Polarity Detector: (On Card #7)

The output of the polarity controller is monitored by the polarity detector. Thus the polarity detector simply has to determine if the polarity is wrong or right.

The circuit consisting of IC705A, R709, R710, CR703, C704 is an inverting peak detector. It has a gain of -1.22, and develops a positive DC voltage across C704 approximately 1.22 times the negative peak value of the output of IC702. Recall that the negative peaks inside the OPTIMOD-AM system correspond to positive modulation of the carrier. Thus if positive-going peak levels exceed negative-going peak levels, it is necessary to reverse polarity.

This determination is made in comparator IC705B. If positive peaks exceed negative peaks by a factor of 1.22, then the output of IC504A will go negative and discharge C705 through CR714. A single peak is usually insufficient to discharge C705 enough to fire the second comparator IC706. However, several closely-spaced peaks will cause the output of IC706 to go positive.

Hysteresis to assure clean switching is introduced into IC706 by positive feedback through R714. R715 and R713 establish a switching reference voltage of -7.5 volts for comparator IC706. R711 provides a slow discharge path for C705. The combination of hysteresis introduced by the -1.22 gain of IC705A plus the immunity to switching on single peaks caused by the use of two cascaded comparators assures that the polarity will switch only on unambiguously asymmetric waveforms.

The output of IC706 drives the clock input of a D-type fipflop IC707 through coupling network C704, R777. This flipflop is connected with feedback between its D input and NOT Q output. Thus every time a positive transition occurs at the CLOCK input, the output of the flipflop changes state.

The state of the flipflop corresponds to whether the polarity controller is in its inverting or non-inverting state. Thus every time the output of comparator IC706 goes positive, the polarity is changed. The flipflop ignores negative transitions, so C705 must charge to at least -7.5 volts before another transition can occur. This further improves the circuit's immunity to changing state on program material that is not consistently asymmetric.

5.c) Polarity Switching Shaper: (On Card #7)

The output of the D-type flipflop changes state in less than one microsecond. The polarity controller must be swept much more slowly to avoid introducing audible phase modulation into the program. The sweep characteristic is generated by the polarity switching shaper, consisting of IC704, IC708, and associated circuitry.

The output of the D-type flipflop is integrated by a ramp generator IC708A, R716, R718, R717, C706. The output of IC708A is a linear ramp which sweeps from approximately -15 to +15 volts.

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In order to minimize the audibility of the polarity switching function, this ramp must be shaped. The shaping is done by a diode/resistor network R719, R772, R720, R721, CR705, VR701. This nonlinear network approximates the desired curve, shown in figure 6.1 by means of a piecewise approximation with three breakpoints. Said network also substantially attenuates the ramp so that it can directly drive the base of the exponential current source transistor IC704.

The shaping network works as follows. When the output of IC708A is negative, neither diode conducts, and maximum attenuation is obtained. When the output of IC708A goes positive, it switches CR705 on and places R772 in parallel with R720, thus increasing the gain. Finally, when the output of IC708A reaches approximately +11 volts, zener diode VR701 conducts, introducing R719 to the circuit and further increasing the gain. Thus the ramp starts out with a slow change of voltage level, and then changes its level faster and faster as the output ramp of IC708A becomes more and more positive.

The exponential voltage-to-current converter consists of IC704, IC701B, R706, R707, R708, C703, and CR702. It provides a final shaping of the drive signal to the LED inside IC703. CR104 is a LED in series with IC703 which provides a front-panel verification that the polarity follower circuit is operating. This LED ordinarily stays rather dim for most of the switching period, and quickly reaches full brightness at the end of the period. When the LED is ON, the polarity controller is inverting; when it is OFF, the polarity controller is non-inverting.

The operation of the exponential current source is very similar to the operation of a similar source in the broadband compressor. The only essential difference is that the limiter uses PNP transistors, whereas the exponential current source in the polarity switching shaper employs NPN transistors. Thus all polarities are reversed compared to the broadband compressor circuit. The reader is referred to section **2.b** for a further discussion.

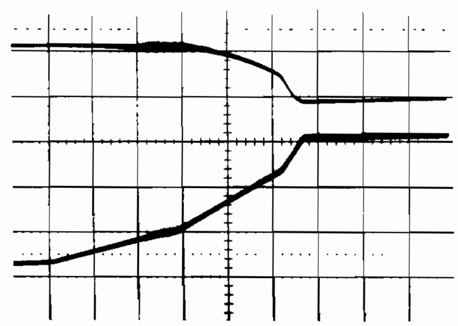

FIG. 6-1: POLARITY FOLLOWER RAMP
top trace=pin 1, IC704
bottom trace=pin 2 IC704
200mS/div horizontal

6.a.A) Pilot VCA (VCA 1) And Clipper: (On Card #7)

The voltage-controlled amplifiers used in the "Smart Clipper" are multipliers rather than dividers, like the VCA's employed in other sections of the OPTIMOD-AM. The basic principles are, however, quite similar, in that the basic variable-gain element is identical in both multiplier and divider circuits.

This element consists of a CA3080 Operational Transconductance amplifier linearized by means of a CA3019 diode bridge placed at the input of the CA3080. The basic operation of this element is detailed in section **2.a.** In the multiplier configuration, the current-source output of the CA3080 IC710 is converted to a low-impedance voltage output by coupling it to the inverting input of an opamp IC712A through AC-coupling network C707, R731. The inverting input of IC712A is a "virtual ground" because the negative feedback through R732 forces the voltage at the inverting input of IC712A to be equal to the voltage at the grounded non-inverting input of this opamp. Thus there is virtually no voltage swing at the output of IC710.

This permits us to use a different scheme than that employed in the divider circuits for determining the gain-control current flowing through pin 5 of IC710.

Recall that pin 5 feeds a diode connected to a current-mirror current source for the input stage of IC710. The cathode of this diode is connected to the V- bus inside IC710 -- i.e., pin 4. We can enclose this diode in the feedback loop of an opamp, and use the opamp to control the current through the diode, and thus the gain of IC710.

The opamp performing this control function is FET-input opamp IC711. Its non-inverting input is connected to the (high impedance) control-voltage bus described in **6.a.E.** Feedback forces the voltage on the inverting input of IC711 to follow the non-inverting input of this opamp. The output of IC711 is connected to pin 4 of IC710 and thus provides all negative operating current for this device. Pin 5 of IC710 is connected to the inverting input of IC711.

The voltage divider R729, R730 can be modeled (by means of its Thevinin equivalent) as a 75.0 K resistor in series with a -7.5 volt source. When feedback forces the voltage at the inverting input of IC711 to be more negative than -7.5 volts, current flows into the inverting input of IC711. Because no current is drawn by this input, said current must all flow into pin 5 of IC710. Thus voltage on the non-inverting input of IC711 forces an accurately proportional current to flow through the gain control node of IC710. This relationship is effected by IC711's adjusting its output voltage appropriately. CR706 protects IC710 from damage in the event that the voltage on the non-inverting input of IC711 is more positive than -7.5 volts by clamping IC711's output 0.6 volts more positive than its input, thus preventing zenering of the current mirror diode inside IC710.

The SMART CLIPPER GAIN REDUCTION meter is connected to the output of IC711. Its far end is connected to a voltage divider whose Thevinin equivalent is 2010 ohms in series with approximately -10 volts. Thus the gain reduction meter has no current flowing through it when the output of IC711 is approximately -10 volts. While this does not indicate <u>maximum</u> gain reduction available, it correctly scales the meter to read "normal" (green) and "excessive" (red) gain reduction. R769 adjusts to force full scale deflection of the meter when maximum current is flowing into pin 5 of IC710 (and therefore maximum gain is obtained from the VCA.)

The deflection of the gain reduction meter is directly proportional to the gain of the VCA. However no logarithmic conversion is used; therefore the scale is highly non-linear in terms of dB gain reduction. For this reason, a simple two-color red/green scale is employed. Deflection of the meter into the red indicates that undesirable audible side effects are likely.

The pilot VCA is followed by a differential clipper. The output of this circuit is the difference between the clipped and unclipped signals.

The operation of the circuit is simple. The input signal is clipped by a passive shunt clipper consisting of R737, R738, R739, CR707, CR708. The output of said clipper is connected through an appropriate pad to the non-inverting input of IC712B. The input of the clipper is connected to the inverting input of IC712B through R734, R735. The feedback resistor which determines both inverting and non-inverting gain is R736. R735 trims the circuit so that the contributions from the inverting and non-inverting inputs cancel exactly unless clipping occurs. When clipping occurs, the inverting and non-inverting components subtract at the output of IC712B to produce the difference between the clipper's input and its output.

The clipper diodes and associated impedances have been chosen so that the action of the clipper is matched as closely as possible to the two other clippers in the "Smart Clipper" section (see **6.c.B** and **6.C.c**). This makes the action of the "pilot system" as relevent as possible in its eventual control of the gain of VCA2 in the main audio path.

6.a.B) Distortion-Scaling VCA (VCA3): (On Card #7)

The output of the differential clipper **6.a.A** is passed through a distortion-scaling VCA, VCA3. The operation of this VCA is <u>identical</u> to the operation of VCA1; the reader is referred to **6.a.A** for details.

6.a.C) Third-Octave Filters And Analog Dividers: (On Card #6)

Eight third-octave filters are employed above 2kHz to divide the midrange into "critical bands". The audibility of distortion in each "critical band" is estimated by dividing the distortion component in each band by the undistorted component in each band. The third-octave filters occur in matched pairs (for distorted and undistorted signals). The frequencies are 2.5kHz, 3.2kHz, 4.0kHz, and 5.0kHz.

To make the filters' responses insensitive to component variations, a coupled negative-feedback topology is employed. The filters are fourth-order with steep skirts (see **Appendix II**). Each filter is synthesized by cascading an inverting second-order bandpass section employing infinite-gain multiple-feedback topology with a non-inverting second-order bandpass section employing low-gain positive-feedback topology. These two sections are both tuned to the same peak frequency. The desired response: a stagger-tuned response with 0.5dB ripple in the passband, is obtained by taking an appropriate amount of negative feedback around the filter. Because the filter is overall inverting, this is easily done with R604,628,652,676 and R613,637,661,685.

All of the filter components interact. Thus servicing a filter is a matter of first testing the opamp (which is ordinarily done by direct substitution). If the opamp is good, the passive components must be bridged one-by-one until the bad component is found. Because the passive components are highly understressed, failure is most improbable, and filter failure is almost always caused by failure of one of the the opamps.

The analog divider is a relatively low-performance circuit designed for minimum parts count. In this application its performance is more than adequate.

The divider combines the division topology detailed in **2.a** with the opamp control-current generation scheme described in **6.a.A.** There are three significant variations:

1) The CA3080 Operational Transconductance Amplifier is <u>not</u> linearized with a CA3019 bridge. The diode bridge is replaced by a RC network C611,622,633,644, R624,648,672,696. The presence of C611,622,633,644 forces the DC output of the divider to be self-centering about ground.

2) No offet nulling is used.

3) The opamp current source is inverting, rather than non-inverting. A constant bias current is provided through R620,644,668,692 which prevents the gain of the divider from becoming too large and destabilizing the overall pilot system feedback loop. Control current to reduce the gain of the divider is introduced to the inverting input of IC604B,608B,613B,617B through R621,645,669,692.

The divider is a two-quadrant device. It handles the distortion as a bipolar AC signal. Its gain control node requires a unipolar DC signal. This signal is derived from the undistorted signal in each given band by means of a simple feedback positive peak detector IC603A(etc.), CR601(etc.), C610(etc.), R622(etc.).

IC603A(etc.) charges C610(etc.) through CR601(etc.) such that the voltage across C610(etc.) follows the positive peak value of the voltage at IC603A(etc.)'s

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non-inverting input by feedback. The decay time of the circuit is approximately 30 milliseconds as determined by R622(etc.), R621(etc.). The attack time of the circuit is approximately 1 millisecond as determined by the characteristics of the opamp employed as IC603A(etc.) and the value of C610(etc.). No significant overshoot is expected.

The 1.8kHz lowpass filter should be briefly mentioned. This filter derives distortion components below 1.8kHz. It has an 18dB/octave slope and 0.18dB ripple in the passband from 0 to 1.8kHz. It is a standard third-order infinite-gain multiple-feedback filter of the type found in any standard active filter text. The comments regarding service of the third-octave filters (above) apply equally to this filter.

6.a.D) Analog "OR" And Current Source: (On Card #9)

The outputs of each of the four analog dividers and of the 1.8kHz lowpass filter are each connected to a back-to-back pair of diodes CR908-CR917. The far sides of these diodes are connected together such that five cathodes are bussed to R974 and five anodes are bussed to R977. IC914A and associated circuitry cause collector current to flow in Q901 whenever the voltage applied to the filter side of any diode pair exceeds either +1.6 or -1.6 volts. The voltage to current conversion gain of the circuit is quite low in order to stabilize the overall "pilot system" feedback loop.

Voltage divider R975, R976, R978 is arranged such that the voltage on the non-inverting input of IC914A is +1 volt, and the voltage on R977 is -1 volt. IC914A forces the voltage on its inverting input to be +1 volt by feedback.

Feedback is taken through two paths: CR918 (which is normally conducting when the inputs to the circuit are less than $\pm$1.6 volts), and R979, which monitors the voltage at the emitter of Q901.

The combination of R980 and R981 yields a circuit whose Thevinin equivalent is a 1.67K resistor in series with +0.9 volts. The normal +1 volt bias on IC914A's non-inverting input thus holds Q901 OFF.

When a pulse exceeding +1 volt is applied to R974, the inverting action of IC914A causes this pulse to appear as a negative-going pulse at the output of IC914A, thus turning CR918 OFF and Q901 ON. An identical event occurs if a pulse more negative than -1 volt appears on R977. Note that the current gain of the circuit is determined by the voltage gain of the IC914A circuit, and also by the emitter resistor of Q901. The output current of Q901 is used as described in **6.a.E** immediately below.

6.a.E) Control Voltage Integrator With Delayed Release: (On Card #9)

The output of Q901 is integrated by a delayed-release integrator CR920, CR921, CR922, C922, C923. Said integrator is very similar to the one described in (2.b). The reader is referred to that section for details.

The OPERATE/PROOF switch forces the output line of the integrator to -9.9 volts in PROOF mode by applying the output of voltage divider R756, R757 to said output line. This forces VCA1 and VCA3 into 10dB gain reduction, thus optimizing signal-to-noise ratio for proofs.

The second section of the OPERATE/PROOF switch gates the release time module through diode CR919, thus making the control voltage line high-impedance and avoiding loading voltage divider R756, R757.

6.b.A) Clock: (On Card #9)

The operation of the clock is extremely straightforward. Two inverting buffer sections of IC903, a CD4049UB six-section CMOS inverting buffer, are used as a 900kHz RC oscillator. Failures in the oscillator are almost certainly due to IC903. IC903 cannot be casually replaced because the oscillator frequency is somewhat dependent upon the characteristics of the individual IC employed. The final test sheet included with your OPTIMOD-AM indicates the correct oscillator frequency for your unit. If IC903 is replaced, a frequency counter should be used to reset the oscillator to the same frequency ±1% by trimming R973.

The Bucket Brigade delay lines (see **6.b.B** and **6.c.C)** require two square wave clocking signals 180 degrees out-of-phase with each other, swinging from 0 to +14 volts. These requirements are met by the use of a chain of CD4013UB CMOS D-type flip-flops with true and complement outputs.

A D-type flip-flop captures the instantaneous state of the D input each time a positive transition occurs at the CLOCK input. By connecting the D input to the COMPLEMENT output, the output of the flip-flop will change state each time the positive edge of a clock pulse is applied to the CLOCK input. In this way, the output frequency of the flip-flop is one-half the frequency applied to the CLOCK input.

550kHz for the 450 microsecond delay is generated by dividing the oscillator

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frequency by two in IC902A. A chain of three more identical flip-flops divide the 550kHz by eight, yielding 69kHz for the 3.7 millisecond delay.

Because of the high frequencies and sharp transitions involved, substantial RF energy is generated by the clock circuitry. Long unshielded test probes and/or operation of card #9 without normal shielding can induce interference into other parts of the OPTIMOD-AM circuitry. Capacitive loads can soften transitions and/or cause ringing, thus giving misleading results when the system is being maintained.

NOTE: If failure of any digital logic in the system occurs, be sure to replace the failed IC with an exact replacement. In particular, system reliability will be seriously compromised if A-series CMOS is employed instead of the recommended B or UB devices.

6.b.B) 3.7 Millisecond Bucket-Brigade Delay: (On Card #9)

The Bucket Brigade Device (BBD) is a hybrid digital/analog device, sometimes called an analog shift register. It samples the input signal at regular intervals, like a digital system. However, the samples are not converted to numbers; instead, they remain in the form of discrete analog voltage levels.

These voltage levels are stored on integrated MOS capacitors on the BBD chip. Each capacitor is buffered by a pair of MOS transistors. One MOS transistor is driven by one of two out-of-phase clock signals. The circuit is arranged so that each voltage sample is stepped along one capacitor at a time. First the voltage in alternate capacitors are transferred to the next adjacent capacitor down the line. Then the "old" voltages which have just been transferred are replaced by "newer" voltages coming up from behind. Like an old-fashioned bucket brigade, charge is transferred from one bucket (capacitor) to the next on alternate clock pulses, finally emerging at the far end of the line. Because of the alternation, an "n"-stage BBD can only handle "n/2" samples.

The BBD employed in the OPTIMOD-AM is a dual 512-stage NMOS device. The available dynamic range between the noise floor and the 1% distortion point is approximately 70dB. Manufacturing techniques have not yet progressed to the point where each device is fully interchangable with the next; thus the circuit must be tweaked for the individual device employed.

CAUTION:

BBD'S ARE MOS DEVICES AND ARE HIGHLY SUBJECT TO DAMAGE FROM STATIC ELECTRICITY! WHEN HANDLING THE BBD OR WHEN WORKING ON CARD #9, ALWAYS USE A GROUNDED WORK STATION. USE ONLY A SOLDERING IRON GROUNDED TO EARTH. AVOID HANDLING THE BBD OR THE CMOS DEVICES BY THEIR LEADS. USE OF A WRIST STRAP GROUNDED THROUGH A I MEG RESISTOR (TO LIMIT POTENTIAL SHOCK CURRENT) IS HIGHLY DESIRABLE. THE BBD IS THE MOST EXPENSIVE DEVICE IN THE OPTIMOD-AM. IF DESTROYED, IT CANNOT BE REPLACED WITHOUT REALIGNMENT OF THE CIRCUIT. SO BE CAREFUL!

The polarity follower output is padded down by voltage divider R901, R902 in order to operate the BBD IC904A in the optimum part of its dynamic range. The BBD overloads at approximately 1.0 volts rms referred to its input.

The BBD requires a DC bias of approximately +6 volts on its input; this varies from device to device and is critical if the overload to noise ratio is to be optimized. Bias is trimmed for the individual BBD employed with R904; associated components R903, R905, C901 provide isolation between the audio and bias supplies.

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The BBD has two outputs. These must be summed to achieve maximum cancellation of the clock component in the output. This summation occurs in R909, R908. R906, R907 provide bias current for the MOS source followers in the output stage of the BBD.

The output of the BBD contains upper sidebands of the clock. This high frequency "garbage" must be lowpass filtered to properly restore the input. If input waveform is to be preserved, the lowpass filter must have constant time delay at all frequencies within its passband.

The required lowpass filtering is achieved by means of fourth-order Chebychev lowpass filter IC905B, R910, R911, R912, R913, R914, R915, R916, C906, C904, C905, C907, and by means of phase corrector IC905A, R917, R918, R919, R920, R921, C908, C909.

The lowpass filter is a single-amplifier fourth-order positive feedback type characterized by high sensitivity to component variations. A gain trim R916 is thus necessary to compensate for component tolerances. This trim is also used to compensate for high frequency response variations between individual BBD's. The operation of this filter is such that all components interact. Thus service consists of first checking the opamp, then testing each passive component with an impedance bridge. If IC905 is replaced, no readjustment of R916 is necessary. If a passive component is replaced, R916 must be readjusted according to the instructions in the **COMPLETE ALIGNMENT** section of this manual.

The phase corrector works by subtracting the output of a bandpass filter with 6dB peak gain from said filter's input. It can be shown that this yields an allpass characteristic: a flat magnitude response, but a frequency-dependent phase response.

Said bandpass filter is an inverting infinite-gain multiple-feedback type and is connected to the output of the lowpass filter. Such bandpass filters are straightforward, and a description can be found in any modern textbook on active filters. Because the filter inverts, the subtraction function is transformed into a simple addition function, realized with R920 and R921.

6.c.A) Slave VCA (VCA2): (On Card #9)

The slave VCA is identical to VCA1, with the exception that the feedback resistor R932 on the current to voltage converter opamp IC909B is adjustable in order to precisely match the gain of VCA2 to the gain of VCA1, and that provision has been made to trim the DC feedthrough from the control voltage into the audio.

The input of this VCA is slightly offset to purposely introduce a second-harmonic distortion component which nulls the dominant second-harmonic distortion in the BBD delay line preceding the VCA. This offset may unbalance the VCA enough to permit significant feedthrough of control voltage. To null this, a DC current is injected through R982 into the input of the VCA. When the magnitude of this current is properly adjusted with R983, this DC is multiplied in the VCA by the control voltage in such a way that it exactly cancels the undesired feedthrough.

Further details on VCA operation are provided in **6.a.A.**

6.c.B) Clipper And 1.8kHz Lowpass Filter: (On Card #9)

The output of the 3.7mS delay line feeds a differential clipper whose characteristics match those of the pilot system differential clipper **6.a.A** as closely as possible. The reader is referred to **6.a.A** for details.

The output of the differential clipper is lowpass-filtered by 1.8kHz third-order 0.18dB ripple Chebychev lowpass filter IC912B, R960, R961, R963, R962, C916, C917, C918. Said lowpass filter is phase corrected with bandpass filter and adder IC913A, R964, R965, R966, R967, R968, C919, C920.

The third-order lowpass filter is a standard infinite-gain multiple-feedback type. The phase correction technique employed has already been described in **6.b.B** and the reader is referred there for details.

6.c.C) 450 Microsecond Delay Line And Clipper: (On Card #9)

The operation of the 450 microsecond BBD delay line is substantially identical to the operation of the 3.7 millisecond delay line up to the lowpass filter. The reader is referred to **6.b.B** for details.

Because of the high clock frequency, lowpass filter requirements are relaxed, and a third-order passive LC minimum-phase filter C913, C914, L901 is employed. This is a standard double-terminated ladder filter, and is phase-linear.

The lowpass filter is buffered by a VCA of the type described in **6.a.A.** It is not used here as a VCA; instead, it is used to introduce a controlled amount of second-harmonic distortion to cancel a substantial part of the second harmonic distortion introduced by the BBD.

A current-to-voltage converter opamp is not used. Instead, the current output of IC911 develops a voltage between R954 and ground. This voltage is clipped by shunt clipper CR904, CR905. Its action is as identical as possible to the clipping action of the other clippers used in the "Smart Clipper" system (i.e. in **6.a.A** and **6.c.B).**

R954's far end is connected to a "virtual ground" summing amplifier IC913B rather than to actual ground (see **6.c.D** below). Thus the output of IC911 is introduced to this summing amplifier through R954. From the point of view of clipper function, this refinement is irrelevant.

6.c.D) Subtractor: (On Card #9)

The subtractor is in fact a simple "virtual ground" summing amplifier IC913B. The subtraction function is achieved by proper choice of inverting or non-inverting action in the circuits feeding the subtractor.

7.a) Lowpass Filter: (On Card #8)

(**NOTE:** All reference designators refer to the "Day" filter. The "Night" filter is topologically identical.) The filter consists of an allpass phase corrector followed by a fifth-order Chebychev lowpass filter.

The allpass phase corrector consists of IC801A and associated circuitry (see for example **6.b.B).**

The lowpass filter IC801B, IC802A consists of a standard third-order infinite-gain multiple-feedback lowpass section cascaded with a standard second-order infinite-gain multiple-feedback section. The filter is followed by unity-gain inverter IC802B; this inverts the polarity of the filter output to assure that the polarity at CR801, CR802 is correct when OPTIMOD-AM is operated asymmetrically. In addition, its "-" input operates at virtual ground, thus assuring proper operation of DAY/NIGHT switching JFET's Q809, Q810.

The three sections of the lowpass filter do not interact; all components within a given section interact. Thus service advice given many times earlier again applies: first check the opamp; then, test each passive component on an impedance bridge until the defective component is identified. Since all sections are relatively low-sensitivity, components may be freely replaced as necessary, bearing in mind that all components have $\pm$1% tolerance except for the 0.01 mfd capacitors, which have $\pm$2% tolerance.

7.b) Safety Clipper: (On Card #8)

The safety clipper, like all other clippers employed in the OPTIMOD-AM, is a shunt clipper. It is loaded by the OUTPUT ATTENUATOR control R817.

Negative bias for CR802 (recall that negative-going signals within OPTIMOD-

AM correspond to positive modulation) is supplied by unity-gain non-inverting buffer amplifier IC804B. Its input is connected to voltage divider R827, R829 which is driven by the main negative clipper bias supply. This supply in turn is adjusted by the POSITIVE PEAK THRESH control R763. Thus the bias on CR802 may be adjusted from approximately 62% to 100% of the bias on the main clippers by means of SAFETY CLIPPER POSITIVE THRESH control R829.

A square wave from an external generator to facilitate adjustment of the TRANSMITTER EQUALIZER controls following may be injected into the safety clipper from TP1 through C841, R815. This AC coupling removes DC offsets from the square wave generator which would otherwise upset operation of the transmitter equalizer. The cutoff frequency of the coupling is sufficiently low to introduce no significant tilt to the test square wave.

7.c) Transmitter Equalizer: (On Card #8)

The H-F SHELF EQ is generated by subtracting a fraction of the output of a highpass filter (formed by C810 and its load resistors R820, R821, R822, R823, R824, R825) from the main signal in IC803A. Said fraction is determined by voltage divider R824, R825. The time constant (and thus the initial frequency at which the shelving takes effect) is determined by the RC product of C810 and its loading resistors. Two different time constants for "Day" and "Night" operation may be selected by turning switching FET's Q811 or Q812 ON by applying 0 volts to their gates. They are OFF when -15 volts is applied.

The H-F DELAY EQ is a first-order allpass network consisting of IC803B and associated components. Its operation is identical to that of the H-F SHELF EQ with the exception that the full output (rather than a fraction) of the highpass filter is subtracted. It can be shown that this results in a flat amplitude response but a phase response that varies with frequency.

The L-F TILT EQ is accomplished by adding a carefully shaped signal developed inside the module to the main signal in summing amplifier IC805B. The amount of correction is determined by the gain of controls R836, R837 which are switched for "Day" and "Night" characteristics by FET's Q815, Q816.

The entire transmitter equalizer can be bypassed by means of S1, which connects the input of IC805B to the buffered output of R817. This buffer is contained within the module.

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7.d) Output Line Amplifier: (On Card #8)

The output line amplifier consists of a inverting amplifier with a gain of -5 followed by an inverting amplifier with a gain of -1. These amplifiers together provide a +26dBm balanced output capability. This is reduced to +20dBm by the output pad and RF filter R8, R9, R10, C1, C2, C117, C118, L5, L6. Both amplifiers are opamps buffered by discrete complementary-symmetry output stages. The operation of the opamp amplifiers is completely straightforward and basic. Thus we will describe only the output buffers, which are identical for the non-inverting and inverting stages. In our discussion, we will refer to the first inverting stage (IC805B).

The buffer is located within the feedback loop of the opamp IC805B. The output of IC805B is connected to the base of NPN emitter follower Q802 and also to a load consisting of diode-connected transistors Q801, Q803 and load resistor R844. Q801 and Q803 are bias diodes and are thermally connected to their associated output transistors to provide thermal feedback to prevent thermal runaway of the output stage. The voltage drop across these diode-connected transistors biases the output stage such that current always flows and thus prevents crossover distortion.

R842 and R843 provide local DC feedback in the emitters of the output transistors to help stabilize the output stage quiescent current. They also work with CR803, CR804 to current-limit the output stage, thus protecting the output transistors from burnout due to a short circuited output. If the current in either output transistor exceeds approximately 130 mA peak, the voltage drop across R842 or R843 will exceed the 0.6 volt turn-on voltage of CR803, CR804. These diodes will then shunt the drive current into the load, thus protecting the output stage.

The output amplifiers are isolated from the outside world by means of LC RFI filters which are effective at both AM and FM frequencies. These filters (C1, C2, C117, C118, L5, L6, and associated resistors) have been designed so that no ringing and/or overshoot will occur.

7.e) Day/Night Switching Logic: (On Card #8)

The "Day" and "Night" modes may be selected by pulsing current through opto-isolators Q818 and Q817 respectively. Current limiting and RF suppression are provided by R851, R852, R853; rectification for AC control signals is provided by CR807, CR808, CR807.

IC806A and IC806B are cross-coupled as a bistable multivibrator (flip-flop). This bistable changes state whenever the transistor in one of the optoisolators turns ON and pulls its collector down to -15 volts.

To assure that the system always comes up in the "Day" mode on powerup, initialization circuit CR810, C815, R855 is used. Upon powerup, the transition of the negative power supply from 0 to -15 volts is coupled through C815 and CR810 to IC806A. Under steady state conditions R855 pulls the anode of CR810 up to 0 volts. CR810 then effectively disconnects the powerup circuitry.

The main ("Day") output of the bistable is the output of IC806A. It drives NAND gate IC806C (connected as an inverter) to produce the complementary "Night" output. IC806D is also connected as an inverter, and buffers the DAY/NIGHT indicator LED drive circuit R857, R858, CR811, CR812, CR813, CR814, Q819.

Q819 inverts once again, and drives the DAY LED CR814 when ON. Current is diverted from CR313 by the voltage drops of CR811, CR812. When Q819 turns OFF, then the current from R858 flows through CR313 (the "Night" LED).

8.a) Unregulated +24 Volt Power Supply:

(On Chassis Outside RF-Tight Enclosure)

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The unregulated power supply is wholly conventional. It consists of a dual-primary transformer T101, two full-wave rectifiers CR101, CR102 and CR103, CR104, and two energy storage capacitors C101, C102.

T101's primary may be switched for 115 volt operation by paralleling its two primaries, or for 230 volt operation by connecting its two primaries in series. RF filtering is provided on the AC line by means of FL101. In addition, VHF and UHF RF is filtered from the unregulated DC supply lines as they enter the main chassis by means of C103, C104, C105, C106, C107, L101, L102. The RF suppression scheme divides the chassis into three major sections. The section to the left contains the meters and the unregulated power supply, and is assumed to contain some RF. The main chassis, to the right, uses RF suppression on each line entering or leaving the area, and is thus RF-free. The RF filter box, on the rear panel, interfaces the audio input and output lines with the outside world. It contains the input pads. Its connections to the main RF-tight compartment are all RF-filtered.

8.b) +15 Volt Regulator: (On Card #1 (On Chassis))

The +15 volt regulator is the main reference for all other voltages in the OPTIMOD-AM system. It employs a 723C IC voltage regulator IC101 in conjunction with an external series-pass transistor Q101. THIS TRANSISTOR IS MOUNTED ON THE REAR APRON OF THE CHASSIS, which serves as a heat sink.

The 723C contains a reference voltage source, an opamp (externally compensated by means of C109 to prevent oscillation), and a current limiting transistor. The reference voltage (nominally +7.15 volts) is developed at pin 6. C108 filters high frequency noise from the reference voltage. The reference voltage is directly connected to the non-inverting input of the internal opamp, pin 5. Voltage divider R105, R106, R107 develops a precise fraction of the output voltage of the regulator at the wiper of R106. R106 adjusts this fraction. The wiper of R106 is connected to the inverting input of IC101's internal opamp. Negative feedback thus forces the voltage at the wiper of R106 to be equal to the reference voltage. Thus the output voltage of the regulator is always the reference voltage divided by the voltage divider gain.

The output current flowing through Q101 develops a voltage drop across R103. When the current exceeds approximately 3/4 amp, said voltage drop is sufficient to turn on the current-limit transistor inside IC101, whose base-emitter junction is connected to pins 2 and 3 of IC101. The current-limit transistor then shunts base drive current from the external series-pass transistor Q101 and prevents damage due to overheating.

If a catastrophic failure in the +15 volt regulator causes it to lose control over its output voltage, the rest of the circuitry must be protected against the full unregulated voltage, or the entire system will be severely damaged. This protection is provided by zener diode VR101, CR105, and 1 amp fast-blo fuse F102.

In the event that the regulator loses control of the output voltage, VR101 will conduct and limit the output voltage to approximately 16.5 volts, which will not damage the system. Extremely large amounts of current will flow in VR101. However, before VR101 is damaged, this current will blow F102, thus disconnecting the circuitry from the unregulated supply. VR101's clamping action will also prevent the negative tracking supply from going any higher than -16.5 volts. If the regulator is operating properly, the current limiting circuitry will prevent F102 from blowing even if the regulator output is short-circuited.

Under certain unusual circumstances, the regulator may lose control of its output voltage, yet the current limiting circuit may still work. If this occurs, F102 will not blow, and VR101 will overheat and burn out. Fortunately, its failure mode is a short-circuit. It will therefore still protect the OPTIMOD-AM circuitry even in this exceptional circumstance.

8.c) -15 Volt Regulator: (On Card #1 (On Chassis))

The -15 volt regulator is an operational amplifier containing a discrete power-booster output stage with current limiting. It "amplifies" the output of the +15 volt regulator by -1, thus producing a -15 volt tracking supply. Shutdown of the +15 volt supply (due to current limit conditions or to a fault which blows F102) will also result in the -15 volt supply's shutting down.

The basic opamp is IC102; its input resistor R109 and feedback resistor R108 are equal-valued, resulting in a gain of -1 ±2%. IC102's negative supply comes from the unregulated -24 volt supply. Fortunately, the common-mode range of the 301A opamp includes the positive power supply. Thus IC102's positive supply is ground. Under normal operating conditions, the "+" input of IC102 is grounded, and its "-" input is within 10mV of ground.

Q103 and Q102 form a conjugate emitter follower which can boost the output current of IC102 to more than 3/4 amp. The basic emitter follower is Q103; Q102 is connected in a 100% negative feedback configuration to boost the current output capability of Q103.

Q104 is a current-limit transistor. If the -15 volt supply is called upon to deliver more than 3/4 amp, sufficient voltage drop (approximately 0.6 volts) will occur across R104 to turn on Q104, thus shunting drive current away from Q103 into the load and protecting Q102/Q103 from burnout. Under these conditions, IC102 is protected by internal current limiting circuitry.

C113 frequency-compensates the -15 volt supply to protect it against high frequency oscillations. R102 increases the circuit's immunity to leakage in Q103.

The rest of the circuitry is protected against a catastrophic failure of the -15 volt regulator by means of zener clamp VR102, CR106, and fuse F103. The

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operation of this circuit is identical to the operation of the corresponding circuit in the +15 volt regulator (see **8.b)**.

8.d through 8.f) Miscellanous Voltage Supplies:

The operation of these supplies is extremely straightforward. No further explanation beyond that given in the **PRINCIPLES OF OPERATION** section is required.

This concludes the **CIRCUIT DESCRIPTION** section of this manual.

APPENDIX I

ALIGNMENT PROCEDURE

I) General: The following section describes how to align and calibrate OPTIMOD-AM. It is included primarily for purposes of reference.

WARNING!

THE AVERAGE RADIO STATION HAS NEITHER THE NECESSARY EXPERIENCE NOR THE REQUISITE TEST EQUIPMENT TO SUCCESSFULLY COMPLETE THIS PROCEDURE. IF CALIBRATION IS NECESSARY, WE STRONGLY RECOMMEND THAT THE CARD IN QUESTION BE RETURNED TO THE FACTORY FOR CALIBRATION BY OUR EXPERIENCED TECHNICIANS, WHO HAVE ACCESS TO SPECIAL TEST FIXTURES AND A SUPPLY OF EXACT-REPLACEMENT SPARE PARTS. ONLY IN AN EMERGENCY SITUATION SHOULD AN ATTEMPT BE MADE TO ALIGN AND CALIBRATE OPTIMOD-AM IN THE FIELD.

The factory aligns each card independently to a standard, so that cards will be completely interchangable. However, the user does not have access to the special test fixtures necessary to complete independent alignment of the cards. The user thus must use his own OPTIMOD-AM chassis as a test fixture, and align the entire unit as a system.

This section is organized on a card-by-card basis. Cards should be calibrated in the same order as their order in the signal path, from input to output. This will occur naturally if the instructions in this section are followed in order from beginning to end. If a card later in the signal path is aligned while an earlier card is misaligned, the later card may not be correctly aligned, even if the instructions for that card are followed conscientiously.

Before commencing alignment, remove OPTIMOD-AM from its normal rack mounting location and place it on the test bench away from RF fields. It is also necessary to remove the top cover to access certain test points.

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2) Required Test Equipment: The following test equipment (or close equivalents) is required. It is assumed that the technician is familiar with the operation of this equipment; if not, he should refer to the manufacturers' manuals, as space precludes giving extremely detailed explanations here.

a) Digital Voltmeter, accurate to ±0.1%

b) Oscilloscope, dual-trace, triggered-sweep, with 5mHz or better vertical bandwidth

c) Ultra-Low Distortion Sinewave Oscillator/THD Test Set (Sound Technology 1700B or 1710B)

d) Low Frequency Spectrum Analyzer with Tracking Generator (Tektronix 5L4N plug-in with 5111 Bistable Storage Mainframe)
(**NOTE:** There is, to our knowledge, no commercially-available equivalent of this test set. Those steps which employ the 5L4N to make swept frequency response measurements can be performed with a sweep generator and X/Y oscilloscope. We will not give detailed instructions for doing this; an experienced technician should easily be able to deduce them.)

e) General-Purpose Frequency Counter, accurate to ±0.01%

f) Phase-Measuring Means, accurate ±2 degrees. Either a phase meter, an oscilloscope with a calibrated, delayed time base, or an accurate X/Y DC-coupled oscilloscope (for Lissajous patterns) may be employed.

g) Pink Noise Generator

REFER TO THE FOLD-OUT SCHEMATICS AND ASSEMBLY DRAWINGS AT THE BACK OF THIS MANUAL.

3) Card #1 (Power Supply):

a) Measure the voltage across C111 (or other convenient point on the +15 volt bus) with the DVM. Adjust R106 until the DVM reads +15.00 volts.

b) Measure the voltage across C112 (or other convenient point on the -15 volt bus). Make sure that the voltage is between -14.85 and -15.15 volts. If it is not, refer to **Section 6 (CIRCUIT DESCRIPTION),** subsection **8.c** for troubleshooting hints.

BEFORE ALIGNING EACH CARD AS DESCRIBED IN THE INSTRUCTIONS BELOW, REMOVE POWER TO OPTIMOD-AM, PLACE THE CARD IN QUESTION ON THE CARD EXTENDER, AND PLUG THE EXTENDER BACK INTO THE EMPTY CARD SLOT. THEN RESTORE POWER. THIS WILL GIVE YOU ACCESS TO THE ALIGNMENT TRIMMERS AND TEST POINTS.

4) Card #3 (Broadband Compressor/Input Buffer And Filter):

a) Place the PROOF/OPERATE switch in the PROOF position.

b) Use the DVM to measure the DC voltage at the output of IC310. SLOWLY adjust R346 until this voltage is 0 volts DC.

c) Connect the low-distortion oscillator to the input of OPTIMOD-AM. Set the oscillator frequency to 1kHz. Measure the AC voltage at the side of R326 which is away from IC305, and adjust the output of the oscillator until this voltage is 0.2V rms.

d) Now measure the AC voltage at the output of IC305, and adjust R366 until this voltage is 2.0V rms.

e) Place the PROOF/OPERATE switch in the OPERATE position. Adjust the oscillator output level until 10dB gain reduction is observed on the BROADBAND GAIN REDUCTION METER.

f) Connect the input of the THD meter to the output of IC305, and read the THD. Adjust R331 to minimize the THD.

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5) Card #5 (Equalizer And Crossover Filters):

This card requires no alignment.

6) Card #2 And Card #4 (Band-Limiters):

The alignment procedures for each of the band-limiters are essentially identical. After each band-limiter is aligned, the 150Hz limiter is adjusted for standard gain (with no gain reduction). Then the sum of the limiter outputs is observed, and, with a sweep generator driving the inputs of the crossover filters, the gains of the other band-limiters (under no-G/R conditions) are adjusted to yield a maximally-flat swept response of the sum.

The component designators refer to CARD #2; for CARD #4, replace the "2" prefix with a "4". When a designator refers to more than one band, it will be in the form of XXx()x. For example, IC2()4 refers to IC204, IC224, and IC244, which perform identical functions in the different bands.

a) To prepare for adjustment, turn each G/R ZERO control R2()8, fully counterclockwise.

b) Adjust all controls for normal operation, except for the INPUT FILTER and EQUALIZER switches, which should be OUT.

c) Connect the low-distortion oscillator to the OPTIMOD-AM input.

d) Perform the following procedure on each limiter in turn:

A) Place the PROOF/OPERATE switch in the PROOF position, and suppress the output of the oscillator.

B) Measure the DC output of IC2()6 with the DVM. SLOWLY adjust R2()8 until the DVM indicates 0 volts DC.

C) Place the PROOF/OPERATE switch in the OPERATE position and restore the oscillator output.

D) Adjust the oscillator frequency to the center of the frequency range of the band-limiter being adjusted.

E) If necessary, readjust the oscillator output until approximately 5dB gain reduction (need not be exact) is indicated on the BROADBAND GAIN REDUCTION METER.

F) Adjust the DENSITY control until 10dB gain reduction is indicated on the BAND GAIN REDUCTION METER of the band being adjusted.

G) Measure the THD at the output of IC2()1 and adjust R2()6 (DISTORTION NULL) for minimum THD.

e) Adjust the oscillator output to 100Hz, and switch the PROOF/OPERATE switch to PROOF. Measure the AC voltage at the end of R265 away from IC201, and adjust the oscillator output until this voltage is 0.158V rms. Now measure the AC voltage at the output of IC201, and adjust R202 (GAIN CAL) until this voltage is 5.0V rms. Return the PROOF/OPERATE switch to OPERATE.

f) The following maneuver involves cards #2, #4, and #7. It should be performed by first extending card #7 so that the output of IC701A is available. Adjustments on cards #2 and #4 must be made from the top of the chassis, since both cards must be adjusted alternately without being extended (unless two spare extenders are available).

Connect the input of the 5L4N spectrum analyzer to the output of IC701A, and observe the output with a 20-20,000 Hz log frequency sweep and a 2dB/division vertical sensitivity. Connect the output of the 5L4N tracking generator to the input of OPTIMOD-AM. BE SURE THAT BOTH THE EQUALIZER AND INPUT FILTER SWITCHES ARE OUT, THAT THE INPUT LEVEL IS HIGH ENOUGH TO KEEP THE GATE LED OFF, AND THAT NO GAIN REDUCTION IS INDICATED IN ANY BAND!

Now adjust R2()2 (GAIN CAL) on all bands EXCEPT THE 150HZ BAND (R202) to achieve a maximally flat swept frequency response. When this adjustment is properly done, ripple will be approximately ±0.75dB, 30-15,000Hz.

7) Card #6 (Third-Octave Filters And Dividers):

This card requires no alignment.

8) Card #7 (Polarity Follower, VCA 1, VCA 3, Differential Clipper):

a) POLARITY FOLLOWER PHASE TRIM

A) Connect the low-distortion oscillator to the OPTIMOD-AM input, and adjust it to 100Hz. All OPTIMOD-AM controls should be set for normal operation. Adjust levels to produce approximately 5dB broadband gain reduction.

B) Connect a phase-measuring means between the output of IC701A and the output of IC702. Said means may be either a phase meter, an accurate DC-coupled oscilloscope with calibrated, delayed timebase, or a DC-coupled oscilloscope capable of producing accurate Lissajous patterns.

C) Force the polarity follower into its inverting mode (POLARITY LED off), if it is not already in this mode. To do this, connect one side of a jumper to a point on the -14 volt bus such as the anode of CR716. Each time the free end of the jumper is touched momentarily to the positive side of C705, the polarity follower will change state.

D) Adjust R707 (PHASE TRIM) for a 100Hz phase shift of 195 degrees.

E) Change the oscillator frequency to 10kHz. Force the polarity follower into its non-inverting (POLARITY LED on) mode. Check to see if the phase shift at 10kHz is approximately 340 degrees. If it is lower than 340 degrees (i.e., further from 360 degrees), iterate back and forth between 100Hz and 10kHz, adjusting R707 such that the deviation from 180 degrees @100Hz (in inverting mode) is approximately equal to the deviation from 360 degrees @10kHz (in non-inverting mode).

F) To verify that you have performed the adjustment correctly, set the oscillator frequency to 1kHz. Verify that in inverting mode, the phase is within 2 degrees of 180 degrees, and that in non-inverting mode, that the phase is within 2 degrees of 360 degrees.

G) Remove the phase-measuring means from IC701 and IC702.

b) DIFFERENTIAL CLIPPER CMRR TRIM

A) Without changing the input connections or OPTIMOD-AM adjustments in (a) above, connect a high-gain oscilloscope or AC VTVM to the output of IC712B. Reduce the SMART CLIPPER DRIVE somewhat below the level which causes gain reduction to be indicated on the SMART CLIPPER GAIN REDUCTION meter.

B) Adjust R735 (Common Mode Rejection Ratio Trim) to null the 100Hz component observed.

c) SMART CLIPPER GAIN REDUCTION METER ZERO: Without changing any adjustments, adjust R769 until the SMART CLIPPER GAIN REDUCTION METER indicates at the top of the green section of the scale.

d) VCA 1 DISTORTION NULL

A) Connect one end of a 100K 1/4 watt 5% carbon resistor to pin 2 of IC710 (use a clip lead and connect it to the IC710 side of R722).

B) Connect the other end of the 100K resistor to the output of the low distortion oscillator. Be sure that the low side of the oscillator output is grounded to the OPTIMOD-AM circuit ground.

C) Observe the output of IC712A with a harmonic distortion meter. Turn the CLIPPING control full CW. Adjust the oscillator frequency to 1kHz, and increase its output until the SMART CLIPPER GAIN REDUCTION METER is in the middle of the red section of the scale. This should correspond to approximately +10dBm output from the oscillator.

D) Measure the THD, and adjust R725 to null it. There will be a residual distortion consisting of odd harmonics; the even harmonics should essentially vanish.

e) VCA 3 BALANCE

A) Connect a pink noise source (or an FM radio tuned to interstation "hash") to the OPTIMOD-AM input. Adjust all controls for normal operation. Adjust the OPTIMOD-AM INPUT ATTENUATOR until about 10dB of BROADBAND GAIN REDUCTION is produced.

B) Connect an oscilloscope to the output of IC708 and observe the waveform. This should consist of spikes riding on both sides of a slightly irregular baseline. The spikes are the desired differentially-clipped control signal; the baseline contains undesired control-voltage feedthrough components from VCA3's control voltage.

C) Now turn the PROOF/OPERATE switch to PROOF. The spikes should vanish, and the irregular baseline should remain. Adjust R743 to smooth the baseline as much as possible. Increase the gain of the scope as necessary to observe the feedthrough. Complete cancellation of the feedthrough will not be possible, but its amplitude should be at least 30dB below the peak amplitude of the spikes.

9) Card #9 (This card contains the majority of the "Smart Clipper" circuitry.)

a) APPROXIMATE CLOCK FREQUENCY: Connect a frequency counter to the "Q" output of IC902A (pin 1), and adjust R973 until the frequency is approximately 550kHz.

b) DELAY 1 FREQUENCY RESPONSE

A) Connect the output of the 5L4N tracking generator to the junction of R901 and R902. Connect the 5L4N input to the output of IC909B.

B) Switch the PROOF/OPERATE switch to PROOF.

C) Adjust the 5L4N for 2dB/div; -10dBV full scale; 1 meg input impedance. Adjust the sweep for linear scale; 0 to 20kHz. Adjust the tracking generator output attenuator to produce an on-scale trace. Sweep slowly enough to avoid distorting the swept frequency response. Now adjust R916 for maximally-flat response. Ideally, this will be +0.5, -0dB from 100 to 11,000Hz.

D) Disconnect the 5L4N from the card.

c) DELAY 1 DISTORTION NULL

A) Connect the low-distortion oscillator to the junction of R901 and R902. Adjust the oscillator frequency to 100Hz. Connect the harmonic distortion meter to the output of IC909B. Monitor the input buffer and distortion outputs of the THD meter with the two traces of the oscilloscope. You may also find it useful to monitor the distortion output with the 5L4N spectrum analyzer, in LOG SPAN 20-20K Hz mode.

B) Advance the output of the oscillator until clipping is observed at the output of IC909B. This represents clipping in IC904A, the BBD delay line. Adjust R904 (DELAY 1 BIAS), and simultaneously adjust the output of the oscillator until the absolute maximum input level has been accepted without clipping.

C) Reduce the oscillator output level 4dB below the level which induces clipping. Now adjust R924 (VCA 2 DISTORTION NULL) to null out as much of the even-order components of the harmonic distortion residual as possible. This is most easily done by observing the 5L4N spectrum analyzer. However, simply nulling the THD as read on the THD meter is also satisfactory.

d) ALIGN VCA 2 AND DELAY 2 TO VCA 1

A) Connect the low-distortion oscillator to the OPTIMOD-AM input. Place the PROOF/OPERATE switch in OPERATE. Adjust the oscillator frequency to 1kHz.

B) Adjust the CLIPPING control to 12:00. Advance the SMART CLIPPER DRIVE control until the SMART CLIPPER GAIN REDUCTION METER reads at the red/green junction.

C) Observe the output of IC912A with an oscilloscope. Adjust R932 until the waveform (representing clipping distortion) just barely vanishes.

WARNING!

Steps (e) and (f) below are very difficult, and should not be performed in the field unless IC904, 910, or 911 have been replaced.!

e) DELAY 2 DISTORTION NULL

A) Connect the harmonic distortion meter to the output of IC913B.

B) Adjust the oscillator to 100Hz. Adjust the oscillator output level until 5dB BROADBAND G/R is indicated.

C) Adjust the SMART CLIPPER DRIVE control to 11:00. Place the PROOF/OPERATE switch in PROOF.

D) The following step establishes a standard level through the BBD delay lines. Said level is 60dB above the noise floor of the BBD's. These instructions specifically assume the use of a Sound Technology 1700B or 1710B Noise and Distortion test set. Other sets having a standard dBm scale, such as the H-P 333A may also be used, with the procedure deduced by analogy.

Suppress the oscillator output. Adjust the 1700B INPUT switch to 3V f.s. Adjust the 1700B RATIO switch to -60dB. Enter the DB/VOLTS mode, and adjust the SENSITIVITY ADJUST pot until the meter reads 0dB (i.e., 60dB below zero dB on the meter).

Now restore the oscillator output, and adjust the OPTIMOD-AM DENSITY

A

control until the 1700B reads 0dB in SET LEVEL mode. Then adjust the 1700B SENSITIVITY ADJUST pot for a full-scale reading.

E) The following procedure iteratively finds the best compromise between THD at 100Hz, 1kHz, and 5kHz. Rock R936 (DELAY 2 BIAS) back and forth to find the two points where the wave starts to clip. Adjust R936 approximately half-way between these points.

F) Adjust R947 to minimize THD.

G) Switch the oscillator frequency to 5kHz. Readjust R936 to minimize THD. Limit your adjustment to the center 50%, considering the distance between the two clip points to be 100%. You should get about 0.5% THD.

H) Recheck the THD at 100Hz. If it is more than 0.4%, slightly adjust R947 to reduce the THD to 0.4%. Don't fully null THD; you'll find you have caused the 5kHz THD to deteriorate excessively.

I) Check the THD at 100Hz, 1kHz, and 5kHz. THD at 100Hz should not exceed 0.4%. THD at 1kHz and 5kHz should not exceed 0.6%. If these specs are not met, try further trading off the settings of R936 and R947.

f) DISTORTION CANCEL TRIM

A) Turn the CLIPPING control full CW. Turn the POS PEAK THRESH control full CCW. Switch the PROOF/OPERATE switch to OPERATE.

B) Adjust the oscillator to 200Hz. Advance the SMART CLIPPER DRIVE control until clipping distortion barely appears in the distortion output of the 1700B.

C) This waveform is the distortion in the sum of the clipped output of IC911, and the distortion-cancelling output of IC912B and IC913A (see (6.d), Section 5 (PRINCIPLES OF OPERATION)). Minimize THD by interactively adjusting three controls: R973 (DELAY TRIM), R951 (MATCH CLIP LEVELS), and R952 (OFFSET NULL). Each adjustment will affect the residual distortion waveform from the output of the THD analyzer in its own distinctive way. Adjust R952 until the distortion appears with equal height above and below the baseline. Adjust R973 to make the shape of the distortion above and below the baseline symmetrical. Adjust R951 to secure a final null.

If R952 is end-stopped, it may be brought into range with a slight readjustment of R947. This will force you to return to step (e).

D) Check to see that the cancellation tracks by advancing the SMART CLIPPER DRIVE control somewhat. If considerable distortion appears, repeat step (C) with varying settings of this control until a good compromise is obtained. When all controls have been optimally adjusted, approximately 0.5% THD @200Hz may be expected.

g) SAFETY CLIPPER HEADROOM

A) Adjust the SMART CLIPPER DRIVE control until the SMART CLIPPER GAIN REDUCTION meter reads at the red/green junction.

B) Connect the THD meter to the output of the OPTIMOD-AM. Advance R969 (SAFETY CLIPPER HEADROOM) until clipping distortion just barely begins to appear in the distortion residual output of the THD meter. Now adjust the THD meter in its SET LEVEL mode to read 0dB.

C) Readjust R969 until the level is reduced by 2.5dB, as read on the THD meter in its SET LEVEL mode.

h) VCA 2 FEEDTHROUGH NULL

A) Without disconnecting the THD meter from the OPTIMOD-AM output, connect a source of program material or pink noise to the OPTIMOD-AM input and adjust the SMART CLIPPER DRIVE control until substantial action is indicated on the SMART CLIPPER GAIN REDUCTION meter.

B) Using an alligator-to-alligator jumper lead, ground the junction of R901 and R902 to suppress the audio passing through VCA 2. The only signal now appearing at the output is feedthrough from the control voltage of VCA 2 due to VCA 2 imbalance.

C) Increase the gain of the THD meter until the low-frequency VCA 2 control voltage feedthrough component is easily visible. Adjust R983 (FEEDTHRU NULL) to null the feedthrough. (This trimmer was added as an engineering change on top of the board, with a 470K 5% carbon film resistor connecting its wiper to the board.)

IMPORTANT! AFTER THIS ADJUSTMENT IS PERFORMED, THE ADJUSTMENT OF R924 (VCA 2 DIST. NULL) MUST NOT BE CHANGED.

A

D) Remove the jumper lead.

10) Card #8 (Output Amplifier And Safety Clipper)

This card requires no field alignment.

This concludes the **ALIGNMENT PROCEDURE.** Remove power and replace all cards in their sockets. Replace the top cover, being sure to fasten it with its full complement of screws to prevent RFI. Replace the subpanel, tighten its four fasteners, and swing the front panel back into place. Tighten its three fasteners.

OPTIMOD-AM is now ready for reinstallation in the station audio chain.

APPENDIX II

REFERENCE FILTER RESPONSES

This appendix provides computer-generated graphs of the frequency response of each important filter employed in the OPTIMOD-AM. These graphs were prepared from the ideal responses of these filters. Because of normal component tolerances, a certain amount of variation from these ideal curves may be expected in the actual circuitry. However, if you measure curves which deviate grossly from the curves presented herein, it clearly indicates that there is a problem with either the opamp, or, less probably, with one of the precision passive components in the filter network.

Most filters are minimum-phase (i.e., their phase response is entirely determined by their magnitude response). Only the magnitude response of minimum-phase filters is graphed.

In the case of phase-linear filters, allpass phase correctors are usually employed to equalize the group delay of the filter. In this case, the magnitude and phase responses are not uniquely related, and graphs of both magnitude and phase responses are provided.

The following graphs are included:

PAGE B-3: INPUT FILTER

1) Overall magnitude response
2) Magnitude response of 100Hz highpass filter IC302A
3) Magnitude response of section associated with IC302B
4) Magnitude response of section associated with IC303A
5) Magnitude response of section associated with IC303B

PAGE B-4: 10kHZ EQUALIZER; THIRD-OCTAVE BANDPASS FILTER

1) Magnitude response of fourth-order 10kHz bandpass filter, IC501

B

2) Magnitude response of section associated with IC501A
3) Magnitude response of section associated with IC501B
4) Magnitude response of typical (2.5kHz) third-octave bandpass filter

PAGE B-5: SIX-BAND CROSSOVER FILTERS

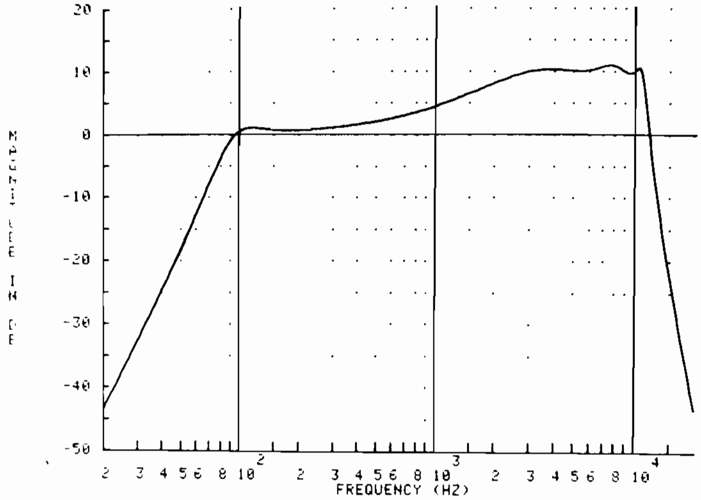
1) Magnitude response of 150Hz lowpass filter, IC505A
2) Magnitude response of 300Hz bandpass filter, IC506
3) Magnitude response of 700Hz bandpass filter, IC507
4) Magnitude response of 1.6kHz bandpass filter, IC508
5) Magnitude response of 3.7kHz bandpass filter, IC509
6) Magnitude response of 7.5kHz highpass filter, IC505B

PAGE B-6: "SMART CLIPPER" FILTERS

1) Magnitude response of delay 1 output lowpass filter, IC905B
2) Phase response of delay 1 output lowpass filter, IC905A
3) Magnitude response of 1.8kHz phase-linear lowpass filter, IC912B,913A
4) Phase response of 1.8kHz phase linear lowpass filter, IC912B,913A
5) Magnitude response of delay 2 passive output lowpass filter

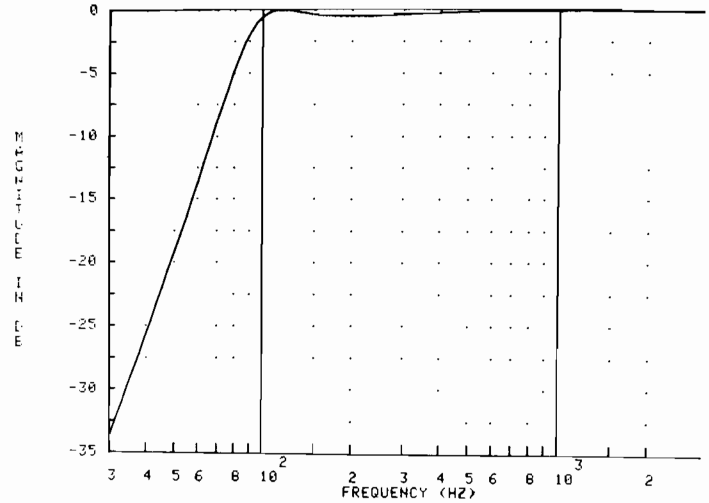
PAGES B-7, B-8, B-9: OUTPUT LOWPASS FILTERS - 11kHZ; 8kHZ; 6kHZ

1) Overall magnitude response
2) Overall phase response (including phase corrector)
3) Magnitude response of section 1, IC2A
4) Magnitude response of section 2, IC2B
5) Magnitude response of bandpass filter used as phase corrector, IC1A



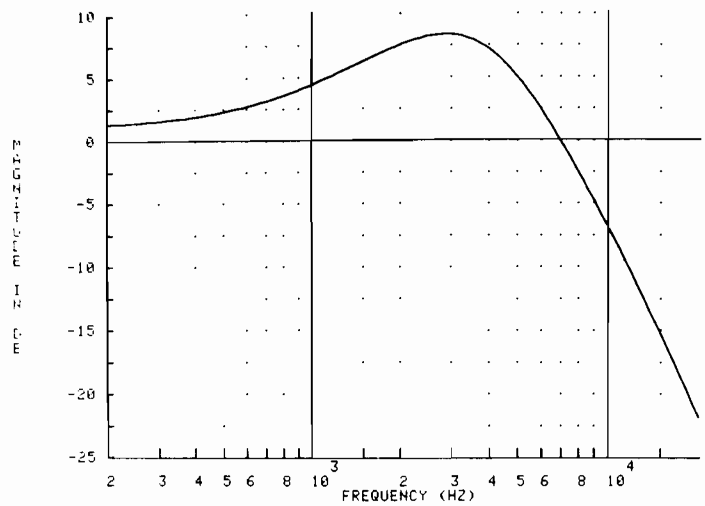
INPUT FILTER - OVERALL (in: IC302A out: IC303B)

FIG.1



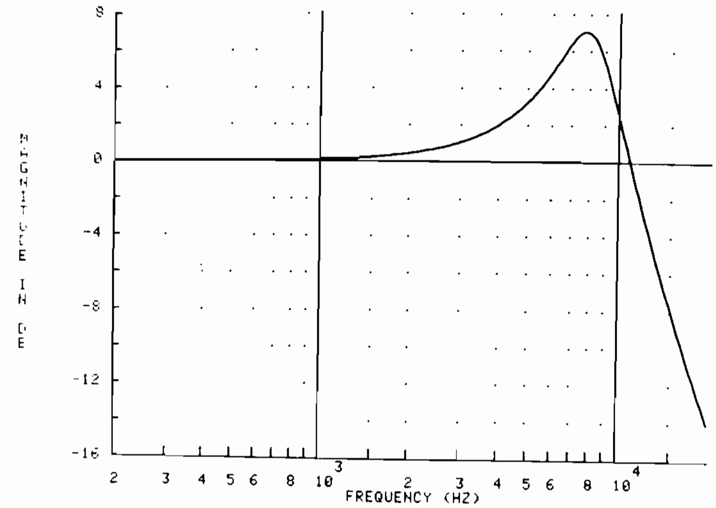
INPUT FILTER: IC302A

FIG.2



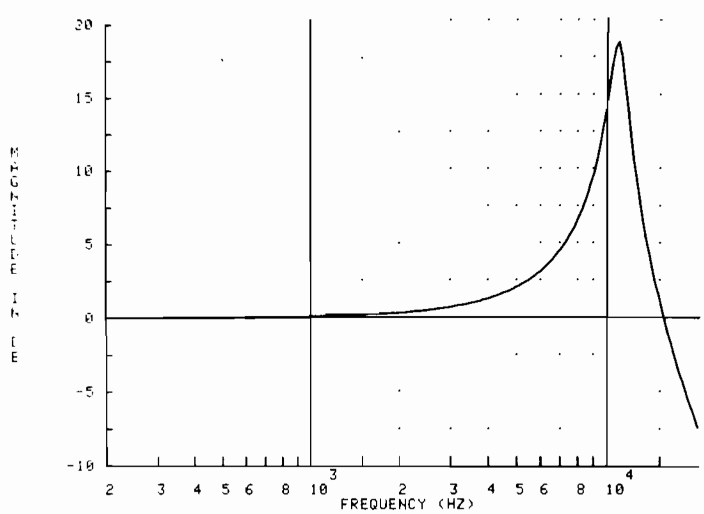
INPUT FILTER: IC302B

FIG.3



INPUT FILTER: IC303A

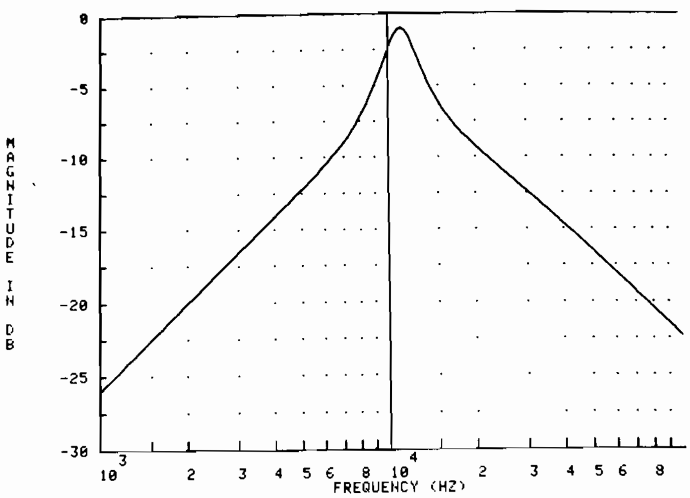
FIG.4



INPUT FILTER: IC303B

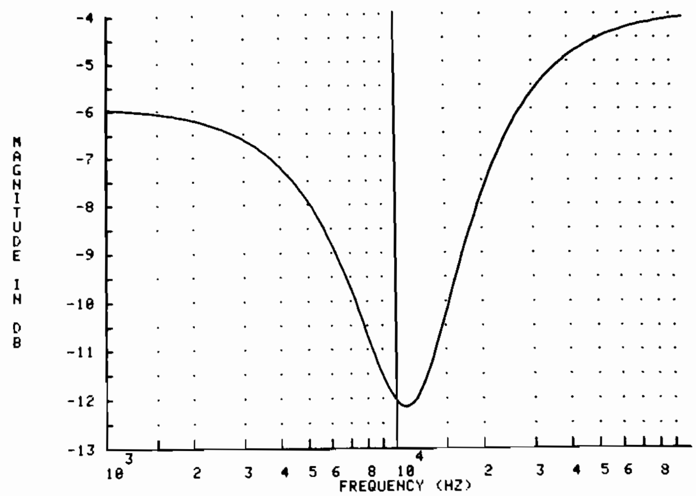
FIG.5

B



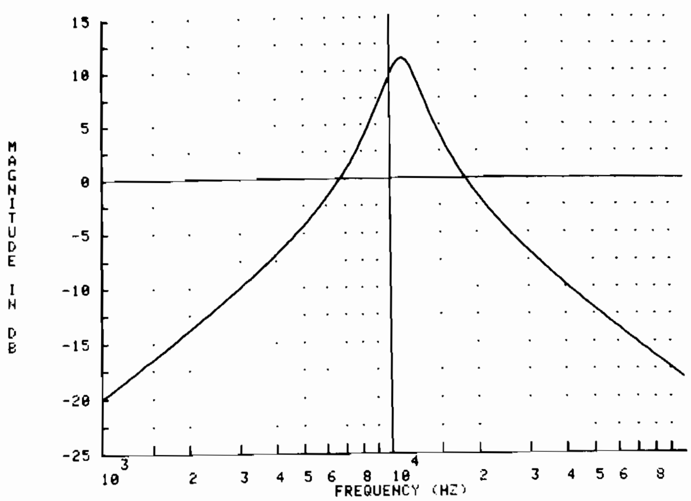
10 kHz EQUALIZER BANDPASS FILTER - OVERALL (IC501)

FIG. 1



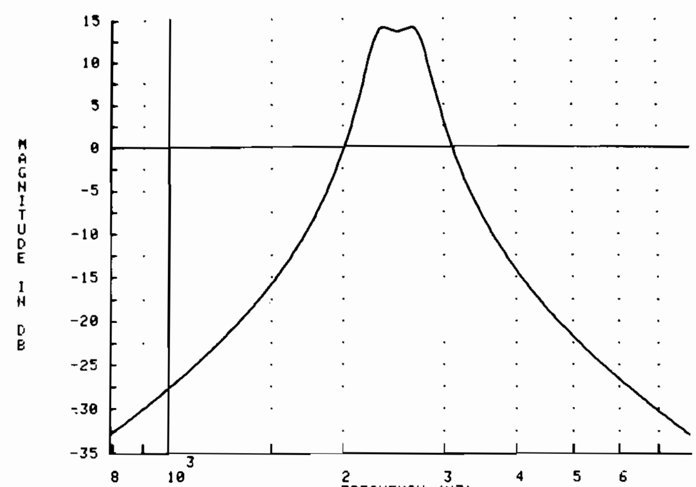
10 kHz EQUALIZER BANDPASS FILTER - PARTIAL (IC501A)

FIG. 2



10 kHz EQUALIZER BANDPASS FILTER - PARTIAL (IC501B)

FIG. 3

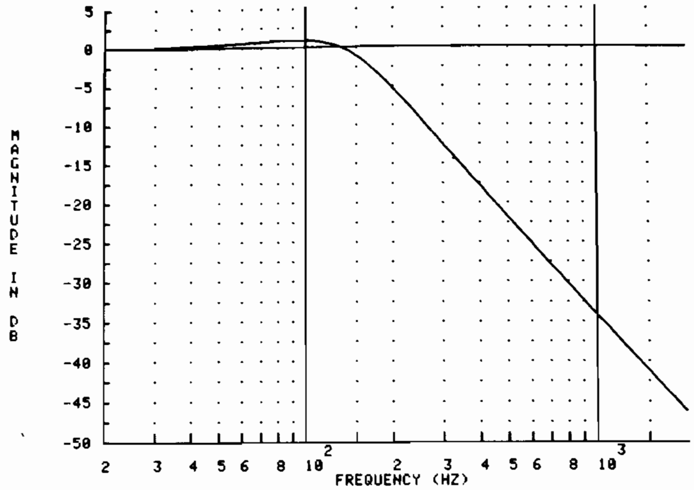


THIRD-OCTAVE BANDPASS FILTER - TYPICAL (2.5kHz)

FIG. 4

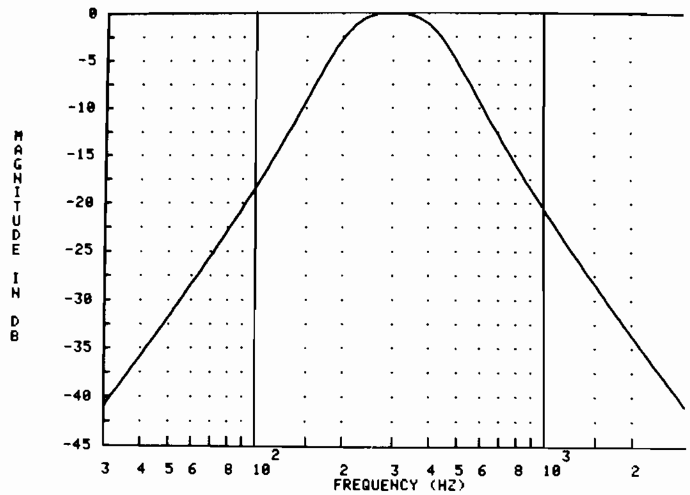
10kHz EQUALIZER

THIRD OCTAVE BANDPASS FILTER



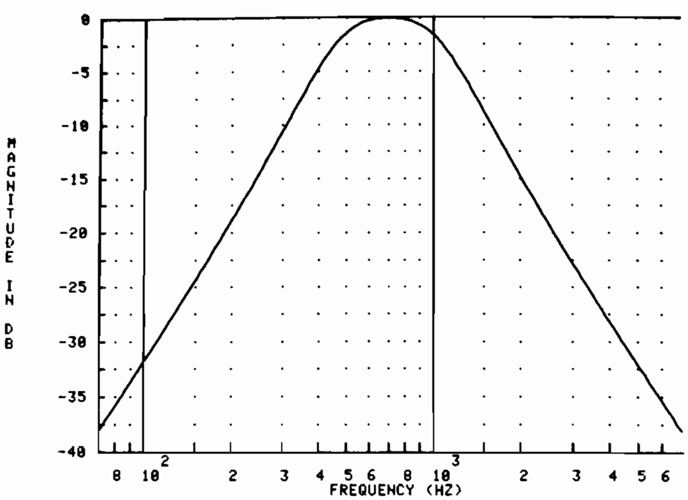
150 HZ CROSSOVER LOWPASS FILTER (IC505A)

FIG.1



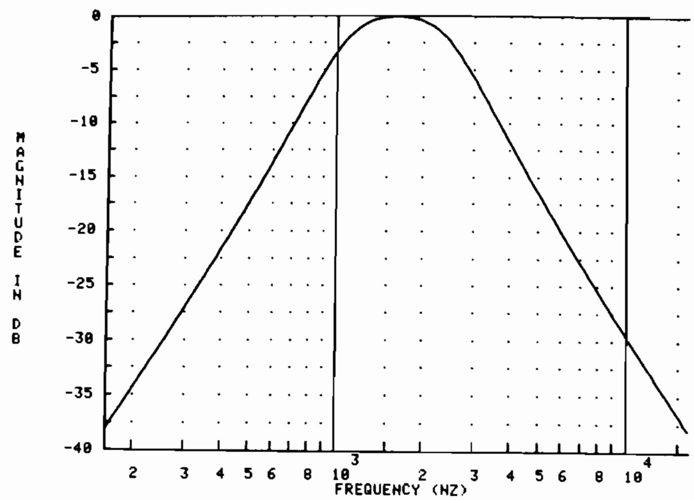
300 HZ CROSSOVER BANDPASS FILTER (IC506)

FIG.2



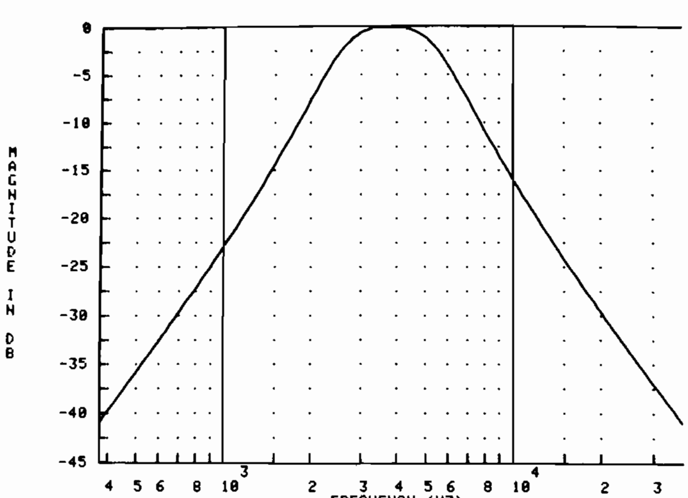
700 HZ CROSSOVER BANDPASS FILTER (IC507)

FIG.3



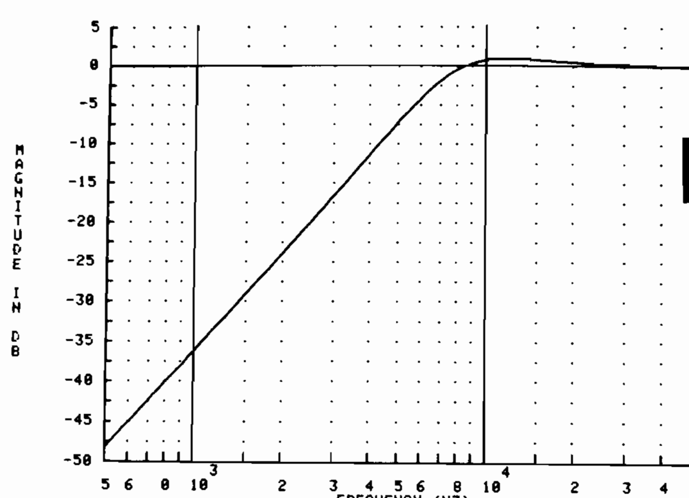
1.6kHz CROSSOVER BANDPASS FILTER (IC508)

FIG.4



3.7kHz CROSSOVER BANDPASS FILTER (IC509)

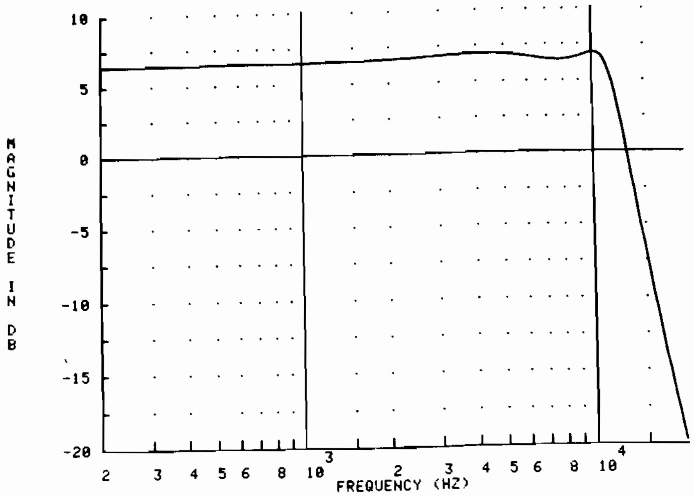
FIG.5



7.5kHz CROSSOVER HIGHPASS FILTER (IC505B)

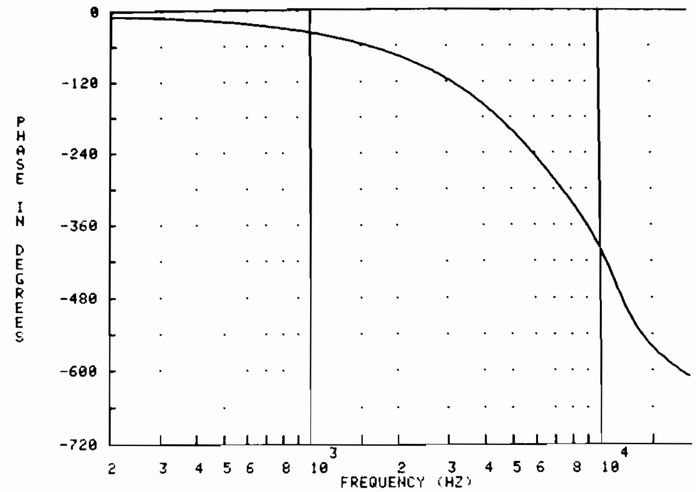
FIG.6

SIX BAND CROSSOVER FILTERS



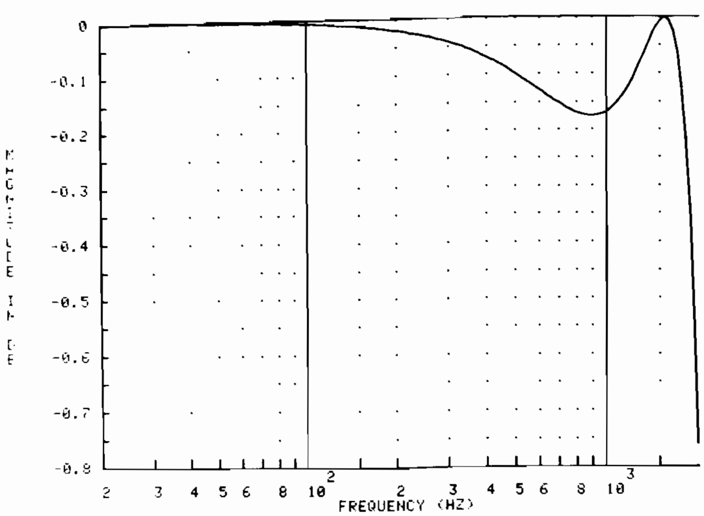
DELAY 1 LOWPASS FILTER - 11kHz Phase Linear (IC905B)

FIG.1



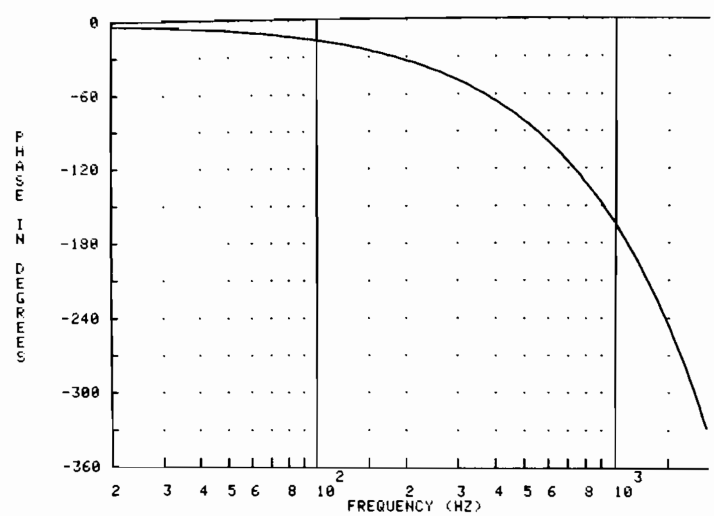
DELAY 1 LOWPASS FILTER - 11kHz Phase Linear (IC905A)

FIG.2



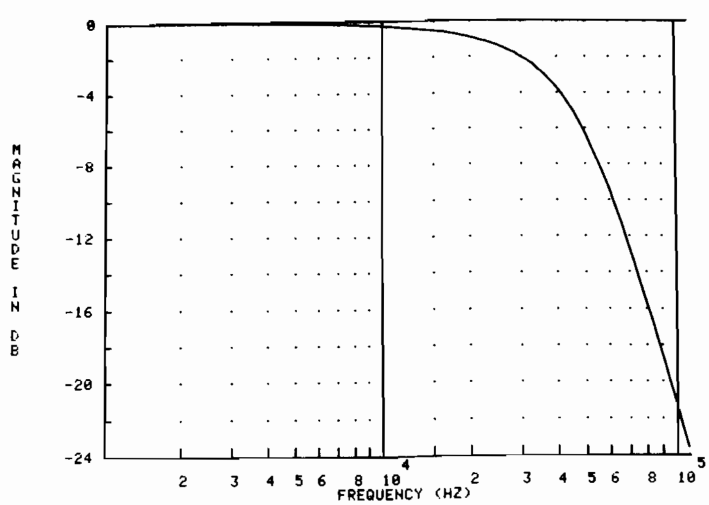
1.8kHz PHASE-LINEAR FILTER (with phase corrector) (IC912B, 913A)

FIG.3



1.8kHz PHASE-LINEAR FILTER (with phase corrector) (IC912B, 913A)

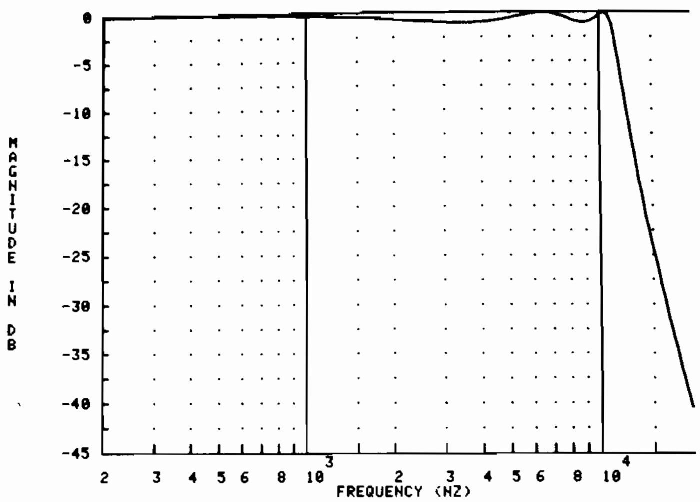
FIG.4



DELAY 2 LOWPASS FILTER

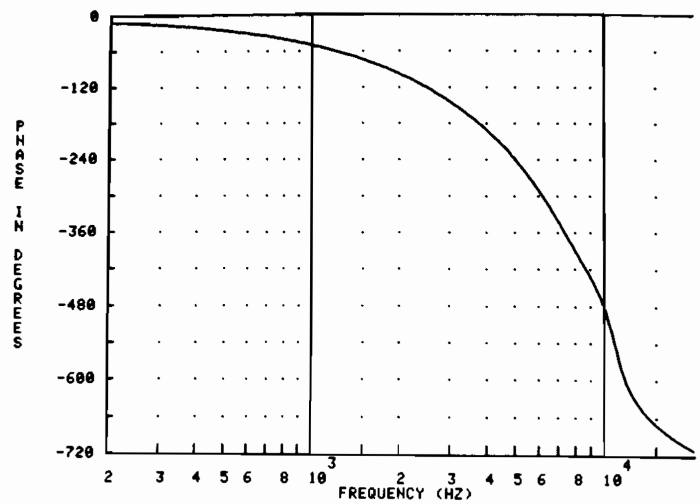
FIG.5

SMART CLIPPER FILTERS



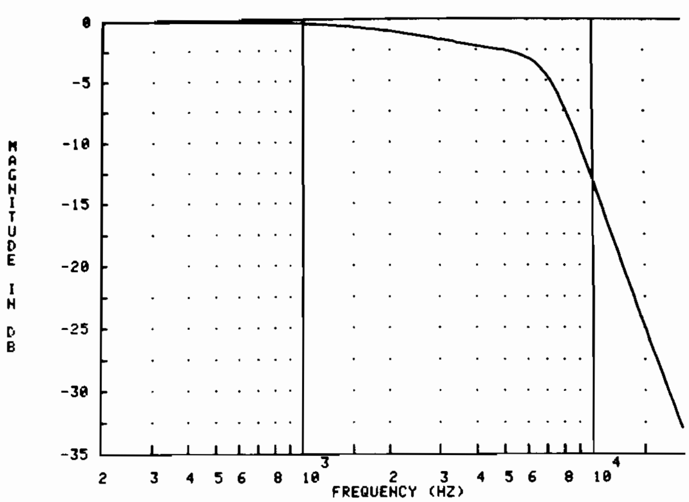
OUTPUT FILTER - 11kHz Phase-Linear (overall)

FIG.1



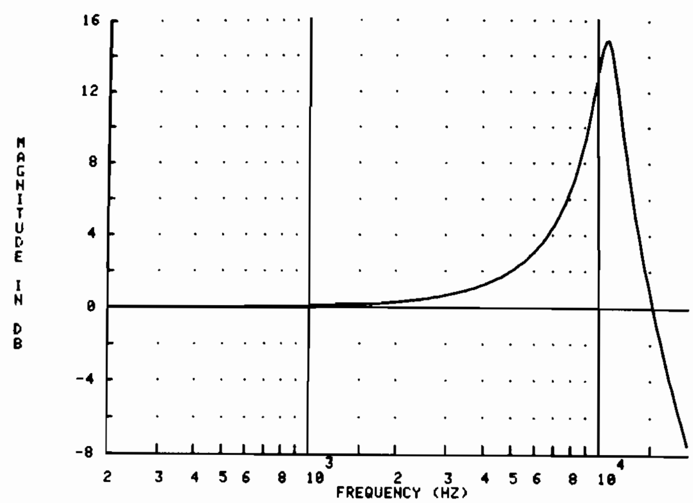
OUTPUT FILTER - 11kHz Phase-Linear (overall)

FIG.2



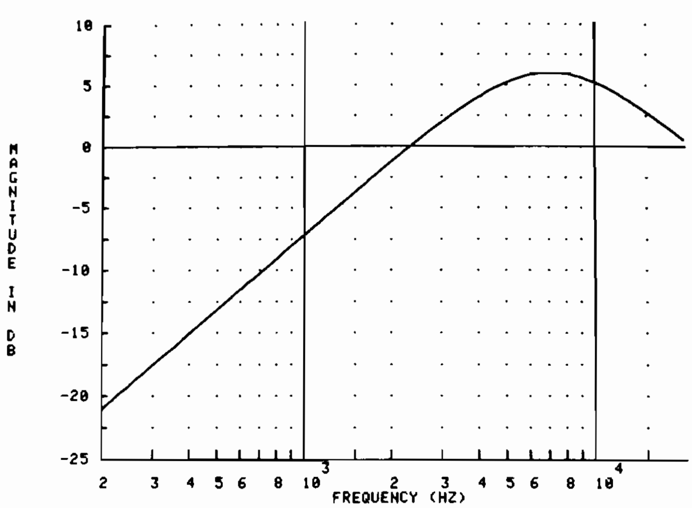
OUTPUT FILTER - 11kHz Phase-Linear (IC2A)

FIG.3



OUTPUT FILTER - 11kHz Phase-Linear (IC2B)

FIG.4

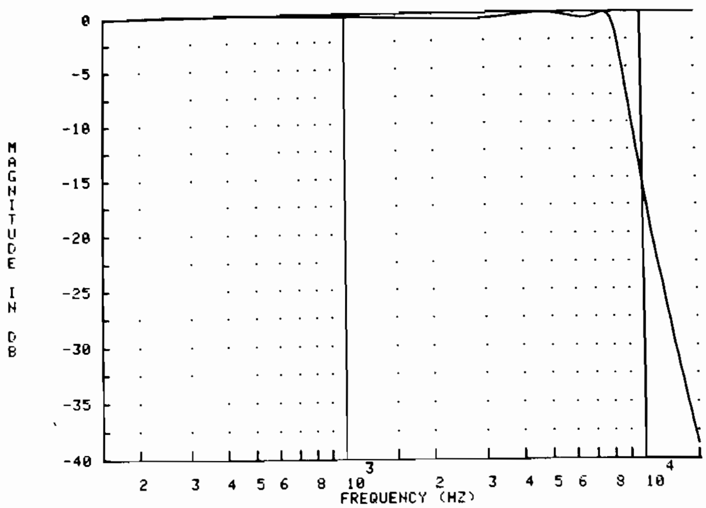


OUTPUT FILTER - 11kHz Phase-Linear (IC1A)

FIG.5

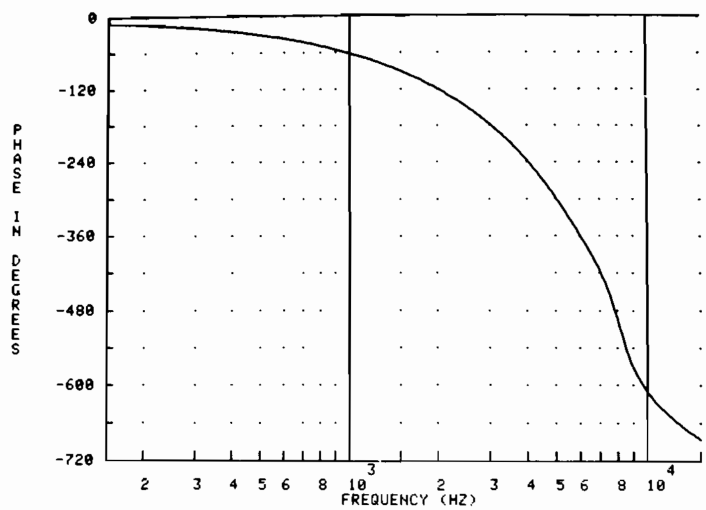
OUTPUT LOWPASS FILTER 11kHz

B



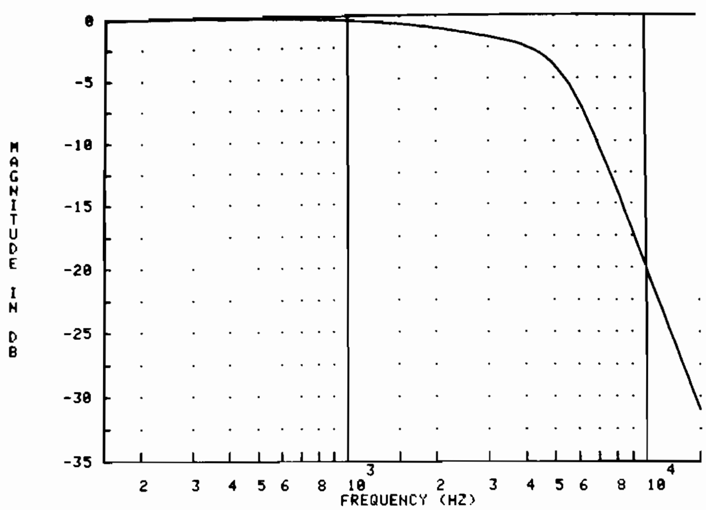
OUTPUT FILTER - 8kHz Phase-Linear (overall)

FIG.1



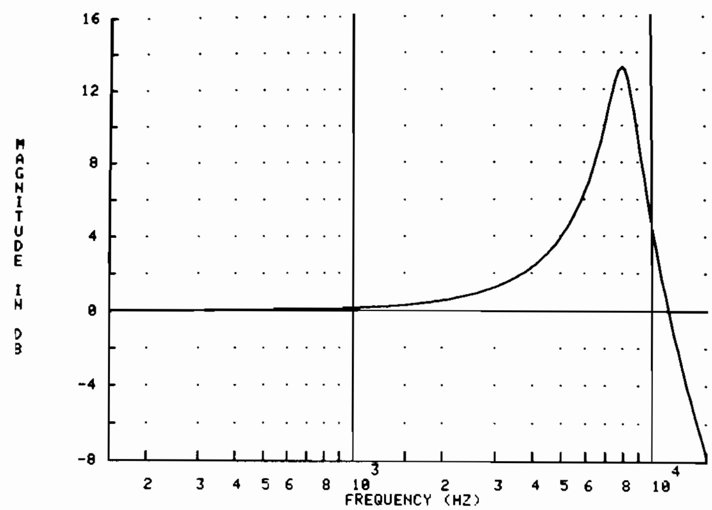
OUTPUT FILTER - 8kHz Phase-Linear (overall)

FIG.2



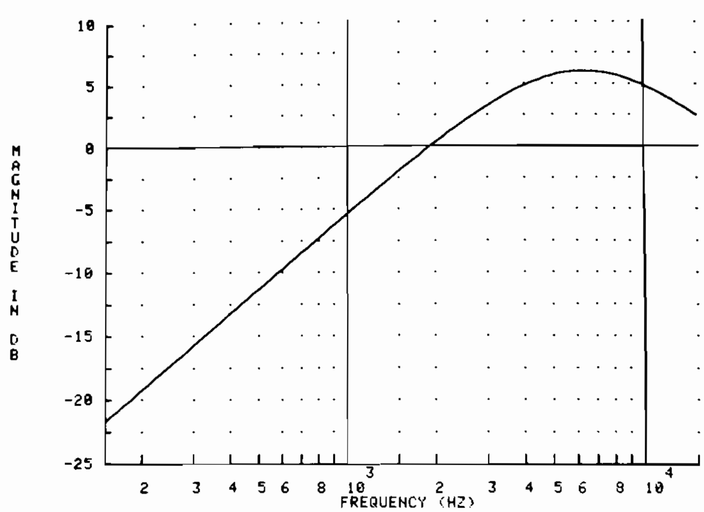
OUTPUT FILTER - 8kHz Phase-Linear (IC2A)

FIG.3



OUTPUT FILTER - 8kHz Phase-Linear (IC2B)

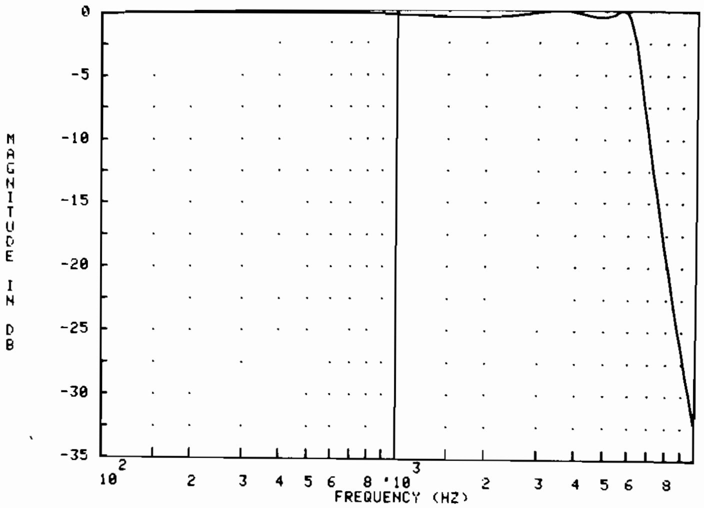
FIG.4



OUTPUT FILTER - 8kHz Phase-Linear (IC1A)

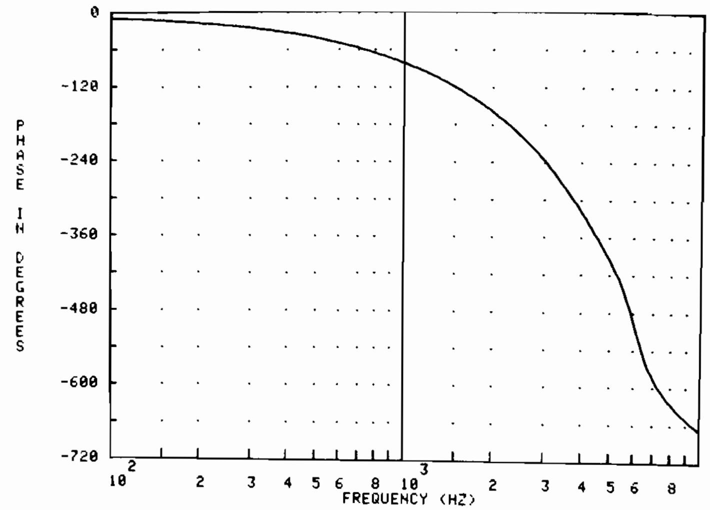
FIG.5

OUTPUT LOWPASS FILTER 8kHz



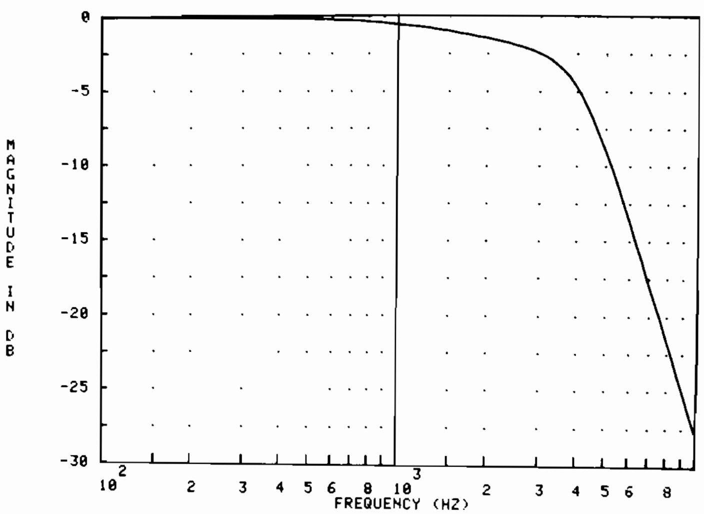
OUTPUT FILTER - 6kHz Phase-Linear (overall)

FIG.1



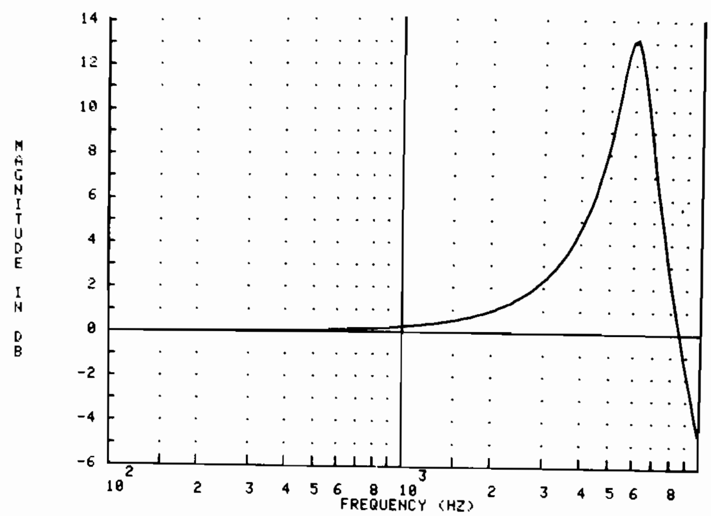
OUTPUT FILTER - 6kHz Phase-Linear (overall)

FIG.2



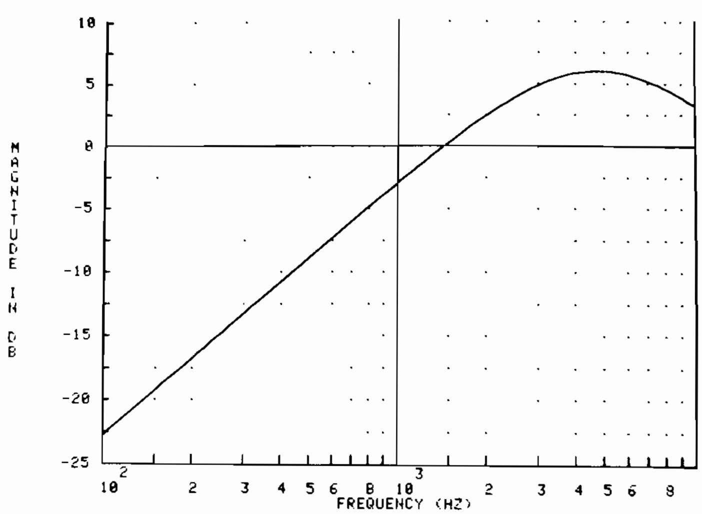
OUTPUT FILTER - 6kHz Phase-Linear (IC2A)

FIG.3



OUTPUT FILTER - 6kHz Phase-Linear (IC2B)

FIG.4



OUTPUT FILTER - 6kHz Phase-Linear (IC1A)

FIG.5

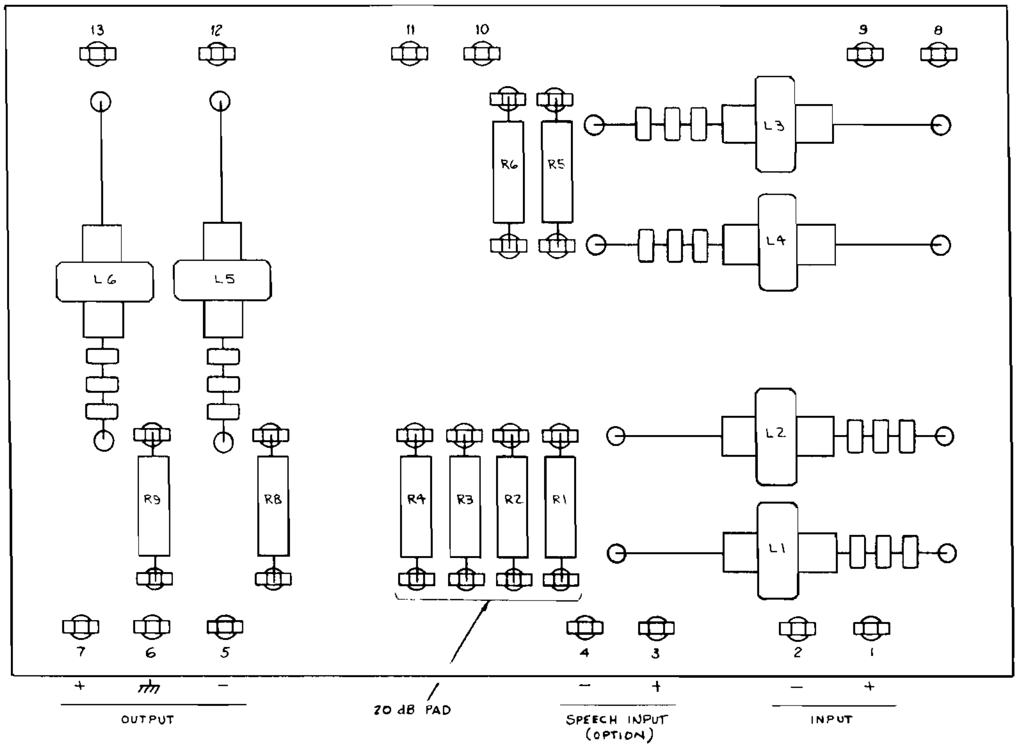
OUTPUT LOWPASS FILTER 6kHz

B

APPENDIX III

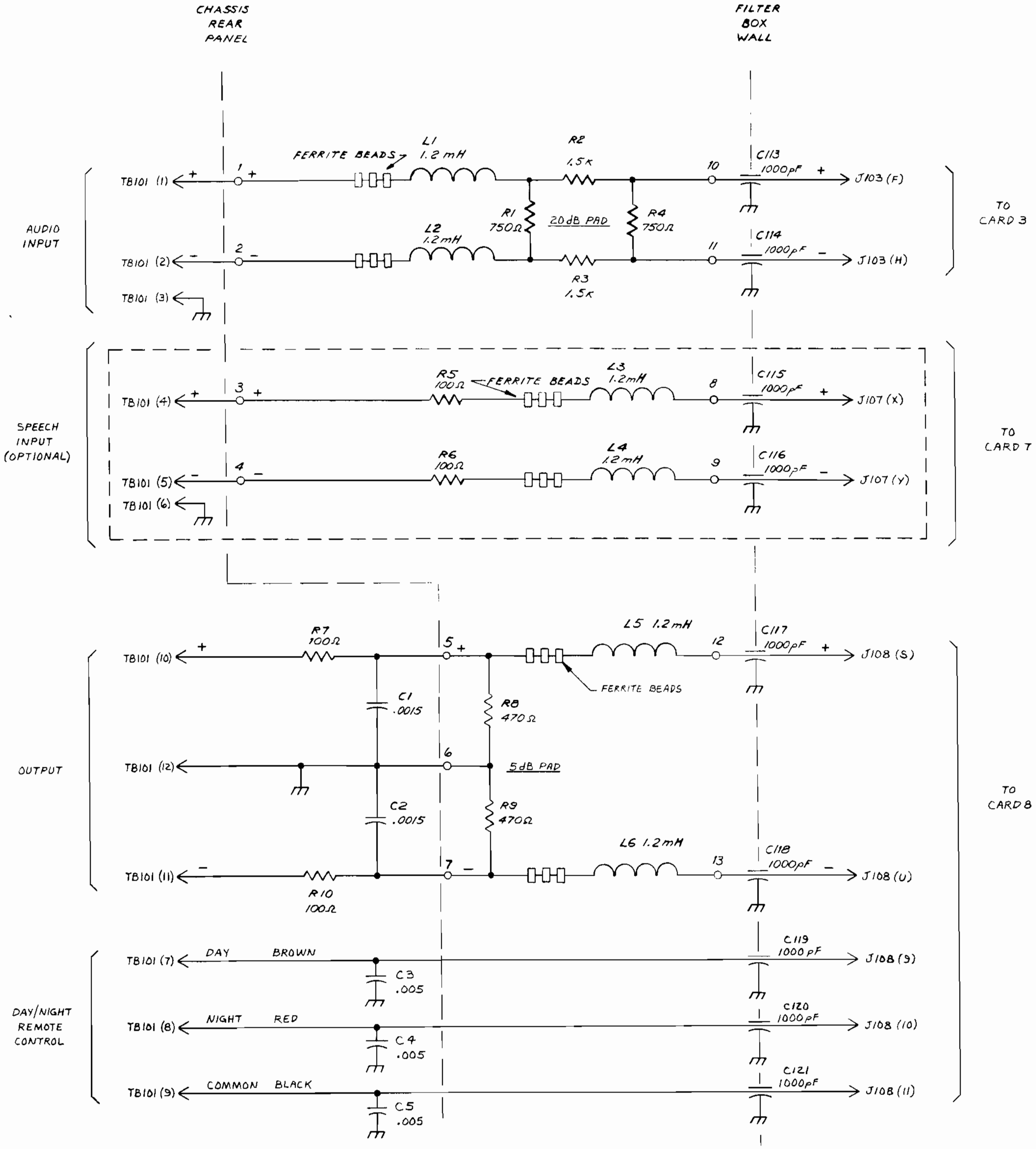
SCHEMATICS, PARTS LOCATORS, PARTS LISTS

C



ASSEMBLY DRAWING, INPUT FILTER BD.
MODEL 9000A OPTIMOD-AM
4-25-78 BDD SCALE 2/1
ORBAN ASSOCIATES SAN FRANCISCO

DOC 30345-000-04

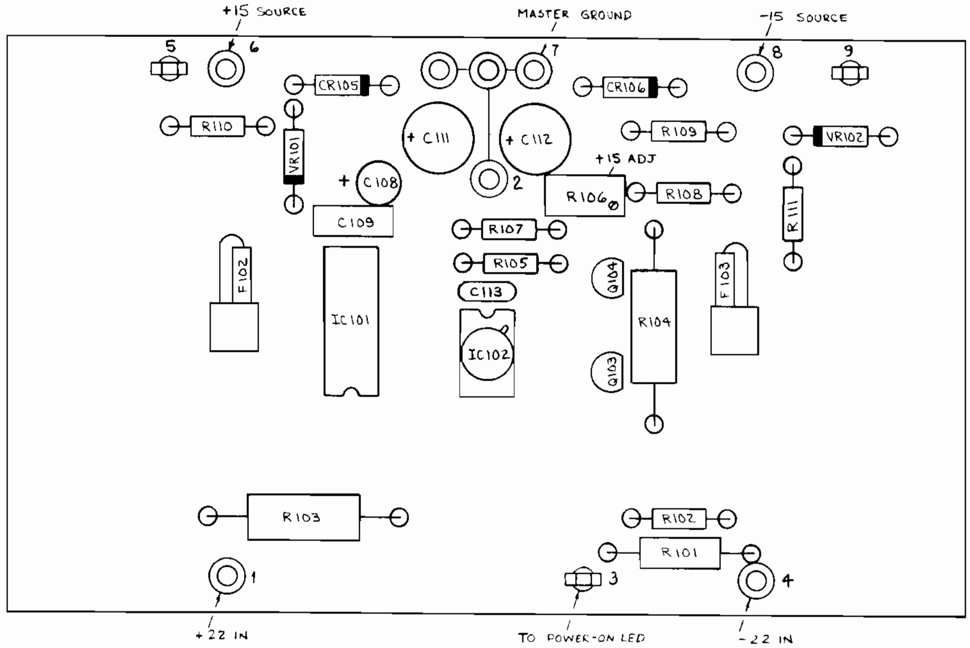


ORBAN OPTIMOD-AM
MODEL 9000A

INPUT FILTER

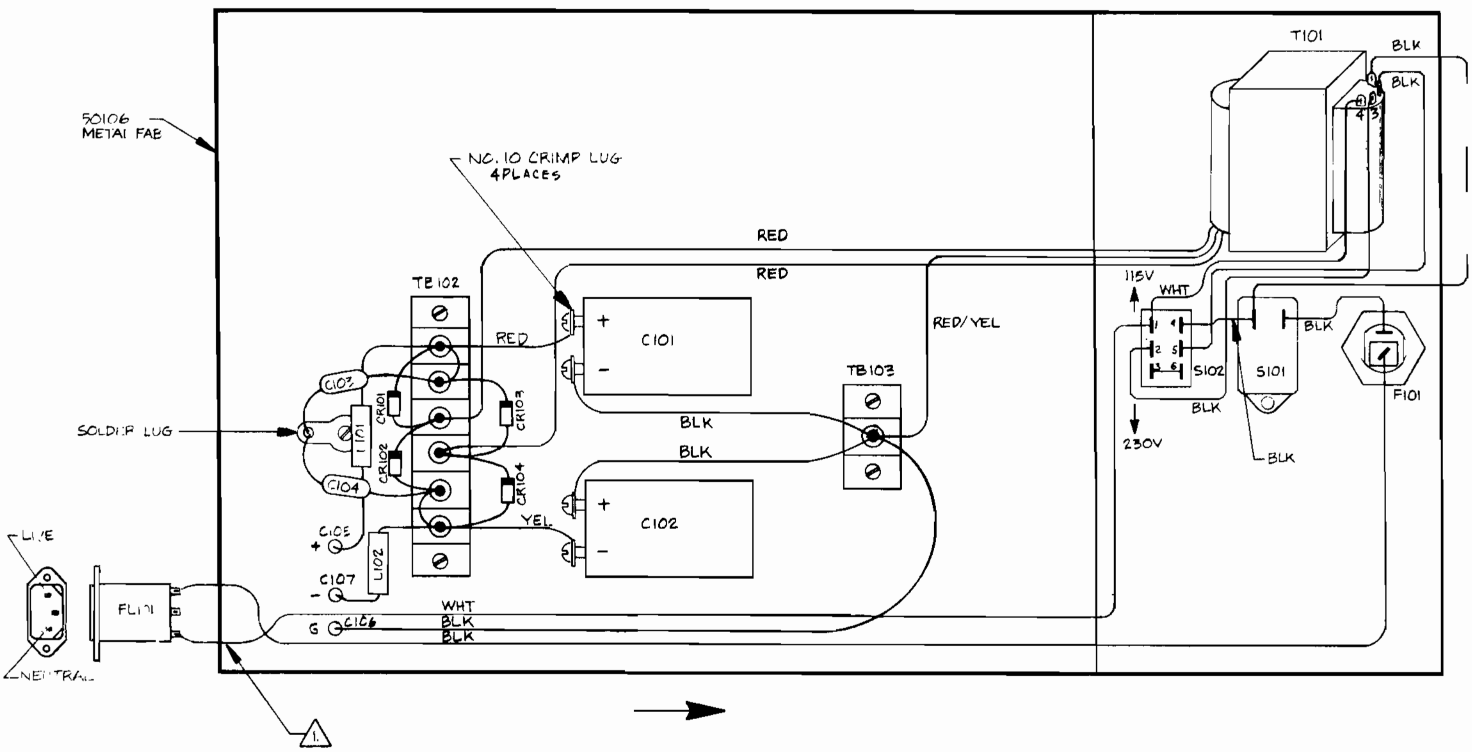
DOC 60030-000-04

C



ASSEMBLY DRAWING, POWER SUPPLY
MODEL 9000 A OPTIMOD-AM
4-25-78 BDD SCALE 2/1
ORBAN ASSOCIATES INC SAN FRANCISCO

DOC 30310-000-04



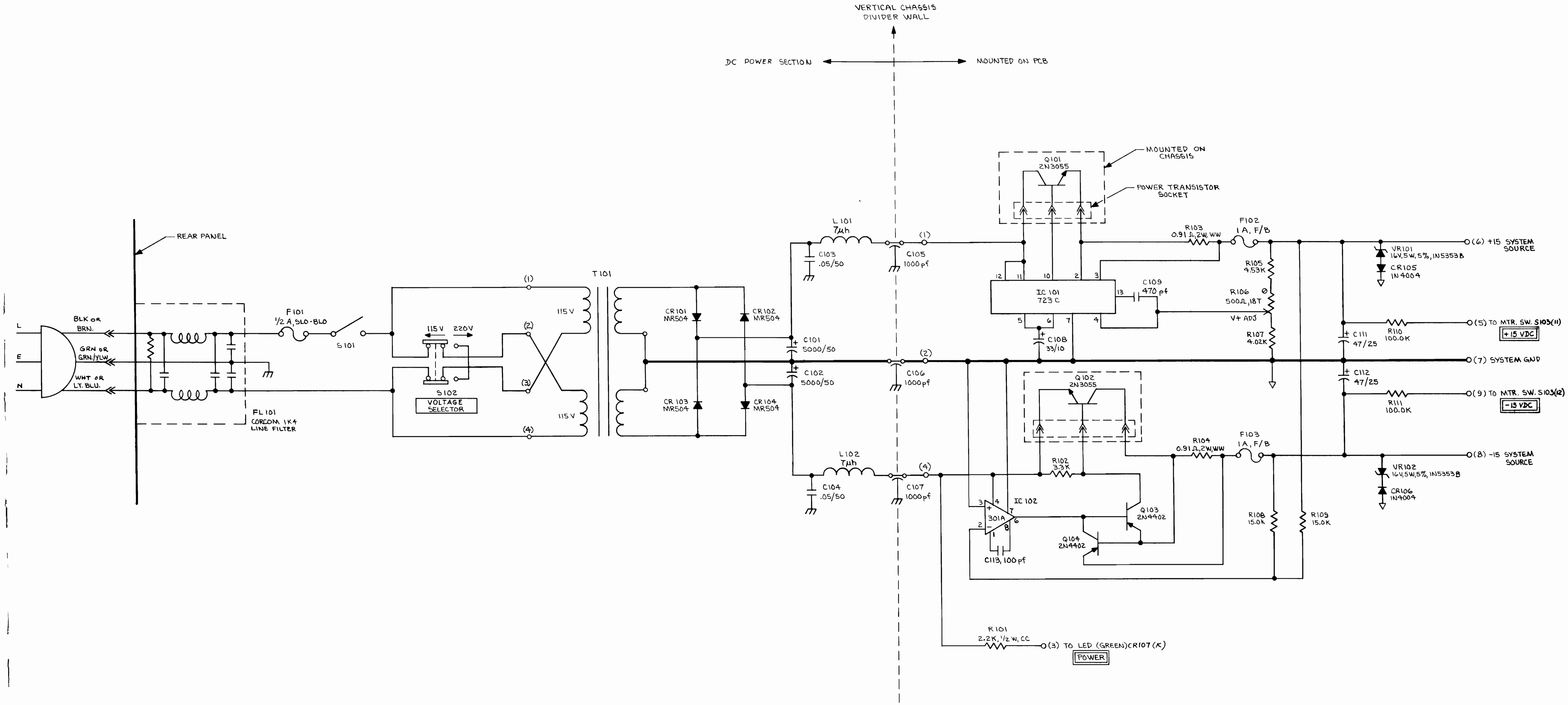
2. ALL WIRE USED IS 18 AWG UL1015 ONLY, 16/30 STRAND.

1 TWIST WIRES SLIGHTLY TOGETHER.

NOTES UNLESS OTHERWISE SPECIFIED.

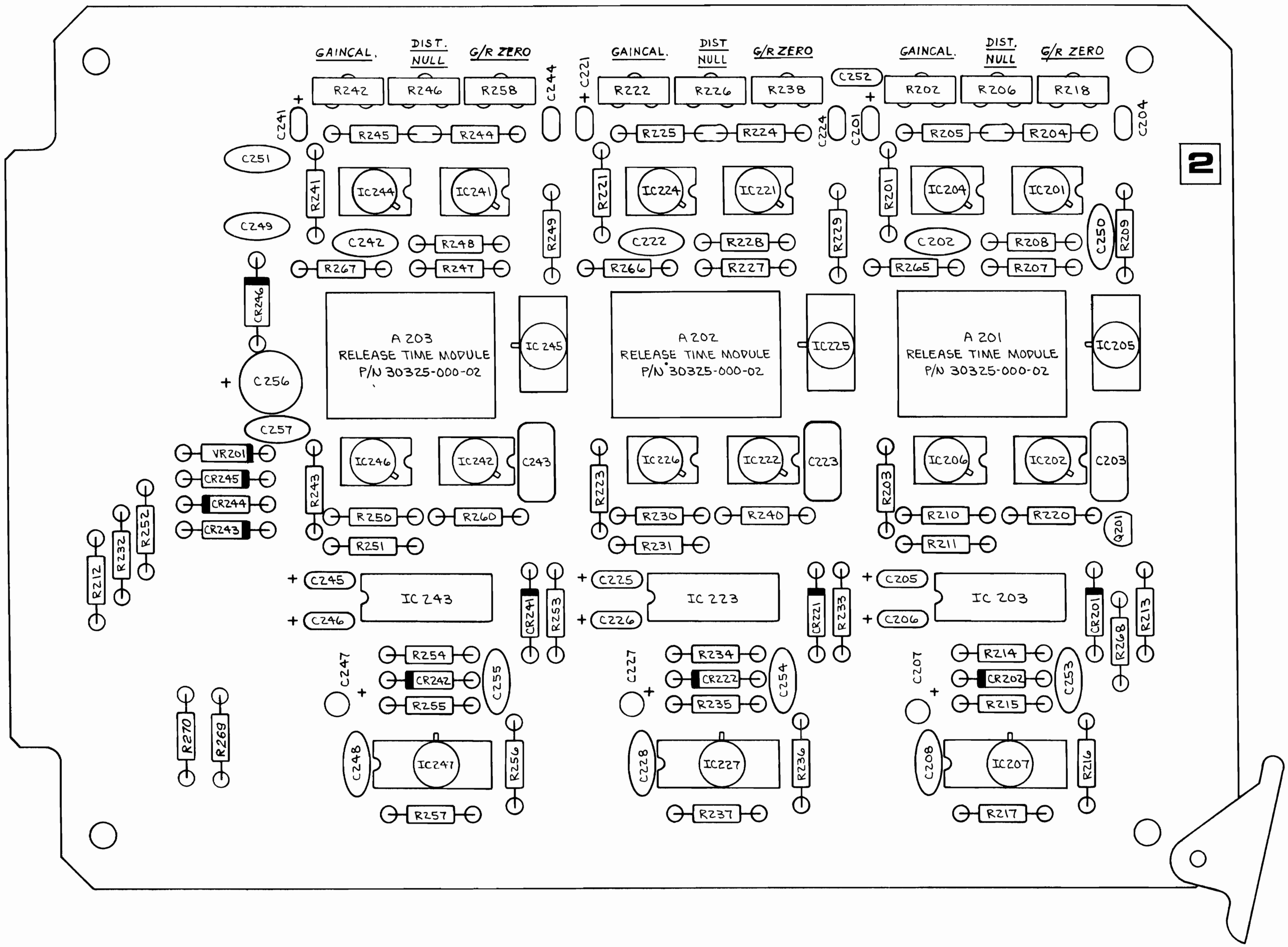
UNLESS OTHERWISE SPECIFIED: ALL DIMS. IN INCHES TOLERANCES .XX = ± .XXX = ±		orban	Orban Associates Inc.		
DRAWN BRIAN D.	DATE 13 JAN 78	TITLE: WIRING DIAGRAM, DC POWER SUPPLY VERTICAL MTG. PLATE OPTIMOD-AM			
CHECKED		SCALE N/A	DRAWING NO. 60106	VERSION 000	REV. -05
APPROVED		DO NOT SCALE DRAWING	MODEL 8100A/9000A	SHEET 1 OF 1	

901010-000-01 9/5/78



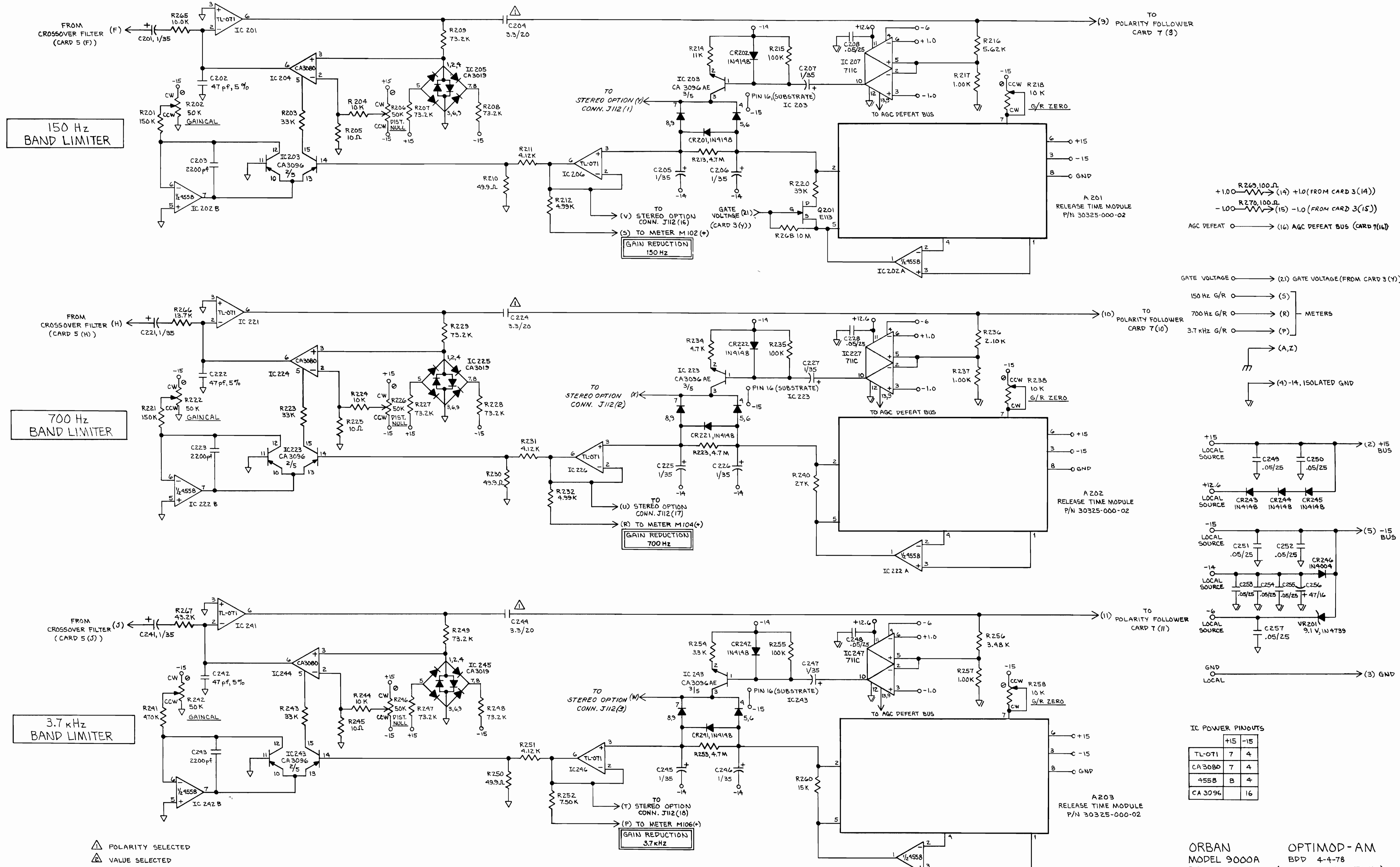
ORBAN
MODEL 9000A
POWER SUPPLY
OPTIMOD-AM
BDD 4-4-78
DOC 60021-000-04
1

C



ASSEMBLY DRAWING, BOARD 2
MODEL 9000A OPTIMOD-AM
4-21-78 BDD SCALE 2/1
ORBAN ASSOCIATES INC. SAN FRANCISCO

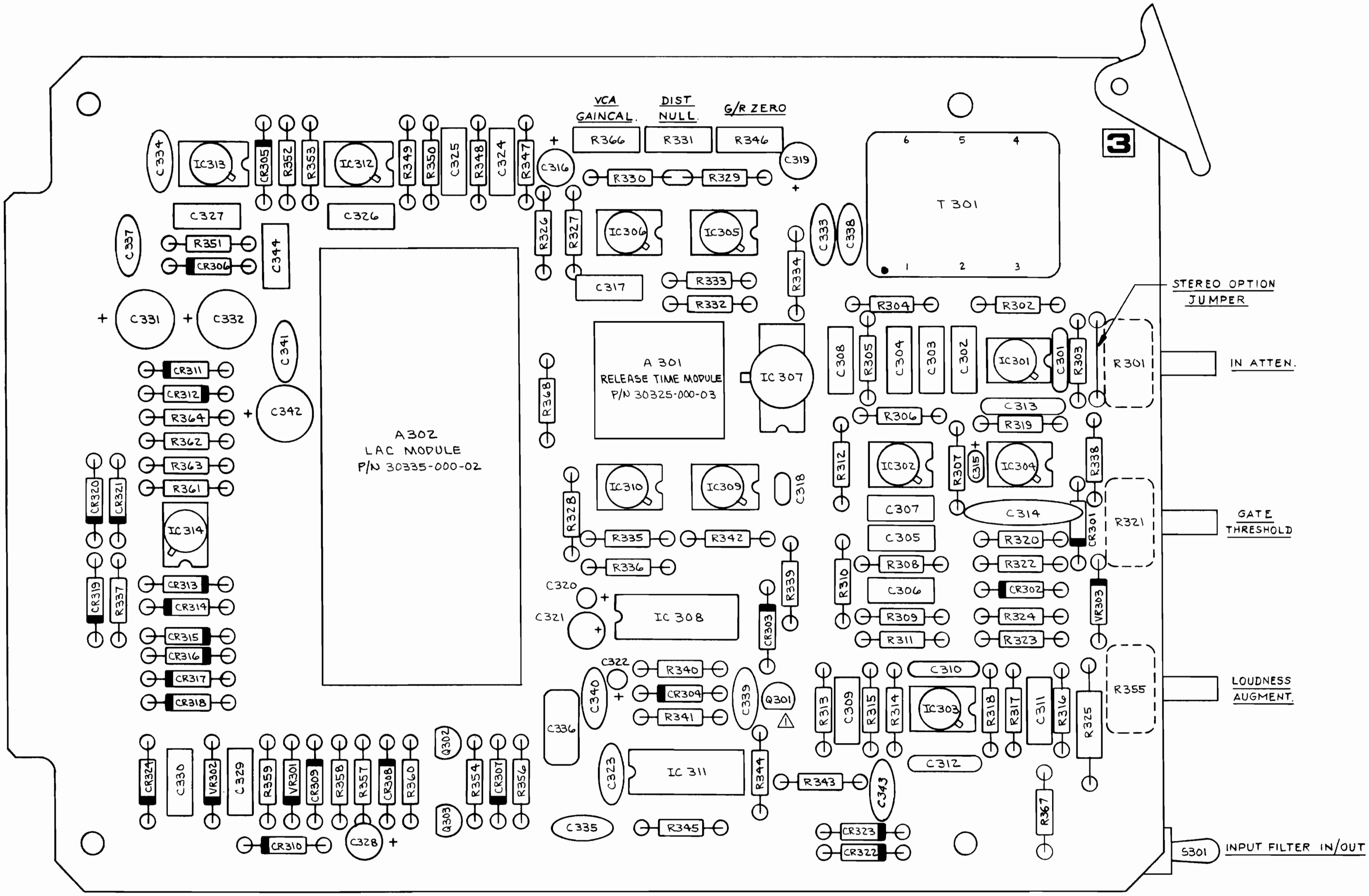
DOC 30320-000-04



IC POWER PINOUTS

	+15	-15
TL-071	7	4
CA3080	7	4
4558	8	4
CA 3096		16

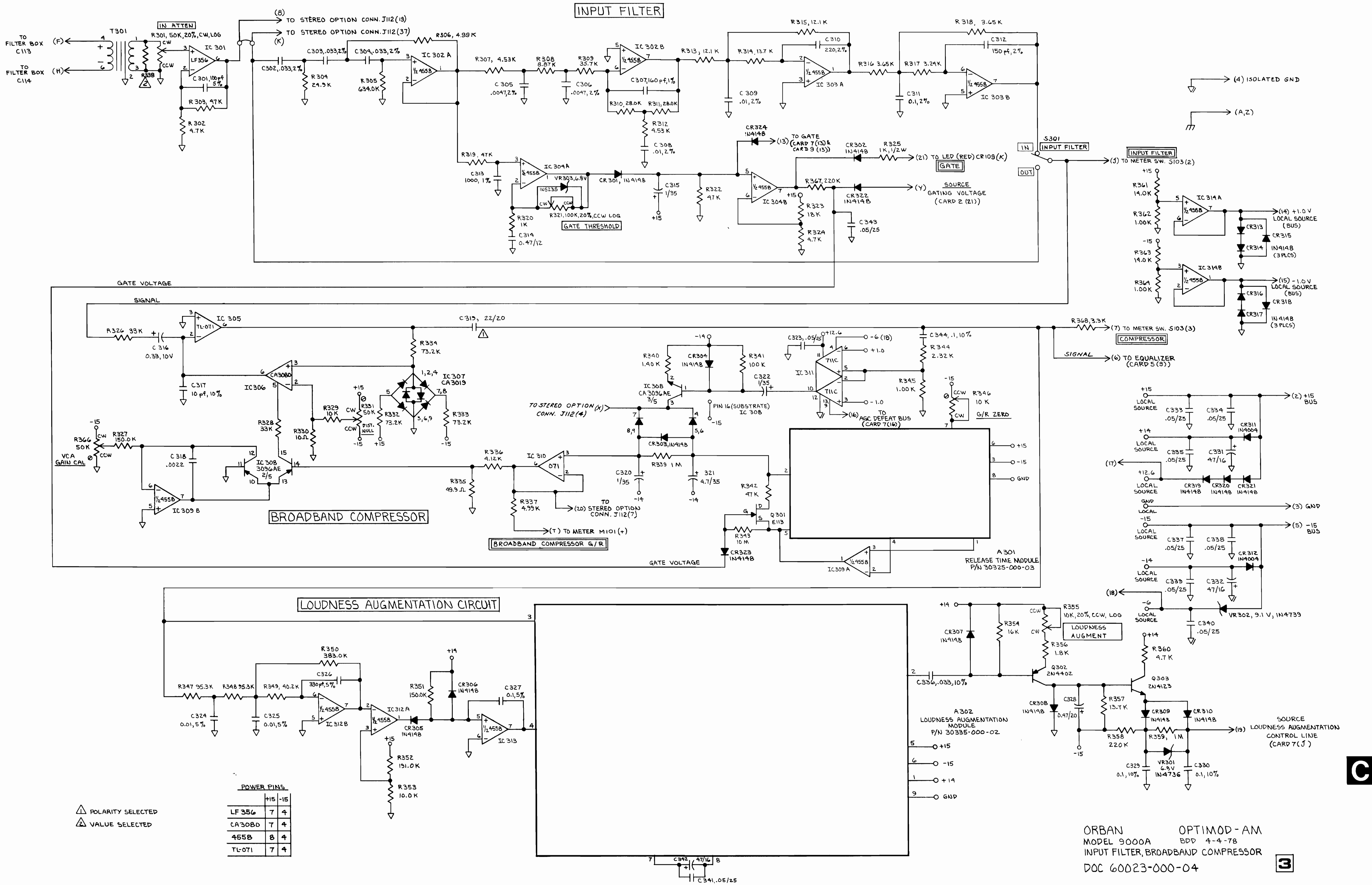
ORBAN OPTIMOD-AM
MODEL 9000A BPD 4-4-78
BAND LIMITERS (150 Hz, 700 Hz, 3.7 KHz)
DOC 60022-000-03 2

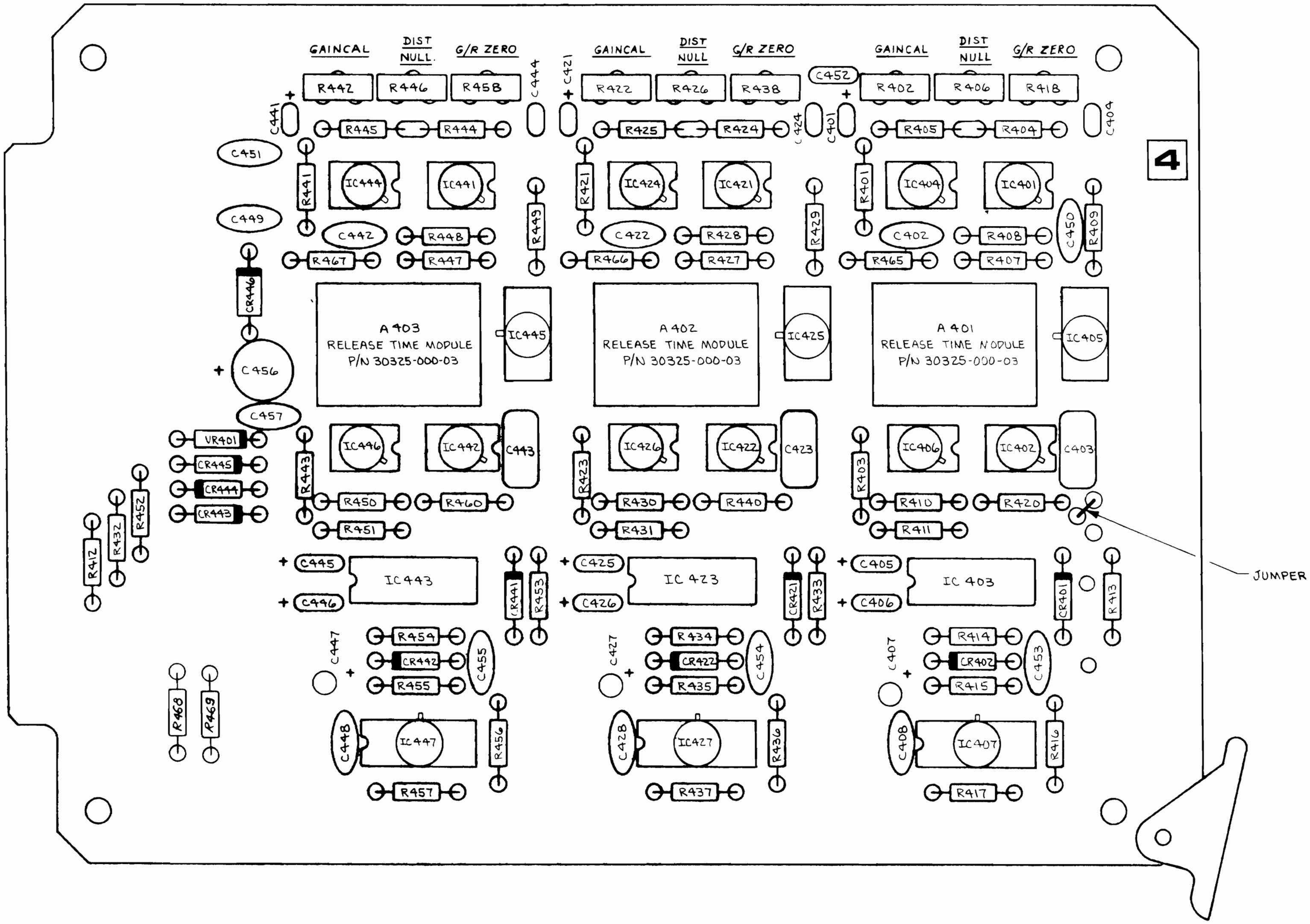


△ IF J113 IS SUBSTITUTED FOR E113, TURN CASE 180° FROM POSITION SHOWN. (Q301)
NOTES:

ASSEMBLY DRAWING, BOARD 3
MODEL 9000 A OPTIMOD-AM
4-21-78 BDD SCALE 2/1
ORBAN ASSOCIATES INC. SAN FRANCISCO

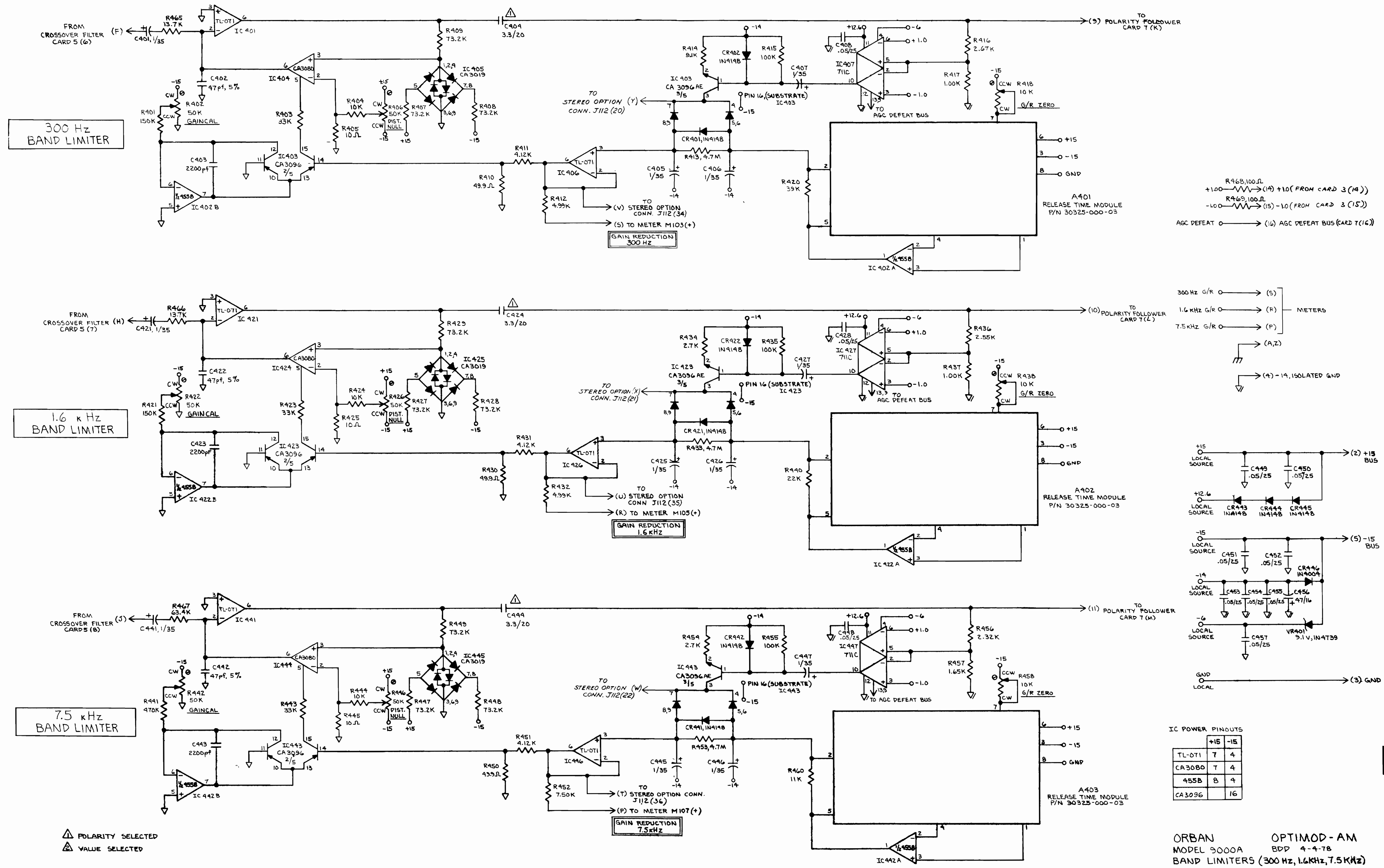
DOC 30330-000-05


INPUT FILTER
TO STEREO OPTION CONN. J112(13)
TO STEREO OPTION CONN. J112(37)
IN ATTEN
T301
TO FILTER BOX C113
TO FILTER BOX C114
R301, 50K, 20%, CW, LOG
IC 301
LF356
C301, 100pf 5%
R303, 47K
R302 4.7K
C302, .033, 2%
R304 24.9K
C303, .033, 2%
C304, .033, 2%
R305 634.0K
R306, 4.99K
IC 302 A
R307, 4.53K
C 305 .0047, 2%
R308 8.87K
C 306 .0047, 2%
R309 35.7K
IC 302 B
C307, 160 pf, 1%
R310, 28.0K
R311, 28.0K
R312 4.53K
C 308 .01, 2%
R313, 12.1K
C 309 .01, 2%
R315, 12.1K
C310 220, 2%
R314, 13.7K
IC 303 A
R316 3.65K
C311 0.1, 2%
R317 3.24K
R318, 3.65K
C312 150 pf, 2%
IC 303 B
(4) ISOLATED GND
(A, Z)
S301 INPUT FILTER
IN
OUT
(3) TO METER SW. S103(2)
INPUT FILTER
R319, 47K
C313 1000, 1%
IC 304 A
VR303, 6.8V
1N5235
R321, 100K, 20%, CCW LOG
GATE THRESHOLD
R320 1K
C314 0.47/12
CR301, 1N4148
C315 1/35
R322 47K
CR324 1N4148
(13) TO GATE (CARD 7 (13) & CARD 9 (13))
CR302 1N4148
R325 1K, 1/2W
(21) TO LED (RED) CR109(K)
GATE
IC 304 B
R367, 220K
CR322 1N4148
(Y) SOURCE GATING VOLTAGE (CARD 2 (21))
R323 18K
R324 4.7K
C343 .05/25
R361 14.0K
R362 1.00K
IC 314 A
(14) +1.0 V LOCAL SOURCE (BUS)
CR313
CR315
CR314
1N4148 (3 PLCS)
R363 14.0K
R364 1.00K
IC 314 B
(15) -1.0 V LOCAL SOURCE (BUS)
CR316
CR318
CR317
1N4148 (3 PLCS)
GATE VOLTAGE
SIGNAL
R326 33K
C 316 0.33, 10V
IC 305
TL-071
C319, 22/20
R368, 3.3K
(7) TO METER SW. S103(3)
COMPRESSOR
SIGNAL
(6) TO EQUALIZER (CARD 5 (8))
C317 10 pf, 10%
CA3080
IC306
R339 73.2K
IC 307 CA3019
R329 10K
R331 50K DIST. NULL
R332 73.2K
R333 73.2K
R328 33K
R330 10Ω
R366 50K
VCA GAIN CAL
R327 150.0K
C318 .0022
IC 308 3096AE 2/5
IC 309 B
BROADBAND COMPRESSOR
R335 49.9Ω
R336 4.12K
IC 310
071
R337 4.99K
(20) STEREO OPTION CONN. J112(7)
(T) TO METER M101 (+)
BROADBAND COMPRESSOR G/R
TO STEREO OPTION CONN. J112(4)
R340 1.40K
CR304 1N4148
R341 100K
IC 308 CA 3096AE 3/5
PIN 16 (SUBSTRATE) IC 308
CR303, 1N4148
R339 1M
C320 1/35
C321 4.7/35
C322 1/35
C323, .05/25
IC311
711C
(16) TO AGC DEFEAT BUS (CARD 7 (16))
C344, .1, 10%
R344 2.32K
R345 1.00K
R346 10K
G/R ZERO
R342 47K
Q301 E113
R343 10M
CR323 1N4148
GATE VOLTAGE
IC 309 A
A301 RELEASE TIME MODULE P/N 30325-000-03
(2) +15 BUS
LOCAL SOURCE
C333 .05/25
C334 .05/25
CR311 1N4004
C335 .05/25
C331 47/16
CR319 1N4148
CR320 1N4148
CR321 1N4148
(3) GND
(5) -15 BUS
C337 .05/25
C338 .05/25
CR312 1N4004
C339 .05/25
C332 47/16
C340 .05/25
VR302, 9.1 V, 1N4739
LOUDNESS AUGMENTATION CIRCUIT
R347 95.3K
R348 95.3K
R349, 40.2K
R350 383.0K
C326 330pf, 5%
C324 0.01, 5%
C325 0.01, 5%
IC 312 B
IC 312 A
R351 150.0K
CR306 1N4148
CR305 1N4148
C327 0.1, 5%
IC 313
R352 131.0K
R353 10.0K
C342 47/16
C341, .05/25
A302 LOUDNESS AUGMENTATION MODULE P/N 30335-000-02
C336, .033, 10%
CR307 1N4148
R354 16K
R355 10K, 20%, CCW, LOG
LOUDNESS AUGMENT
R356 1.8K
Q302 2N4402
CR308 1N4148
C328 0.47/20
R357 13.7K
R358 220K
R360 4.7K
Q303 2N4123
CR309 1N4148
CR310 1N4148
R359, 1M
VR301 6.8V 1N4736
C329 0.1, 10%
C330 0.1, 10%
(19) SOURCE LOUDNESS AUGMENTATION CONTROL LINE (CARD 7 (J))
POWER PINS
	+15	-15
LF356	7	4
CA3080	7	4
4558	8	4
TL-071	7	4
POLARITY SELECTED
VALUE SELECTED
ORBAN OPTIMOD-AM
MODEL 9000A BDD 4-4-78
INPUT FILTER, BROADBAND COMPRESSOR
DOC 60023-000-04
3
C



ASSEMBLY DRAWING, BOARD 4
MODEL 9000A OPTIMOD-AM
4-21-78 BDD SCALE 2/1
ORBAN ASSOCIATES INC. SAN FRANCISCO

DOC 30340-000-04

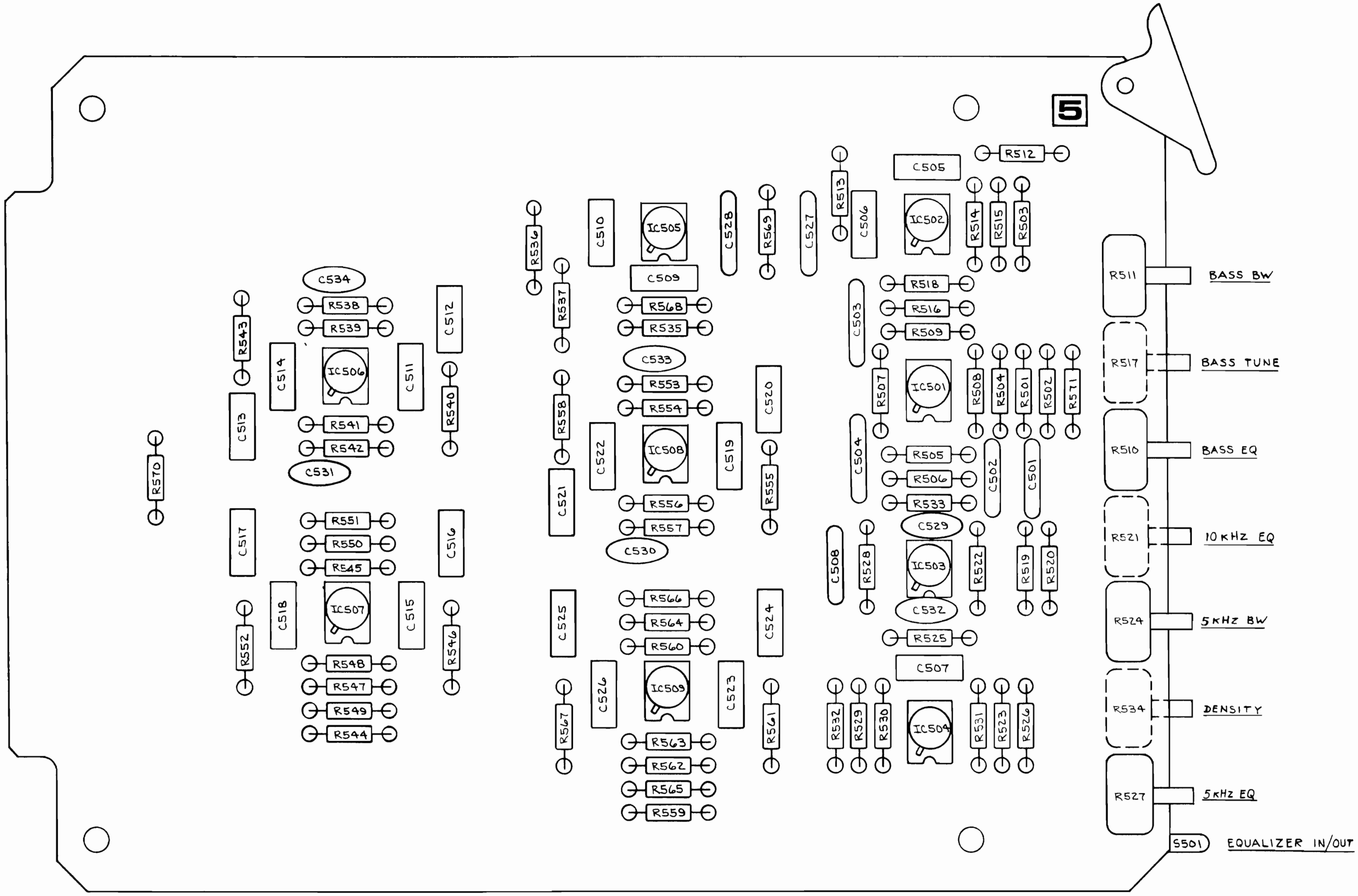


	+15	-15
TL-071	7	4
CA3080	7	4
4558	8	4
CA3096		16

△ POLARITY SELECTED
△ VALUE SELECTED

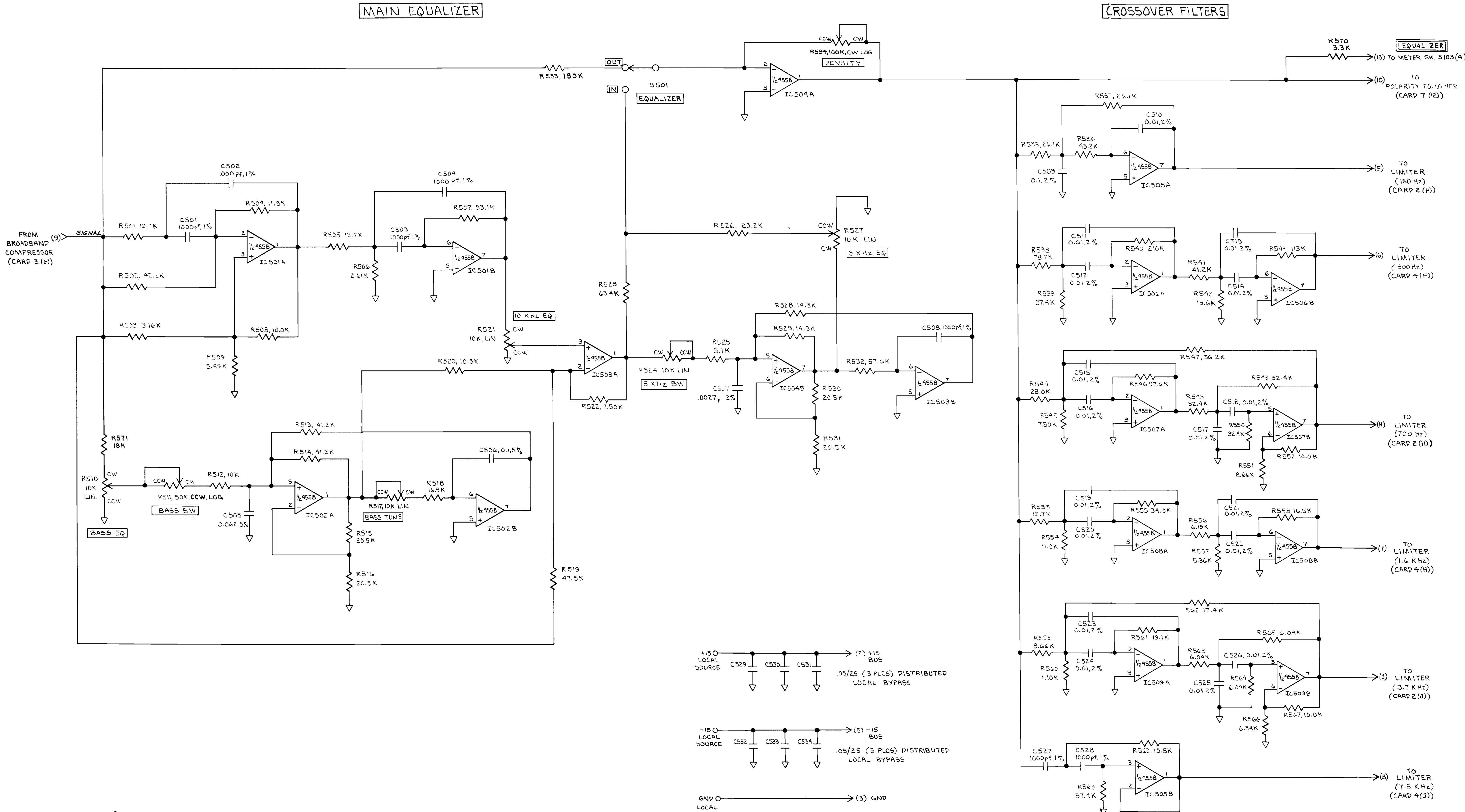
ORBAN OPTIMOD-AM
MODEL 9000A BDP 4-4-78
BAND LIMITERS (300 Hz, 1.6 kHz, 7.5 kHz)
DOC 60024-000-03

4



ASSEMBLY DRAWING, BOARD 5
MODEL 9000 A OPTIMOD-AM
4-24-78 BDD SCALE 2/1
ORBAN ASSOCIATES INC SAN FRANCISCO

DOC 30350-000-04



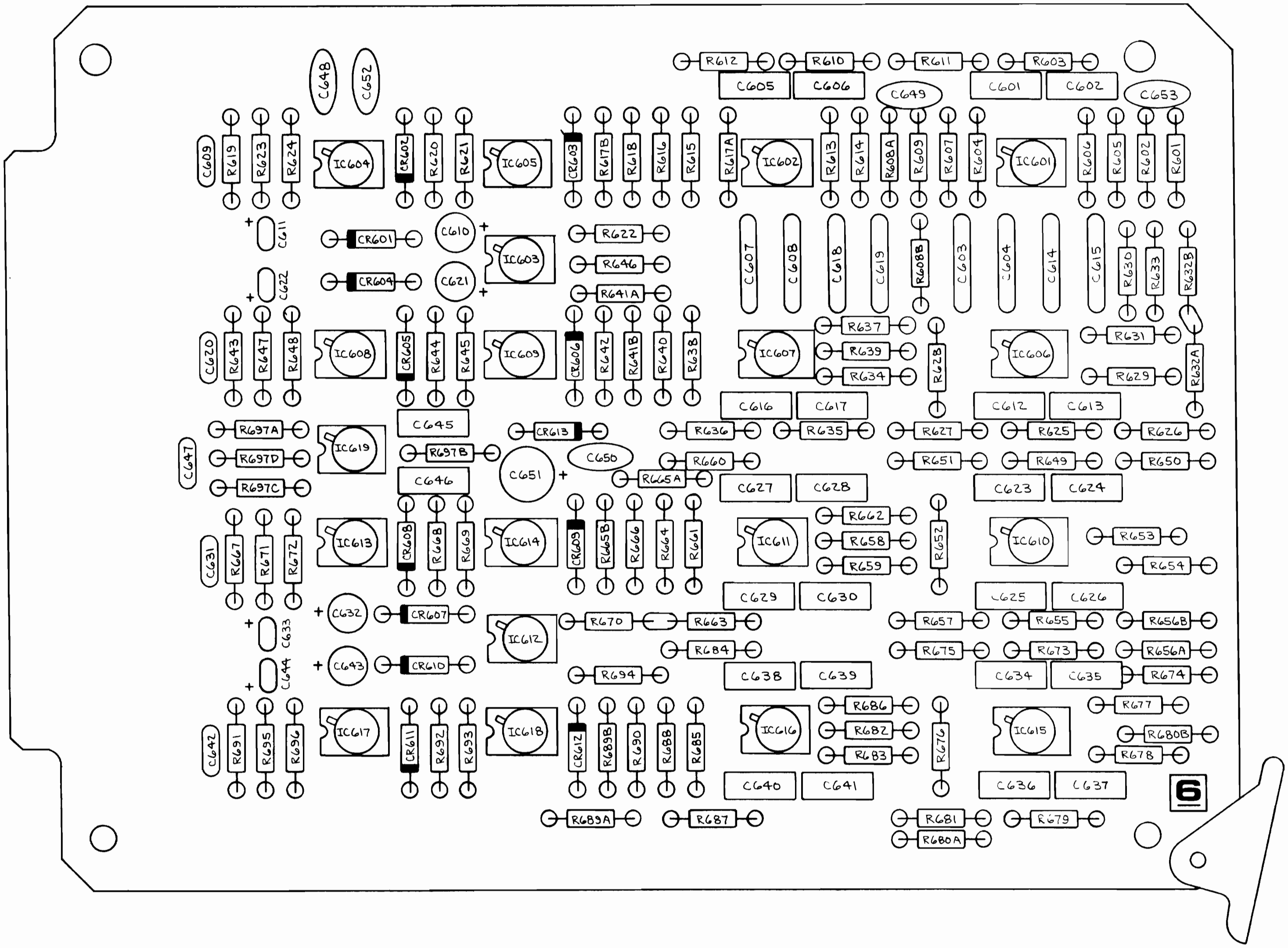
△ VALUE SELECTED

PINOUTS FOR 4558: +15 PIN 8, -15 PIN 4

ORBAN OPTIMOD-AM
MODEL 9000A BDD 4-4-78
MAIN EQUALIZER & CROSSOVER FILTERS
DOC 60025-000-03

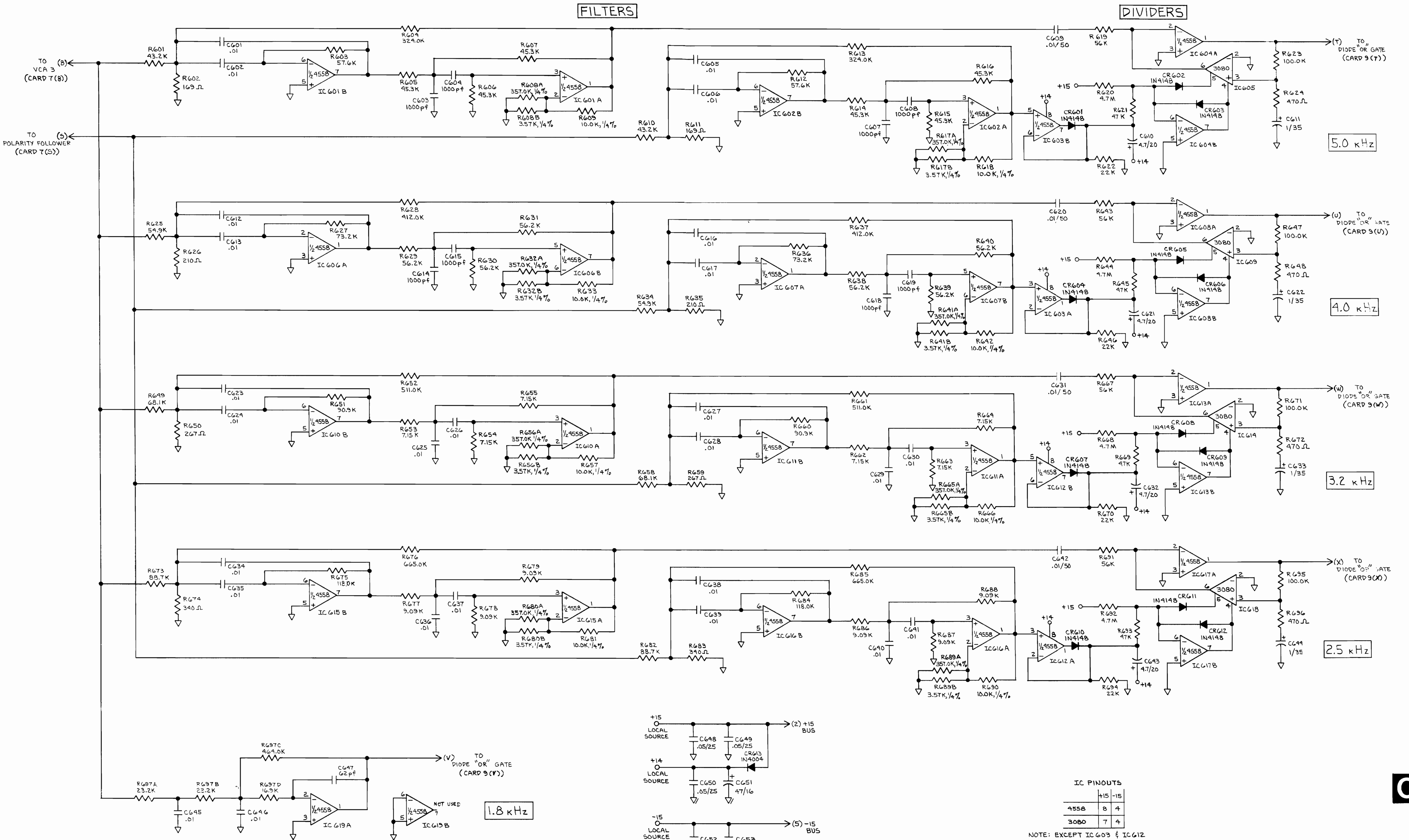
5

C



ASSEMBLY DRAWING BOARD 6
MODEL 9000A OPTIMOD-AM
4-24-78 BDD
SCALE 2/1
ORBAN ASSOCIATES INC
SAN FRANCISCO

DOC 30360-000-04



NOTE:
UNLESS OTHERWISE NOTED, ALL FILTER CAPACITORS ARE ±1%

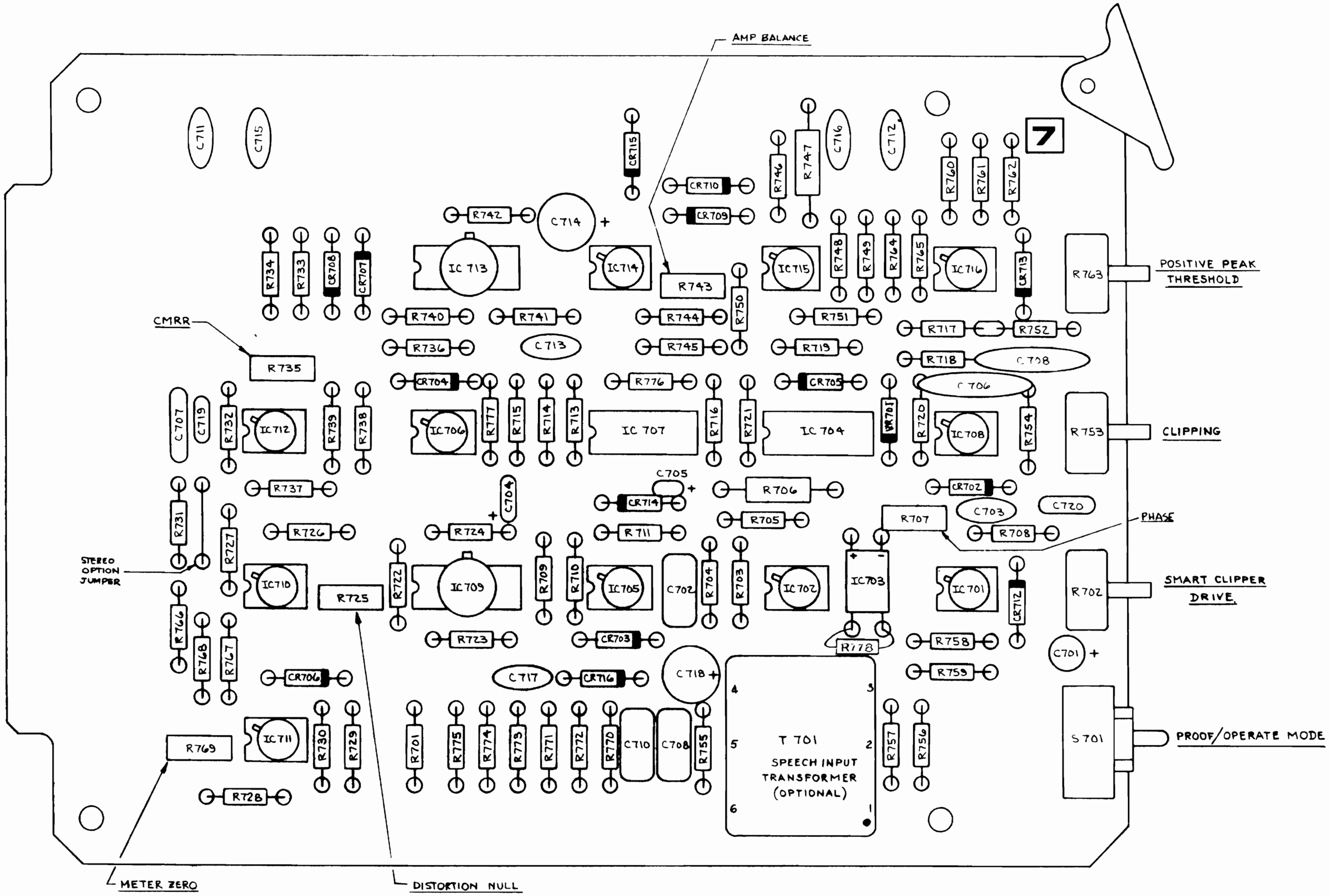
IC PINOUTS

	+15	-15
4558	8	4
3080	7	4

NOTE: EXCEPT IC603 & IC612 WHICH ARE SUPPLIED WITH +14 ON PIN (8)

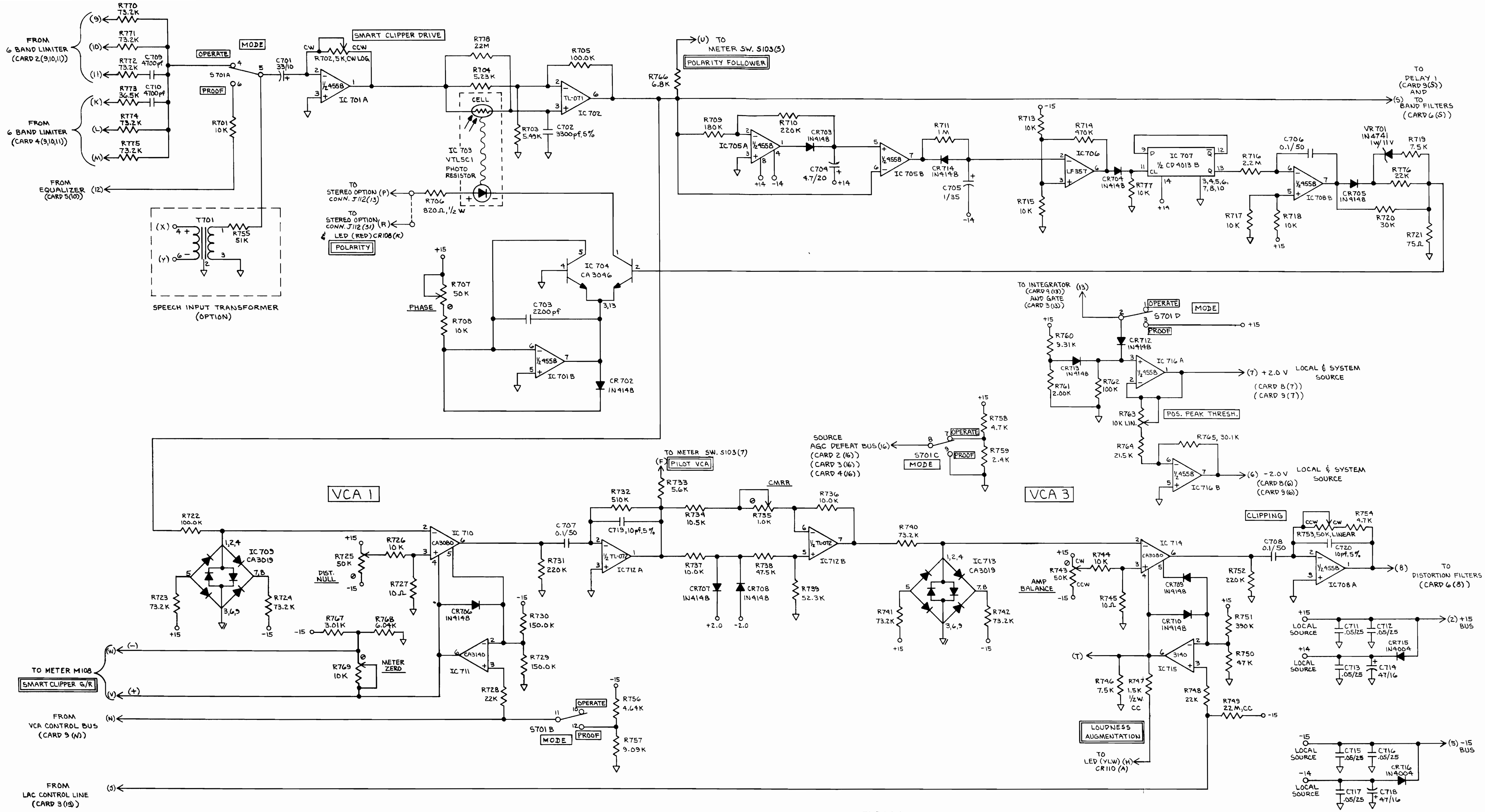
ORBAN OPTIMOD-AM
MODEL 9000A BDD 4-4-78
FILTERS AND DIVIDERS
DOC 60026-000-03

6



ASSEMBLY DRAWING, BOARD 7
MODEL 9000A OPTIMOD-AM
4-24-78 BDV SCALE 2/1
ORBAN ASSOCIATES INC SAN FRANCISCO

DOC 30370-000-04
+TPF 002



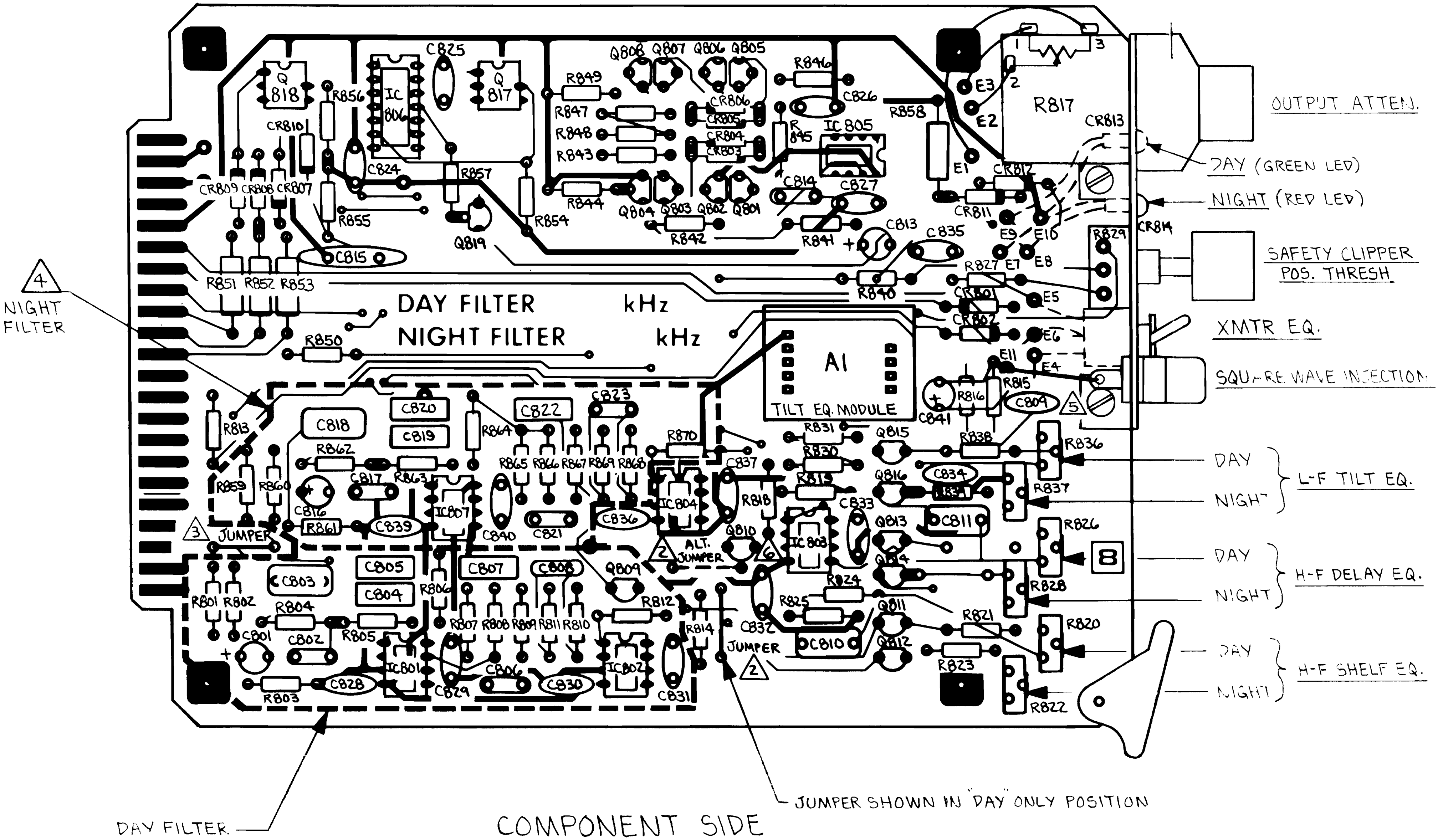
IC PINOUTS

	+15	-15	G
4558	8	4	
3080	7	4	
3140	7	4	
TL-071	7	4	
TL-072	8	4	

△ POLARITY SELECTED
△ VALUE SELECTED

ORBAN OPTIMOD-AM
MODEL 9000A BDD 4-4-78
SMART CLIPPER, POLARITY FOLLOWER, VCA 1 & 3
DOC 60027-000-04

7



COMPONENT SIDE

6. Q810 IS PART OF THE NIGHT FILTER

5. C809, INSTALLED AS NECESSARY

4. R859 - R870, C816 - C823, C839, C840, Q809, Q809, Q810 AND IC 807 OPTIONAL NIGHT FILTER

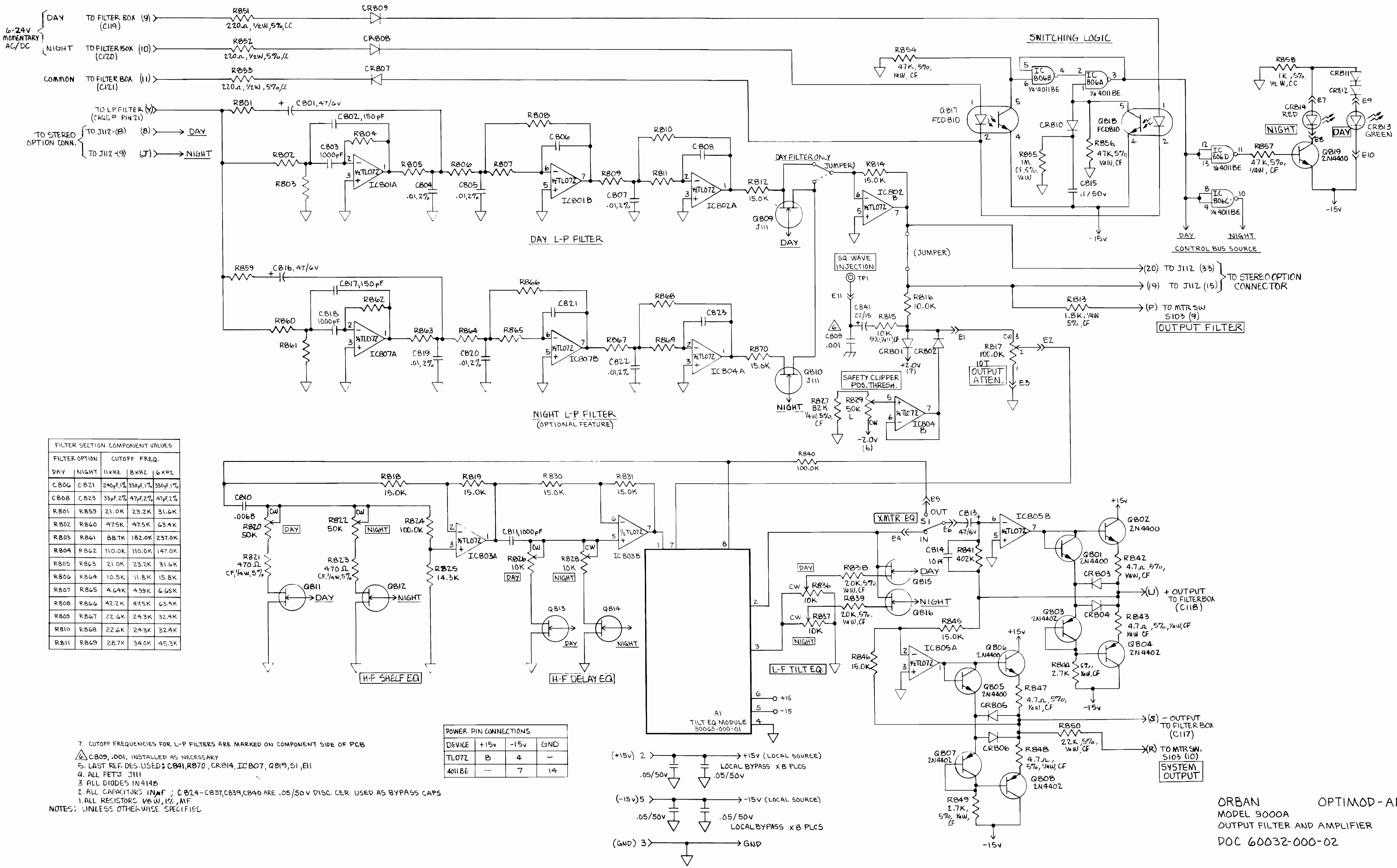
3. JUMPER TO BE REMOVED FOR STEREO OPERATION

2. JUMPER SHOWN IN "DAY" FILTER ONLY POSITION, MOVE TO ALTERNATE POSITION SHOWN FOR "DAY AND NIGHT" FILTER OPTION.

1. REF. DOCUMENTS: SCH. 60032-000-XX
FAB. 30416-000-XX

ASSEMBLY DRAWING, BOARD 8
MODEL 9000A OPTIMOD-AM
6-15-79 BDD
ORBAN ASSOCIATES INC. SAN FRANCISCO

DOC 30415-VER-03



FILTER SECTION COMPONENT VALUES				
FILTER OPTION		CUTOFF FREQ.		
DAY	NIGHT	11KHZ	8KHZ	6KHZ
C806	C821	240pF,1%	330pF,1%	330pF,1%
C808	C823	33pF,2%	47pF,2%	47pF,2%
R801	R859	21.0K	23.2K	31.6K
R802	R860	47.5K	47.5K	63.4K
R803	R861	88.7K	182.0K	237.0K
R804	R862	110.0K	110.0K	147.0K
R805	R863	21.0K	23.2K	31.6K
R806	R864	10.5K	11.8K	15.8K
R807	R865	4.64K	4.99K	6.65K
R808	R866	42.2K	47.5K	63.4K
R809	R867	22.6K	24.3K	32.4K
R810	R868	22.6K	24.3K	32.4K
R811	R869	28.7K	34.0K	45.3K

POWER PIN CONNECTIONS			
DEVICE	+15v	-15v	GND
TL072	8	4	—
4011BE	—	7	14

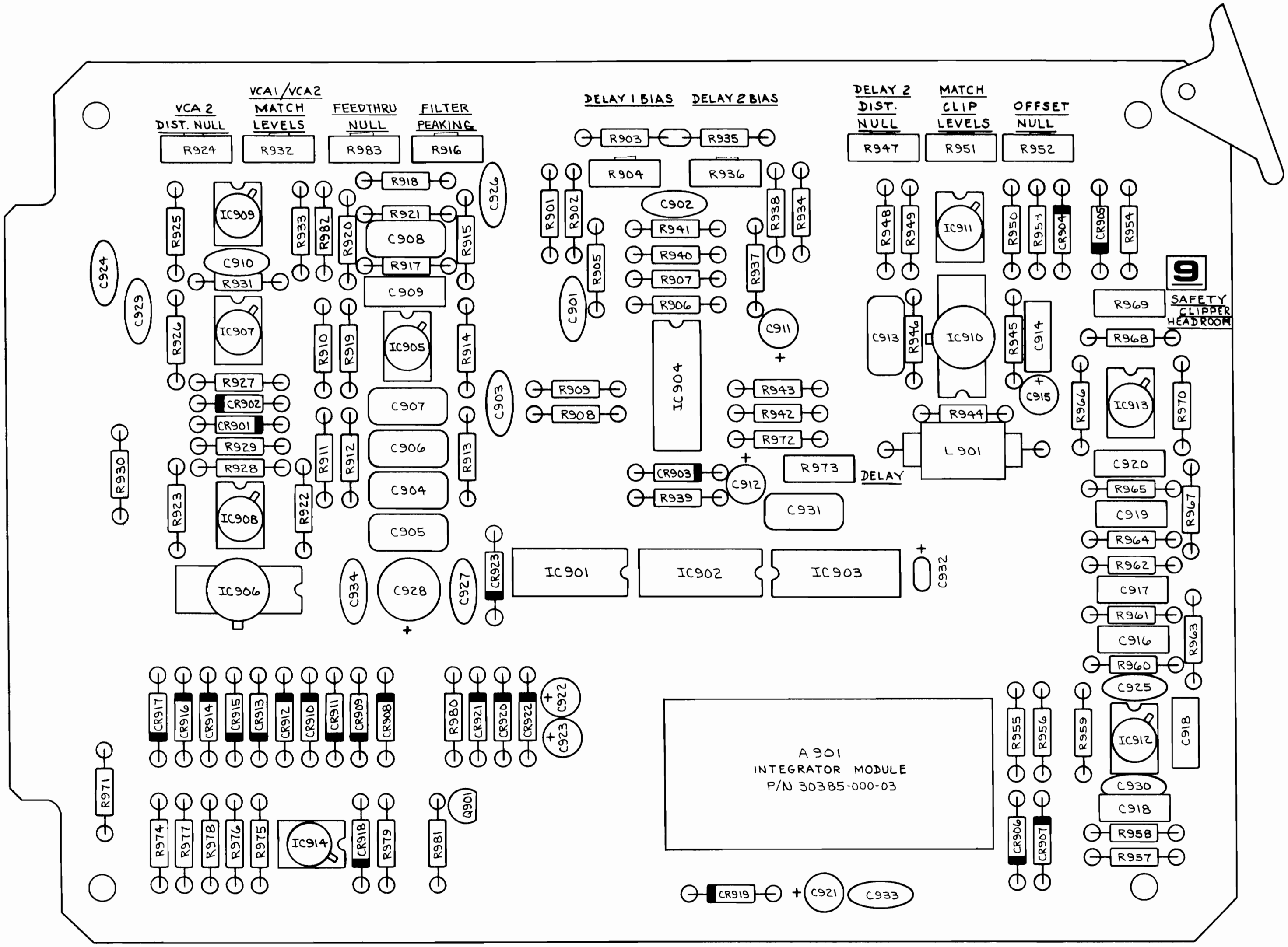
7. CUTOFF FREQUENCIES FOR L-P FILTERS ARE MARKED ON COMPONENT SIDE OF PCB
6. C809, .001, INSTALLED AS NECESSARY
5. LAST REF. DES. USED: C841, R870, CR814, IC807, Q819, S1, E11
4. ALL FET'S J111
3. ALL DIODES IN4148
2. ALL CAPACITORS IN µF ; C824-C837, C839, C840 ARE .05/50V DISC. CER. USED AS BYPASS CAPS
1. ALL RESISTORS 1/8 W, 1%, MF

NOTES: UNLESS OTHERWISE SPECIFIED

ORBAN OPTIMOD-AM
MODEL 9000A
OUTPUT FILTER AND AMPLIFIER
DOC 60032-000-02

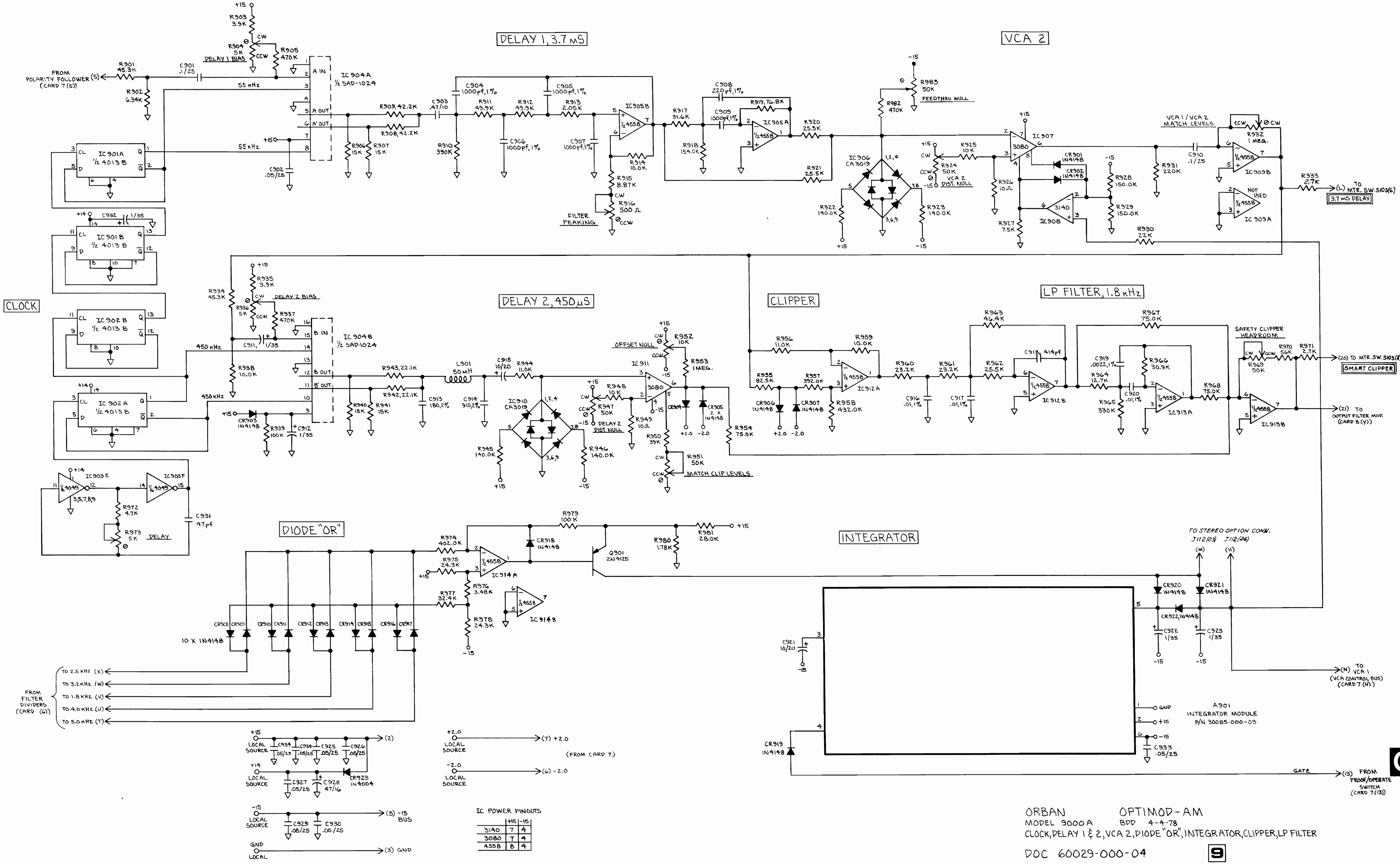
C

8



ASSEMBLY DRAWING, BOARD 9
MODEL 9000A OPTIMOD-AM
4-24-78 BDD SCALE 2/1
ORBAN ASSOCIATES INC SAN FRANCISCO

DOC 30390-000-04

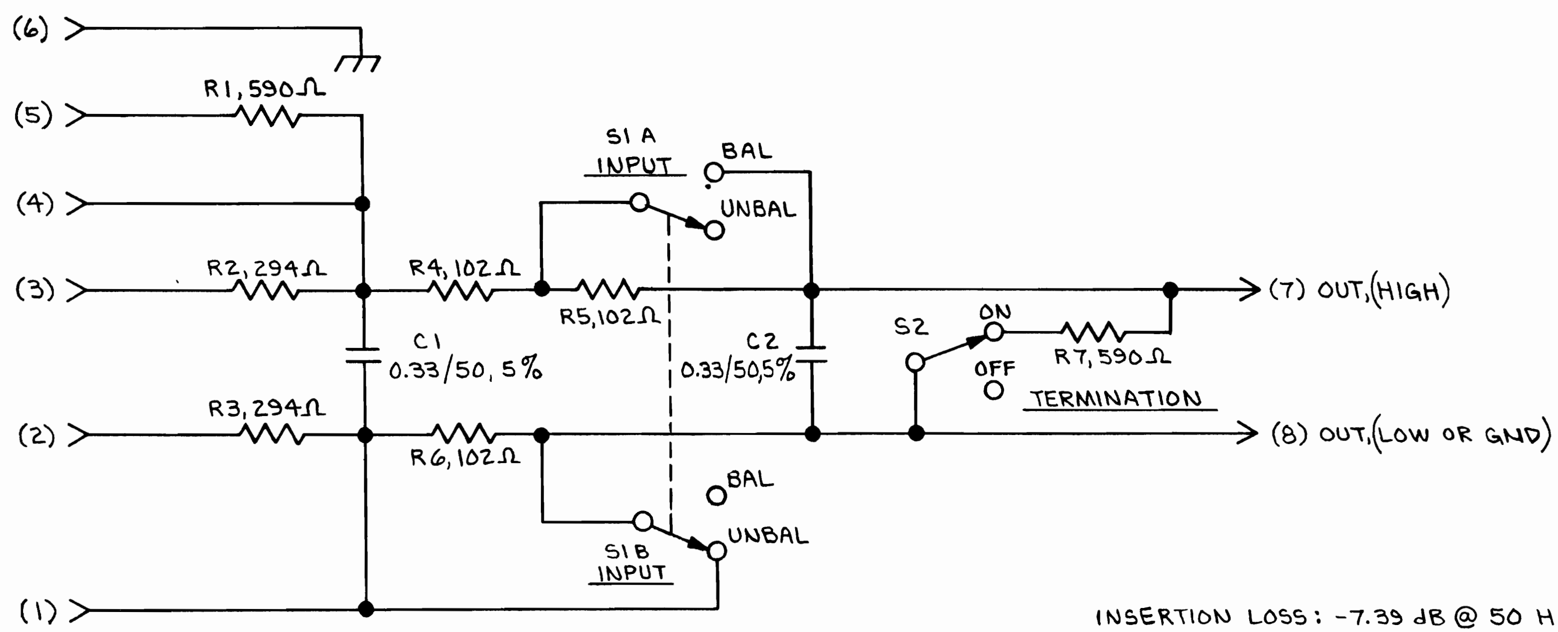


ORBAN OPTIMOD-AM
MODEL 9000A BDD 4-4-78
CLOCK, DELAY 1 & 2, VCA 2, DIODE "OR", INTEGRATOR, CLIPPER, LP FILTER

DOC 60029-000-04

9

C



INSERTION LOSS: -7.39 dB @ 50 Hz
LP ROLLOFF: -3dB @ 795 Hz
12 dB/OCTAVE

CONNECTION CHART

	SOURCE	IN HI	IN LO	OUT HI	OUT LO	⏚
BALANCED	600 OHM	4	1	7	8	6
	VOLTAGE	3	2	7	8	
UNBALANCED	600 OHM	4	1 (⏚)	7	8 (⏚)	
	VOLTAGE	5	1 (⏚)	7	8 (⏚)	

ALL RESISTORS ARE 1/8W, 1%, METAL FILM

ACCESSORY FOR OPTIMOD-AM

ORBAN OPTIMOD-AM
MODEL MRF-1A 7-13-78 BDD
MONITOR ROLLOFF FILTER

DOC 60031-000-01

TABLE 1

STEREO CONNECTOR WIRING

PIN NO. & COLOR		DESCRIPTION	BACK PLANE DESIGNATORS	WIRE RECOMMENDED	
1 BRN	ribbon cable	150 Hz integrator in	2(Y)	24 AWG	n.5
2 RED		700 Hz integrator in	2(X)	24 AWG	
3 ORN		3.7 kHz integrator in	2(W)	24 AWG	
4 YEL		B.B. compressor integrator in	3(X)	24 AWG	
5		N/C			
6 BLK		chassis jumper & pin 25		24 AWG	
7 BRN		B.B. compressor control	3(20)	24 AWG	
8 WHT/BLU		"DAY" switching bus out	8(8)	24 AWG	
9 WHT/GRN		"NIGHT" switching bus out	8(J)	24 AWG	
10		N/C			
11		N/C			
12		N/C			
13 BRN & WHT		to polarity circuit	7(P)	24 AWG	n.2
14		N/C			
15 RED	ribbon cable	to output stage	8(19)	24 AWG	n.4
16 ORN		150 Hz limiter control	2(V)	24 AWG	
17 YEL		700 Hz limiter control	2(U)	24 AWG	
18 GRN		3.7 kHz limiter control	2(T)	24 AWG	
20 GRY	ribbon cable	300 Hz integrator in	4(Y)	24 AWG	n.5
21 VIO		1.6 kHz integrator in	4(X)	24 AWG	
22 BLU		7.5 kHz integrator	4(W)	24 AWG	
23 GRN		smart clipper integrator in	9(M)	24 AWG	
24		N/C			
25 BLK - jumper		chassis from pin 6	gnd solder lug 2	24 AWG	
26 WHT/BLK		smart clipper control	9(")	24 AWG	
27		N/C			
28 RED	twisted	+25 VDC	PS (1)	22 AWG	
29 BLK		signal GND	PS(2)	22 AWG	
30 YEL		-25 VDC	PS(4)	22 AWG	
31 WHT & ORN		from "polarity" LED	7(R)	24 AWG	n.2
32		N/C			
33 WHT	ribbon cable	from output filter	8(20)	24 AWG	n.4
34 GRY		300 Hz limiter control	4(V)	24 AWG	
35 VIO		1.6 kHz limiter control	4(U)	24 AWG	
36 BLU		7.5 kHz limiter control	4(T)	24 AWG	
19 COAX		audio from buffer	3(8)	nts. 1&3 1 pair shielded audio cable 8451	
37		audio to processor from adapter	3(K)		

NOTES:
1. Jumped together on PCB 3 for Mono use.
2. Jumped together on PCB 7 for Mono use.
3. Shield to pin 25 (chassis) from 8451 cable.
4. Jumped together on PCB 8 for Mono use.
5. Not to be intertwined with other wires of cable.

APPENDIX III

SCHEMATICS, PARTS LOCATORS, PARTS LISTS

FOREWORD TO PARTS LISTS

Certain components are specially selected and/or matched.

Most selected components are indicated on the schematic drawings. Matched components and certain selected components are not indicated.

If Parts List does not agree with component value or specification encountered, replace with an exact duplicate of the actual part.

On certain boards, potted module assemblies are employed which are not field repairable. Boards containing such module assemblies should be returned to Factory Service for repair. "Loaner" boards are generally available during the repair cycle.

Some component replacement requires recalibration as indicated in the "Alignment" section of this Manual.

For these reasons, it is wisest to refer all component replacement to the Factory Service Department which, as a result of ongoing training and daily experience, is aware of every nuance involved in component replacement. In addition, Factory Service has immediate access to all replacement parts and is fully equipped to rapidly and accurately perform any realignment that might be indicated.

DESCRIPTION CODES USED IN PARTS LISTS:

ASY Assembly
CAP Capacitor
- RAD - Radial
- ALUM - Aluminum

DIO Diode
HDE Hardware
IC Integrated Circuit
- LIN - Linear
- MULT - Multiple Device

LED Light-Emitting Diode
MSE Miscellaneous
- uH - Microhenry

TRA Transistor
- SIG - Signal

RES Resistor
- CF - Carbon Film
- MF - Metal Film
- CC - Carbon Composition
- WW - Wire Wound

POT Potentiometer
- WW - Wire Wound
- T - Turns
- CW - Clockwise Taper
- CCW - Counter Clockwise Taper

SWI Switch
- MIN - Miniature Toggle
- ROT - Rotary

XFR Transformer

C

9000A/1 PARTS LISTS

FRONT PANEL

PART NUMBER	DESCRIPTION	
25103-000	LED	RED, FLV-150
25104-000	LED	GREEN, FLV-355
25105-000	LED	YELLOW, FLV-450
26076-306	SWI	SWITCH, ROT, 1P11T, CTS T-205
28002-003	MSE	METER, VU, BLACK/GRAY, DIXSON 330T
28009-001	MSE	METER, G/R, 1mA, 0-20 dB SCALE, EMICO 132D5
28009-002	MSE	METER, G/R, 1mA, 0-30 dB SCALE, EMICO 132D5
28009-003	MSE	METER, G/R, 1mA, RED/GREEN SCALE, EMICO 132D5

VERTICAL DIVIDER (RAW DC SUPPLY)

21107-350	CAP	CERAMIC, 20%, 50V, .05 uF
21118-210	CAP	CERAMIC, FEEDTHROUGH, 1000pF (ERIE)
21250-850	CAP	ALUM, AXIAL 50V 5000 uF
22203-400	DIO	RECTIFIER, 3A, 400V, MOTOROLA MR504
26002-001	SWI	SWITCH, TOGGLE, AC PWR, SPST
26108-000	SWI	LINE VOLTAGE SELECTOR, SWITCHCRAFT 46256LFR
28004-150	MSE	FUSE, 3AG, LITTLEFUSE, 1/2A, SLO-BLO
29004-000	XFR	TRANSFORMER, POWER; 1A
29501-004	MSE	INDUCTOR, 7 uH, OHMITE Z-50

REAR PANEL

20014-110	RES	CC, 1/2W, 5% 100 OHM
21112-215	CAP	CERAMIC, 10%, 1000V .0015 uF
21118-210	CAP	CERAMIC, FEEDTHROUGH, 1000 pF (ERIE)
23601-501	TRA	POWER, 15A, TO-3, RCA 2N3055
27301-000	HDE	COVER, INSULATOR, THERMALLOY 8903NW
28014-001	MSE	FILTER, RFI-EMI, LINE TO LINE, CORCOM 3EF1
28102-002		LINE CORD SET, AC

CARD CAGE

27030-004	CON	PCB EDGE, 22 PIN, METHODE 186-412-01

MONITOR ROLLOFF FILTER

20040-102	RES	MF, 1/8W, 1% 102 OHM
20040-294	RES	MF, 1/8W, 1% 294 OHM
20040-590	RES	MF, 1/8W, 1% 590 OHM
21603-433	CAP	POLYCARBONATE, 5%, .33 uF
26106-000	SWI	SWITCH, SLIDE, DPDT

BOARD #1 POWER SUPPLY REGULATOR
30310-000-04

C108	21303-633	CAP	TANTALUM, 10%, 10V, 33 MFD
C109	21020-147	CAP	MICA, 5%, 500V, CD15 470 PF
C111	21207-647	CAP	ALUM, RAD 35V 47 MFD
C112	21207-647	CAP	ALUM, RAD 35V 47 MFD
C113	21020-110	CAP	MICA, 5%, 500V, CD15 100 PF
CR105	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
CR106	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
F102	28011-210	MSE	FUSE, 1A, LITTLEFUSE 275001
F103	28011-210	MSE	FUSE, 1A, LITTLEFUSE 275001
IC101	24301-302	IC	P.S. REGULATOR, NATIONAL LM723CN
IC102	24003-102	IC	LIN, SINGLE OPAMP, NATIONAL LM301AH
Q103	23002-101	TRA	SIG, PNP, FAIRCHILD 2N4402
Q104	23002-101	TRA	SIG, PNP, FAIRCHILD 2N4402
R101	20014-222	RES	CC, 1/2W, 5% 2.2K
R102	20001-233	RES	CF, 1/4W, 5% 3.3K
R103	20028-891	RES	WW, 2W, 5% 0.91 OHM
R104	20028-891	RES	WW, 2W, 5% 0.91 OHM
R105	20041-453	RES	MF, 1/8W, 1% 4.53K
R106	20511-150	POT	TRIM, CERMET, 18T, BECKMAN 68WR500 OHM
R107	20041-402	RES	MF, 1/8W, 1% 4.02K
R108	20042-150	RES	MF, 1/8W, 1% 15.0K
R109	20042-150	RES	MF, 1/8W, 1% 15.0K
R110	20043-100	RES	MF, 1/8W, 1% 100K
R111	20043-100	RES	MF, 1/8W, 1% 100K
VR101	22005-160	DIO	ZENER, 5W, 5%, 16V, MOTOROLA 1N5353B
VR102	22005-160	DIO	ZENER, 5W, 5%, 16V, MOTOROLA 1N5353B

BOARD "IF" INPUT FILTER
30345-000-04

REF. DES.	PART #	DESCRIPTION	
C001	21112-215	CAP	CERAMIC, 10%, 1000V, .0015 MFD
C002	21112-215	CAP	CERAMIC, 10%, 1000V, .0015 MFD
L001	29503-000	MSE	INDUCTOR, 1.2 mh, MILLER 73F123AF
L002	29503-000	MSE	INDUCTOR, 1.2 mh, MILLER 73F123AF
L003	29503-000	MSE	INDUCTOR, 1.2 mh, MILLER 73F123AF
L004	29503-000	MSE	INDUCTOR, 1.2 mh, MILLER 73F123AF
L005	29503-000	MSE	INDUCTOR, 1.2 mh, MILLER 73F123AF
L006	29503-000	MSE	INDUCTOR, 1.2 mh, MILLER 73F123AF
R001	20014-175	RES	CC, 1/2W, 5% 750 OHM
R002	20014-215	RES	CC, 1/2W, 5% 1.5K
R003	20014-215	RES	CC, 1/2W, 5% 1.5K
R004	20014-175	RES	CC, 1/2W, 5% 750 OHM
R005	20014-110	RES	CC, 1/2W, 5% 100 OHM
R006	20014-110	RES	CC, 1/2W, 5% 100 OHM
R007	20014-110	RES	CC, 1/2W, 5% 100 OHM
R008	20014-147	RES	CC, 1/2W, 5% 470 OHM
R009	20014-147	RES	CC, 1/2W, 5% 470 OHM
R010	20014-110	RES	CC, 1/2W, 5% 100 OHM

BOARD #2 BAND LIMITERS
30320-000-04

A201	30325-000	ASY	MODULE, RELEASE TIME, 9000A
A202	30325-000	ASY	MODULE, RELEASE TIME, 9000A
A203	30325-000	ASY	MODULE, RELEASE TIME, 9000A
C201	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C202	21020-047	CAP	MICA, 5%, 500V, CD15 47 PF
C203	21401-222	CAP	POLYESTER, RAD, 100V, 10%, .0022 MFD
C204	21307-533	CAP	TANTALUM, 10%, 35V, 3.3 MFD
C205	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C206	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C207	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C208	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C221	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C222	21020-047	CAP	MICA, 5%, 500V, CD15 47 PF
C223	21401-222	CAP	POLYESTER, RAD, 100V, 10%, .0022 MFD
C224	21307-533	CAP	TANTALUM, 10%, 35V, 3.3 MFD
C225	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C226	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C227	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C228	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C241	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C242	21020-047	CAP	MICA, 5%, 500V, CD15 47 PF
C243	21401-222	CAP	POLYESTER, RAD, 100V, 10%, .0022 MFD
C244	21307-533	CAP	TANTALUM, 10%, 35V, 3.3 MFD
C245	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C246	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C247	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C248	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C249	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C250	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C251	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C252	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C253	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C254	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C255	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C256	21205-647	CAP	ALUM, RAD 16V 47 MFD
C257	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
CR201	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR202	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR221	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR222	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR241	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR242	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR243	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR244	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR245	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR246	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
IC201	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC202	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC203	24406-302	IC	MULT DISCRETE, RCA CA3096AE
IC204	24011-103	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. B
IC205	24401-101	IC	MULT DISCRETE, NATIONAL LM3019, AS PURCHASED
IC206	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC207	24701-102	IC	SPECIAL FUNCTION, RAYTHEON RC711T
IC221	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC222	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC223	24406-302	IC	MULT DISCRETE, RCA CA3096AE
IC224	24011-103	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. B
IC225	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC226	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC227	24701-102	IC	SPECIAL FUNCTION, RAYTHEON RC711T
IC241	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC242	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC243	24406-302	IC	MULT DISCRETE, RCA CA3096AE
IC244	24011-103	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. B
IC245	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC246	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC247	24701-102	IC	SPECIAL FUNCTION, RAYTHEON RC711T
Q201	23406-101	TRA	FET, SILICONIX E113
R201	20001-415	RES	CF, 1/4W, 5% 150K
R202	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R203	20001-333	RES	CF, 1/4W, 5% 33K
R204	20001-310	RES	CF, 1/4W, 5% 10K
R205	20001-010	RES	CF, 1/4W, 5% 10 OHM
R206	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R207	20042-732	RES	MF, 1/8W, 1% 73.2K
R208	20042-732	RES	MF, 1/8W, 1% 73.2K
R209	20042-732	RES	MF, 1/8W, 1% 73.2K
R210	20039-499	RES	MF, 1/8W, 1% 49.9 OHM
R211	20041-412	RES	MF, 1/8W, 1% 4.12K
R212	20041-499	RES	MF, 1/8W, 1% 4.99K
R213	20001-547	RES	CF, 1/4W, 5% 4.7 MEG
R214	20001-311	RES	CF, 1/4W, 5% 11K
R215	20001-410	RES	CF, 1/4W, 5% 100K
R216	20041-562	RES	MF, 1/8W, 1% 5.62K
R217	20041-100	RES	MF, 1/8W, 1% 1.00K
R218	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R220	20001-339	RES	CF, 1/4W, 5% 39K
R221	20001-415	RES	CF, 1/4W, 5% 150K
R222	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R223	20001-333	RES	CF, 1/4W, 5% 33K
R224	20001-310	RES	CF, 1/4W, 5% 10K
R225	20001-010	RES	CF, 1/4W, 5% 10 OHM
R226	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R227	20042-732	RES	MF, 1/8W, 1% 73.2K
R228	20042-732	RES	MF, 1/8W, 1% 73.2K
R229	20042-732	RES	MF, 1/8W, 1% 73.2K
R230	20039-499	RES	MF, 1/8W, 1% 49.9 OHM
R231	20041-412	RES	MF, 1/8W, 1% 4.12K
R232	20041-499	RES	MF, 1/8W, 1% 4.99K
R233	20001-547	RES	CF, 1/4W, 5% 4.7 MEG
R234	20001-247	RES	CF, 1/4W, 5% 4.7K
R235	20001-410	RES	CF, 1/4W, 5% 100K
R236	20041-210	RES	MF, 1/8W, 1% 2.10K
R237	20041-100	RES	MF, 1/8W, 1% 1.00K
R238	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R240	20001-327	RES	CF, 1/4W, 5% 27K
R241	20001-447	RES	CF, 1/4W, 5% 470K
R242	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K

30320-000 ASY BAND LIMITER, 9000A BOARD #2

REF. DES.	PART #	DESCRIPTION	
R243	20001-333	RES	CF, 1/4W, 5% 33K
R244	20001-310	RES	CF, 1/4W, 5% 10K
R245	20001-010	RES	CF, 1/4W, 5% 10 OHM
R246	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R247	20042-732	RES	MF, 1/8W, 1% 73.2K
R248	20042-732	RES	MF, 1/8W, 1% 73.2K
R249	20042-732	RES	MF, 1/8W, 1% 73.2K
R250	20039-499	RES	MF, 1/8W, 1% 49.9 OHM
R251	20041-412	RES	MF, 1/8W, 1% 4.12K
R252	20041-750	RES	MF, 1/8W, 1% 7.50K
R253	20001-547	RES	CF, 1/4W, 5% 4.7 MEG
R254	20001-233	RES	CF, 1/4W, 5% 3.3K
R255	20001-410	RES	CF, 1/4W, 5% 100K
R256	20041-348	RES	MF, 1/8W, 1% 3.48K
R257	20041-100	RES	MF, 1/8W, 1% 1.00K
R258	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R260	20001-315	RES	CF, 1/4W, 5% 15K
R265	20042-100	RES	MF, 1/8W, 1% 10.0K
R266	20042-137	RES	MF, 1/8W, 1% 13.7K
R267	20042-432	RES	MF, 1/8W, 1% 43.2K
R268	20011-610	RES	CC, 1/4W, 5% 10 MEG
R269	20001-110	RES	CF, 1/4W, 5% 100 OHM
R270	20001-110	RES	CF, 1/4W, 5% 100 OHM
VR201	22003-091	DIO	ZENER, 1W, 10%, 9.1V, MOTOROLA 1N4739

BOARD #3 INPUT FILTER/BROADBAND COMPRESSOR
30330-000-05

A301	30325-000	ASY	MODULE, RELEASE TIME, 9000A
A302	30335-000	ASY	MODULE, LAC, 9000A
C301	21020-110	CAP	MICA, 5%, 500V, CD15 100 PF
C302	21602-333	CAP	POLYCARBONATE, 2%, .033 MFD
C303	21602-333	CAP	POLYCARBONATE, 2%, .033 MFD
C304	21602-333	CAP	POLYCARBONATE, 2%, .033 MFD
C305	21602-247	CAP	POLYCARBONATE, 2%, .0047 MFD
C306	21602-247	CAP	POLYCARBONATE, 2%, .0047 MFD
C307	21018-116	CAP	MICA, 1%, 500V. CD15 160 PF
C308	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C309	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C310	21019-122	CAP	MICA, 2%, 500V, CD15 220 PF
C311	21602-410	CAP	POLYCARBONATE, 2%, .1 MFD
C312	21019-115	CAP	MICA, 2%, 500V, CD15 150 PF
C313	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C314	21103-447	CAP	CERAMIC, 20%, 12V, .47 MFD
C315	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C316	21307-433	CAP	TANTALUM, 10%, 35V, .33 MFD
C317	21017-010	CAP	MICA, 1/2 PF, 500V, CD15 10 PF
C318	21112-222	CAP	CERAMIC, 10%, 1000V, .0022 MFD
C319	21307-622	CAP	TANTALUM, 10%, 35V, 22 MFD
C320	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C321	21307-547	CAP	TANTALUM, 10%, 35V, 4.7 MFD
C322	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C323	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C324	21603-310	CAP	POLYCARBONATE, 5%, .01 MFD
C325	21603-310	CAP	POLYCARBONATE, 5%, .01 MFD
C326	21020-133	CAP	MICA, 5%, 500V, CD15 330 PF
C327	21603-410	CAP	POLYCARBONATE, 5%, .1 MFD
C328	21307-447	CAP	TANTALUM, 10%, 35V, .47 MFD
C329	21401-410	CAP	POLYESTER, RAD, 100V, 10%, .1 MFD
C330	21401-410	CAP	POLYESTER, RAD, 100V, 10%, .1 MFD
C331	21205-647	CAP	ALUM, RAD 16V 47 MFD
C332	21205-647	CAP	ALUM, RAD 16V 47 MFD
C333	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C334	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C335	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C336	21401-333	CAP	POLYESTER, RAD, 100V, 10%, .033 MFD
C337	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C338	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C339	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C340	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C341	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C342	21205-647	CAP	ALUM, RAD 16V 47 MFD
C343	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C344	21401-410	CAP	POLYESTER, RAD, 100V, 10%, .1 MFD
CR301	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR302	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR303	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR304	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR305	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR306	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR307	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR308	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR309	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR310	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR311	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
CR312	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
CR313	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR314	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR315	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR316	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR317	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR318	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR319	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR320	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR321	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR322	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR323	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR324	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
IC301	24009-102	IC	LIN, FET OPAMP, NATIONAL LF356H
IC302	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC303	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC304	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC305	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC306	24011-103	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. B
IC307	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC308	24406-302	IC	MULT DISCRETE, RCA CA3096AE
IC309	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC310	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC311	24701-102	IC	SPECIAL FUNCTION, RAYTHEON RC711T
IC312	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC313	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC314	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
Q301	23406-101	TRA	FET, SILICONIX E113
Q302	23002-101	TRA	SIG, PNP, FAIRCHILD 2N4402
Q303	23201-101	TRA	SIG, NPN, MOTOROLA 2N4123
R301	20721-000	POT	SINGLE, LOG, CW, 50K
R302	20001-247	RES	CF, 1/4W, 5% 4.7K
R303	20001-347	RES	CF, 1/4W, 5% 47K
R304	20042-249	RES	MF, 1/8W, 1% 24.9K
R305	20043-634	RES	MF, 1/8W, 1% 634K
R306	20041-499	RES	MF, 1/8W, 1% 4.99K
R307	20041-453	RES	MF, 1/8W, 1% 4.53K
R308	20041-887	RES	MF, 1/8W, 1% 8.87K
R309	20042-357	RES	MF, 1/8W, 1% 35.7K
R310	20042-280	RES	MF, 1/8W, 1% 28.0K
R311	20042-280	RES	MF, 1/8W, 1% 28.0K
R312	20041-453	RES	MF, 1/8W, 1% 4.53K
R313	20042-121	RES	MF, 1/8W, 1% 12.1K
R314	20042-137	RES	MF, 1/8W, 1% 13.7K
R315	20042-121	RES	MF, 1/8W, 1% 12.1K
R316	20041-365	RES	MF, 1/8W, 1% 3.65K
R317	20041-324	RES	MF, 1/8W, 1% 3.24K
R318	20041-365	RES	MF, 1/8W, 1% 3.65K
R319	20001-347	RES	CF, 1/4W, 5% 47K
R320	20001-210	RES	CF, 1/4W, 5% 1.0K
R321	20726-000	POT	SINGLE, LOG, CW, 100K, CTS-200
R322	20001-347	RES	CF, 1/4W, 5% 47K

R323	20001-318	RES	CF, 1/4W, 5% 18K
R324	20001-247	RES	CF, 1/4W, 5% 4.7K
R325	20014-210	RES	CC, 1/2W, 5% 1.0K
R326	20001-333	RES	CF, 1/4W, 5% 33K
R327	20043-150	RES	MF, 1/8W, 1% 150K
R328	20001-333	RES	CF, 1/4W, 5% 33K
R329	20001-310	RES	CF, 1/4W, 5% 10K
R330	20001-010	RES	CF, 1/4W, 5% 10 OHM
R331	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R332	20042-732	RES	MF, 1/8W, 1% 73.2K
R333	20042-732	RES	MF, 1/8W, 1% 73.2K
R334	20042-732	RES	MF, 1/8W, 1% 73.2K
R335	20039-499	RES	MF, 1/8W, 1% 49.9 OHM
R336	20041-412	RES	MF, 1/8W, 1% 4.12K
R337	20041-499	RES	MF, 1/8W, 1% 4.99K
R339	20001-510	RES	CF, 1/4W, 5% 1.0 MEG
R340	20041-140	RES	MF, 1/8W, 1% 1.40K
R341	20001-410	RES	CF, 1/4W, 5% `100K
R342	20001-347	RES	CF, 1/4W, 5% 47K
R343	20011-610	RES	CC, 1/4W, 5% 10 MEG
R344	20041-232	RES	MF, 1/8W, 1% 2.32K
R345	20041-100	RES	MF, 1/8W, 1% 1.00K
R346	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R347	20042-953	RES	MF, 1/8W, 1% 95.3K
R348	20042-953	RES	MF, 1/8W, 1% 95.3K
R349	20042-402	RES	MF, 1/8W, 1% 40.2K
R350	20043-383	RES	MF, 1/8W, 1% 383K
R351	20043-150	RES	MF, 1/8W, 1% 150K
R352	20043-191	RES	MF, 1/8W, 1% 191K
R353	20042-100	RES	MF, 1/8W, 1% 10.0K
R354	20001-316	RES	CF, 1/4W, 5% 16K
R355	20723-000	POT	SINGLE, LOG, CW, 10K
R356	20001-218	RES	CF, 1/4W, 5% 1.8K
R357	20042-137	RES	MF, 1/8W, 1% 13.7K
R358	20001-422	RES	CF, 1/4W, 5% 220K
R359	20001-510	RES	CF, 1/4W, 5% 1.0 MEG
R360	20001-247	RES	CF, 1/4W, 5% 4.7K
R361	20042-140	RES	MF, 1/8W, 1% 14.0K
R362	20041-100	RES	MF, 1/8W, 1% 1.00K
R363	20042-140	RES	MF, 1/8W, 1% 14.0K
R364	20041-100	RES	MF, 1/8W, 1% 1.00K
R366	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R367	20001-422	RES	CF, 1/4W, 5% 220K
R368	20001-233	RES	CF, 1/4W, 5% 3.3K
S301	26037-001	SWI	TOGGLE, MIN, SPDT, C&K 7101
T301	29101-000	XFR	INPUT, INGLOT A194C
VR301	22003-068	DIO	ZENER, 1W, 10%, 6.8V, MOTOROLA 1N4736
VR302	22003-091	DIO	ZENER, 1W, 10%, 9.1V, MOTOROLA 1N4739
VR303	22003-068	DIO	ZENER, 1W, 10%, 6.8V, MOTOROLA 1N4736

A401	30325-000	ASY	MODULE, RELEASE TIME, 9000A
A402	30325-000	ASY	MODULE, RELEASE TIME, 9000A
A403	30325-000	ASY	MODULE, RELEASE TIME, 9000A
C401	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C402	21020-047	CAP	MICA, 5%, 500V, CD15 47 PF
C403	21401-222	CAP	POLYESTER, RAD, 100V, 10%, .0022 MFD
C404	21307-533	CAP	TANTALUM, 10%, 35V, 3.3 MFD
C405	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C406	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C407	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C408	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C421	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C422	21020-047	CAP	MICA, 5%, 500V, CD15 47 PF
C423	21401-222	CAP	POLYESTER, RAD, 100V, 10%, .0022 MFD
C424	21307-533	CAP	TANTALUM, 10%, 35V, 3.3 MFD
C425	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C426	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C427	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C428	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C441	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C442	21020-047	CAP	MICA, 5%, 500V, CD15 47 PF
C443	21401-222	CAP	POLYESTER, RAD, 100V, 10%, .0022 MFD
C444	21307-533	CAP	TANTALUM, 10%, 35V, 3.3 MFD
C445	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C446	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C447	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C448	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C449	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C450	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C451	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C452	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C453	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C454	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C455	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C456	21205-647	CAP	ALUM, RAD 16V 47 MFD
C457	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
CR401	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR402	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR421	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR422	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR441	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR442	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR443	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR444	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR445	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR446	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
IC401	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC402	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC403	24406-302	IC	MULT DISCRETE, RCA CA3096AE
IC404	24011-103	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. B
IC405	24401-101	IC	MULT DISCRETE, NATIONAL LM3019, AS PURCHASED
IC406	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC407	24701-102	IC	SPECIAL FUNCTION, RAYTHEON RC711T
IC421	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC422	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC423	24406-302	IC	MULT DISCRETE, RCA CA3096AE
IC424	24011-103	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. B
IC425	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC426	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC427	24701-102	IC	SPECIAL FUNCTION, RAYTHEON RC711T
IC441	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC442	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC443	24406-302	IC	MULT DISCRETE, RCA CA3096AE
IC444	24011-103	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. B
IC445	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC446	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC447	24701-102	IC	SPECIAL FUNCTION, RAYTHEON RC711T
R401	20001-415	RES	CF, 1/4W, 5% 150K
R402	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R403	20001-333	RES	CF, 1/4W, 5% 33K
R404	20001-310	RES	CF, 1/4W, 5% 10K
R405	20001-010	RES	CF, 1/4W, 5% 10 OHM
R406	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R407	20042-732	RES	MF, 1/8W, 1% 73.2K
R408	20042-732	RES	MF, 1/8W, 1% 73.2K
R409	20042-732	RES	MF, 1/8W, 1% 73.2K
R410	20039-499	RES	MF, 1/8W, 1% 49.9 OHM
R411	20041-412	RES	MF, 1/8W, 1% 4.12K
R412	20041-499	RES	MF, 1/8W, 1% 4.99K
R413	20001-547	RES	CF, 1/4W, 5% 4.7 MEG
R414	20001-291	RES	CF, 1/4W, 5% 9.1K
R415	20001-410	RES	CF, 1/4W, 5% 100K
R416	20041-267	RES	MF, 1/8W, 1% 2.67K
R417	20041-100	RES	MF, 1/8W, 1% 1.00K
R418	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R420	20001-339	RES	CF, 1/4W, 5% 39K
R421	20001-415	RES	CF, 1/4W, 5% 150K
R422	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R423	20001-333	RES	CF, 1/4W, 5% 33K
R424	20001-310	RES	CF, 1/4W, 5% 10K
R425	20001-010	RES	CF, 1/4W, 5% 10 OHM
R426	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R427	20042-732	RES	MF, 1/8W, 1% 73.2K
R428	20042-732	RES	MF, 1/8W, 1% 73.2K
R429	20042-732	RES	MF, 1/8W, 1% 73.2K
R430	20039-499	RES	MF, 1/8W, 1% 49.9 OHM
R431	20041-412	RES	MF, 1/8W, 1% 4.12K
R432	20041-499	RES	MF, 1/8W, 1% 4.99K
R433	20001-547	RES	CF, 1/4W, 5% 4.7 MEG
R434	20001-227	RES	CF, 1/4W, 5% 2.7K
R435	20001-410	RES	CF, 1/4W, 5% 100K
R436	20041-255	RES	MF, 1/8W, 1% 2.55K
R437	20041-100	RES	MF, 1/8W, 1% 1.00K
R438	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R440	20001-322	RES	CF, 1/4W, 5% 22K
R441	20001-447	RES	CF, 1/4W, 5% 470K
R442	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R443	20001-333	RES	CF, 1/4W, 5% 33K

R444	20001-310	RES	CF, 1/4W, 5% 10K
R445	20001-010	RES	CF, 1/4W, 5% 10 OHM
R446	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R447	20042-732	RES	MF, 1/8W, 1% 73.2K
R448	20042-732	RES	MF, 1/8W, 1% 73.2K
R449	20042-732	RES	MF, 1/8W, 1% 73.2K
R450	20039-499	RES	MF, 1/8W, 1% 49.9 OHM
R451	20041-412	RES	MF, 1/8W, 1% 4.12K
R452	20041-750	RES	MF, 1/8W, 1% 7.50K
R453	20001-547	RES	CF, 1/4W, 5% 4.7 MEG
R454	20001-227	RES	CF, 1/4W, 5% 2.7K
R455	20001-410	RES	CF, 1/4W, 5% 100K
R456	20041-232	RES	MF, 1/8W, 1% 2.32K
R457	20041-165	RES	MF, 1/8W, 1% 1.65K
R458	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R460	20001-311	RES	CF, 1/4W, 5% 11K
R465	20042-137	RES	MF, 1/8W, 1% 13.7K
R466	20042-137	RES	MF, 1/8W, 1% 13.7K
R467	20042-634	RES	MF, 1/8W, 1% 63.4K
R468	20001-110	RES	CF, 1/4W, 5% 100 OHM
R469	20001-110	RES	CF, 1/4W, 5% 100 OHM
VR401	22003-091	DIO	ZENER, 1W, 10%, 9.1V, MOTOROLA 1N4739

BOARD #5 MAIN EQ AND CROSSOVER FILTERS
30350-000-04

C501	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C502	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C503	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C504	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C505	21603-362	CAP	POLYCARBONATE, 5%, .062 MFD
C506	21603-410	CAP	POLYCARBONATE, 5%, .1 MFD
C507	21602-227	CAP	POLYCARBONATE, 2%, .0027 MFD
C508	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C509	21602-410	CAP	POLYCARBONATE, 2%, .1 MFD
C510	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C511	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C512	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C513	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C514	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C515	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C516	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C517	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C518	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C519	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C520	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C521	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C522	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C523	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C524	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C525	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C526	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C527	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C528	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C529	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C530	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C531	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C532	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C533	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C534	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
IC501	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC502	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC503	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC504	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC505	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC506	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC507	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC508	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC509	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
R501	20042-127	RES	MF, 1/8W, 1% 12.7K
R502	20042-422	RES	MF, 1/8W, 1% 42.2K
R503	20041-316	RES	MF, 1/8W, 1% 3.16K
R504	20042-118	RES	MF, 1/8W, 1% 11.8K
R505	20042-127	RES	MF, 1/8W, 1% 12.7K
R506	20041-261	RES	MF, 1/8W, 1% 2.61K
R507	20042-931	RES	MF, 1/8W, 1% 93.1K
R508	20042-100	RES	MF, 1/8W, 1% 10.0K
R509	20041-549	RES	MF, 1/8W, 1% 5.49K
R510	20720-000	POT	SINGLE, LIN, 10K, CTS-200
R511	20724-000	POT	SINGLE, LOG, CCW, 50K
R512	20001-310	RES	CF, 1/4W, 5% 10K
R513	20042-412	RES	MF, 1/8W, 1% 41.2K
R514	20042-412	RES	MF, 1/8W, 1% 41.2K
R515	20042-205	RES	MF, 1/8W, 1% 20.5K
R516	20042-205	RES	MF, 1/8W, 1% 20.5K
R517	20720-000	POT	SINGLE, LIN, 10K, CTS-200
R518	20042-169	RES	MF, 1/8W, 1% 16.9K
R519	20042-475	RES	MF, 1/8W, 1% 47.5K
R520	20042-105	RES	MF, 1/8W, 1% 10.5K
R521	20720-000	POT	SINGLE, LIN, 10K, CTS-200
R522	20041-750	RES	MF, 1/8W, 1% 7.50K
R523	20042-634	RES	MF, 1/8W, 1% 63.4K
R524	20720-000	POT	SINGLE, LIN, 10K, CTS-200
R525	20001-251	RES	CF, 1/4W, 5% 5.1K
R526	20042-232	RES	MF, 1/8W, 1% 23.2K
R527	20720-000	POT	SINGLE, LIN, 10K, CTS-200
R528	20042-143	RES	MF, 1/8W, 1% 14.3K
R529	20042-143	RES	MF, 1/8W, 1% 14.3K
R530	20042-205	RES	MF, 1/8W, 1% 20.5K
R531	20042-205	RES	MF, 1/8W, 1% 20.5K
R532	20042-576	RES	MF, 1/8W, 1% 57.6K
R533	20001-418	RES	CF, 1/4W, 5% 180K
R534	20726-000	POT	SINGLE, LOG, CW, 100K, CTS-200
R535	20042-261	RES	MF, 1/8W, 1% 26.1K
R536	20042-432	RES	MF, 1/8W, 1% 43.2K
R537	20042-261	RES	MF, 1/8W, 1% 26.1K
R538	20042-787	RES	MF, 1/8W, 1% 78.7K
R539	20042-374	RES	MF, 1/8W, 1% 37.4K
R540	20043-210	RES	MF, 1/8W, 1% 210K
R541	20042-412	RES	MF, 1/8W, 1% 41.2K
R542	20042-196	RES	MF, 1/8W, 1% 19.6K
R543	20043-113	RES	MF, 1/8W, 1% 113K
R544	20042-280	RES	MF, 1/8W, 1% 28.0K
R545	20041-750	RES	MF, 1/8W, 1% 7.50K
R546	20042-976	RES	MF, 1/8W, 1% 97.6K
R547	20042-562	RES	MF, 1/8W, 1% 56.2K
R548	20042-324	RES	MF, 1/8W, 1% 32.4K
R549	20042-324	RES	MF, 1/8W, 1% 32.4K
R550	20042-324	RES	MF, 1/8W, 1% 32.4K
R551	20041-866	RES	MF, 1/8W, 1% 8.66K
R552	20042-100	RES	MF, 1/8W, 1% 10.0K
R553	20042-127	RES	MF, 1/8W, 1% 12.7K
R554	20042-110	RES	MF, 1/8W, 1% 11.0K
R555	20042-340	RES	MF, 1/8W, 1% 34.0K
R556	20041-619	RES	MF, 1/8W, 1% 6.19K
R557	20041-536	RES	MF, 1/8W, 1% 5.36K
R558	20042-165	RES	MF, 1/8W, 1% 16.5K
R559	20041-866	RES	MF, 1/8W, 1% 8.66K
R560	20041-110	RES	MF, 1/8W, 1% 1.10K
R561	20042-191	RES	MF, 1/8W, 1% 19.1K
R562	20042-174	RES	MF, 1/8W, 1% 17.4K
R563	20041-604	RES	MF, 1/8W, 1% 6.04K
R564	20041-604	RES	MF, 1/8W, 1% 6.04K
R565	20041-604	RES	MF, 1/8W, 1% 6.04K
R566	20041-634	RES	MF, 1/8W, 1% 6.34K
R567	20042-100	RES	MF, 1/8W, 1% 10.0K
R568	20042-374	RES	MF, 1/8W, 1% 37.4K
R569	20042-105	RES	MF, 1/8W, 1% 10.5K
R570	20001-233	RES	CF, 1/4W, 5% 3.3K
R571	20001-318	RES	CF, 1/4W, 5% 18K
S501	26037-001	SWI	TOGGLE, MIN, SPDT, C&K 7101

BOARD #6 FILTERS AND DIVIDERS
30360-000-04

C601	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C601	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C602	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C602	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C603	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C603	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C604	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C604	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C605	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C605	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C606	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C606	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C607	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C607	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C608	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C608	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C609	21107-310	CAP	CERAMIC, 20%, 50V, .01 MFD
C609	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C610	21307-547	CAP	TANTALUM, 10%, 35V, 4.7 MFD
C610	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C611	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C611	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C612	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C612	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
C613	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C614	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C615	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C616	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C617	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C618	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C619	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C620	21107-310	CAP	CERAMIC, 20%, 50V, .01 MFD
C621	21307-547	CAP	TANTALUM, 10%, 35V, 4.7 MFD
C622	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C623	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C624	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C625	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C626	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C627	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C628	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C629	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C630	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C631	21107-310	CAP	CERAMIC, 20%, 50V, .01 MFD
C632	21307-547	CAP	TANTALUM, 10%, 35V, 4.7 MFD
C633	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C634	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C635	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C636	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C637	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C638	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C639	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C640	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C641	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C642	21107-310	CAP	CERAMIC, 20%, 50V, .01 MFD
C643	21307-547	CAP	TANTALUM, 10%, 35V, 4.7 MFD
C644	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C645	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C646	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C647	21018-062	CAP	MICA, 1%, 500V, CD15 62 PF
C648	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C649	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C650	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C651	21205-647	CAP	ALUM, RAD 16V 47 MFD
C652	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C653	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
CR613	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
IC601	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC602	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC603	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC604	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC605	24011-104	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. C
IC606	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC607	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC608	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC609	24011-104	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. C
IC610	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC611	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC612	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC613	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC614	24011-104	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. C
IC615	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC616	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC617	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC618	24011-104	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. C
IC619	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
R601	20042-432	RES	MF, 1/8W, 1% 43.2K
R602	20040-169	RES	MF, 1/8W, 1% 169 OHM
R603	20042-576	RES	MF, 1/8W, 1% 57.6K
R604	20043-324	RES	MF, 1/8W, 1% 324K
R605	20042-453	RES	MF, 1/8W, 1% 45.3K
R606	20042-453	RES	MF, 1/8W, 1% 45.3K
R607	20042-453	RES	MF, 1/8W, 1% 45.3K
R608A	20043-357	RES	MF, 1/8W, 1% 357K
R608B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K
R609	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K
R610	20042-432	RES	MF, 1/8W, 1% 43.2K
R611	20040-169	RES	MF, 1/8W, 1% 169 OHM
R612	20042-576	RES	MF, 1/8W, 1% 57.6K
R613	20043-324	RES	MF, 1/8W, 1% 324K
R614	20042-453	RES	MF, 1/8W, 1% 45.3K
R615	20042-453	RES	MF, 1/8W, 1% 45.3K
R616	20042-453	RES	MF, 1/8W, 1% 45.3K
R617A	20043-357	RES	MF, 1/8W, 1% 357K
R617B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K
R618	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K
R619	20001-356	RES	CF, 1/4W, 5% 56K
R620	20001-547	RES	CF, 1/4W, 5% 4.7 MEG
R621	20001-347	RES	CF, 1/4W, 5% 47K

R622	20001-322	RES	CF, 1/4W, 5%	22K
R623	20043-100	RES	MF, 1/8W, 1%	100K
R624	20001-147	RES	CF, 1/4W, 5%	470 OHM
R625	20042-549	RES	MF, 1/8W, 1%	54.9K
R626	20040-210	RES	MF, 1/8W, 1%	210 OHM
R627	20042-732	RES	MF, 1/8W, 1%	73.2K
R628	20043-412	RES	MF, 1/8W, 1%	412K
R629	20042-562	RES	MF, 1/8W, 1%	56.2K
R630	20042-562	RES	MF, 1/8W, 1%	56.2K
R631	20042-562	RES	MF, 1/8W, 1%	56.2K
R632A	20043-357	RES	MF, 1/8W, 1%	357K
R632B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K	
R633	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K	
R634	20042-549	RES	MF, 1/8W, 1%	54.9K
R635	20040-210	RES	MF, 1/8W, 1%	210 OHM
R636	20042-732	RES	MF, 1/8W, 1%	73.2K
R637	20043-412	RES	MF, 1/8W, 1%	412K
R638	20042-562	RES	MF, 1/8W, 1%	56.2K
R639	20042-562	RES	MF, 1/8W, 1%	56.2K
R640	20042-562	RES	MF, 1/8W, 1%	56.2K
R641A	20043-357	RES	MF, 1/8W, 1%	357K
R641B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K	
R642	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K	
R643	20001-356	RES	CF, 1/4W, 5%	56K
R644	20001-547	RES	CF, 1/4W, 5%	4.7 MEG
R645	20001-347	RES	CF, 1/4W, 5%	47K
R646	20001-322	RES	CF, 1/4W, 5%	22K
R647	20043-100	RES	MF, 1/8W, 1%	100K
R648	20001-147	RES	CF, 1/4W, 5%	470 OHM
R649	20042-681	RES	MF, 1/8W, 1%	68.1K
R650	20040-267	RES	MF, 1/8W, 1%	267 OHM
R651	20042-909	RES	MF, 1/8W, 1%	90.9K
R652	20043-511	RES	MF, 1/8W, 1%	511K
R653	20041-715	RES	MF, 1/8W, 1%	7.15K
R654	20041-715	RES	MF, 1/8W, 1%	7.15K
R655	20041-715	RES	MF, 1/8W, 1%	7.15K
R656A	20043-357	RES	MF, 1/8W, 1%	357K
R656B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K	
R657	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K	
R658	20042-681	RES	MF, 1/8W, 1%	68.1K
R659	20040-267	RES	MF, 1/8W, 1%	267 OHM
R660	20042-909	RES	MF, 1/8W, 1%	90.9K
R661	20043-511	RES	MF, 1/8W, 1%	511K
R662	20041-715	RES	MF, 1/8W, 1%	7.15K
R663	20041-715	RES	MF, 1/8W, 1%	7.15K
R664	20041-715	RES	MF, 1/8W, 1%	7.15K
R665B	20043-357	RES	MF, 1/8W, 1%	357K
R665B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K	
R666	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K	
R667	20001-356	RES	CF, 1/4W, 5%	56K
R668	20001-547	RES	CF, 1/4W, 5%	4.7 MEG
R669	20001-347	RES	CF, 1/4W, 5%	47K
R670	20001-322	RES	CF, 1/4W, 5%	22K
R671	20043-100	RES	MF, 1/8W, 1%	100K
R672	20001-147	RES	CF, 1/4W, 5%	470 OHM
R673	20042-887	RES	MF, 1/8W, 1%	88.7K
R674	20040-340	RES	MF, 1/8W, 1%	340 OHM
R675	20043-118	RES	MF, 1/8W, 1%	118K
R676	20043-665	RES	MF, 1/8W, 1%	665K
R677	20041-909	RES	MF, 1/8W, 1%	9.09K
R678	20041-909	RES	MF, 1/8W, 1%	9.09K
R679	20041-909	RES	MF, 1/8W, 1%	9.09K
R680A	20043-357	RES	MF, 1/8W, 1%	357K
R680B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K	
R681	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K	
R682	20042-887	RES	MF, 1/8W, 1%	88.7K
R683	20040-340	RES	MF, 1/8W, 1%	340 OHM
R684	20043-118	RES	MF, 1/8W, 1%	118K
R685	20043-665	RES	MF, 1/8W, 1%	665K
R686	20041-909	RES	MF, 1/8W, 1%	9.09K
R687	20041-909	RES	MF, 1/8W, 1%	9.09K
R688	20041-909	RES	MF, 1/8W, 1%	9.09K
R689B	20043-357	RES	MF, 1/8W, 1%	357K
R689B	28503-357	RES	SELECTED, MF, 1/8W, 1/4% 3.57K	
R690	28504-100	RES	SELECTED, MF, 1/8W, 1/4% 10.0K	
R691	20001-356	RES	CF, 1/4W, 5%	56K
R692	20001-547	RES	CF, 1/4W, 5%	4.7 MEG
R693	20001-347	RES	CF, 1/4W, 5%	47K
R694	20001-322	RES	CF, 1/4W, 5%	22K
R695	20043-100	RES	MF, 1/8W, 1%	100K
R696	20001-147	RES	CF, 1/4W, 5%	470 OHM
R697A	20042-232	RES	MF, 1/8W, 1%	23.2K
R697B	20042-232	RES	MF, 1/8W, 1%	23.2K
R697C	20043-464	RES	MF, 1/8W, 1%	464K
R697D	20042-169	RES	MF, 1/8W, 1%	16.9K

BOARD #7 SMART CLIPPER, POLARITY FOLLOWER, VCA 1 & 3
30370-000-04 (FELU 226)

C701	21303-633	CAP	TANTALUM, 10%, 10V, 33 MFD
C702	21430-000	CAP	POLYESTER, RAD, 100V, 10%, .0033 MFD SEL
C703	21112-222	CAP	CERAMIC, 10%, 1000V, .0022 MFD
C704	21307-547	CAP	TANTALUM, 10%, 35V, 4.7 MFD
C705	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C706	21107-410	CAP	CERAMIC, 20%, 50V, .1 MFD
C707	21107-410	CAP	CERAMIC, 20%, 50V, .1 MFD
C708	21107-410	CAP	CERAMIC, 20%, 50V, .1 MFD
C709	21401-247	CAP	POLYESTER, RAD, 100V, 10%, .0047 MFD
C710	21401-247	CAP	POLYESTER, RAD, 100V, 10%, .0047 MFD
C711	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C712	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C713	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C714	21205-647	CAP	ALUM, RAD 16V 47 MFD
C715	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C716	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C717	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C718	21205-647	CAP	ALUM, RAD 16V 47 MFD
C719	21017-010	CAP	MICA, 1/2 PF, 500V, CD15 10 PF
C720	21017-010	CAP	MICA, 1/2 PF, 500V, CD15 10 PF
CR702	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR703	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR704	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR705	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR706	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR707	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR708	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR709	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR710	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR712	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR713	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR714	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR715	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
CR716	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
IC701	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC702	24013-202	IC	LIN, SINGLE OPAMP, T.I.-TL071CJG
IC703	25002-000	IC	OPTOISOLATOR, VALTEC VTL-5C
IC704	24402-302	IC	MULT DISCRETE, RCA CA3046
IC705	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC706	24010-102	IC	LIN, SINGLE OPAMP, NATIONAL LF357H
IC707	24502-302	IC	DIGITAL, FLIP-FLOP, RCA CA4013BE
IC708	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC709	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC710	24011-102	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. A
IC711	24006-102	IC	LIN, SINGLE OPAMP, RCA CA3140S
IC712	24206-402	IC	LIN, DUAL OPAMP, T.I. TL072CJG
IC713	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC714	24011-102	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. A
IC715	24006-102	IC	LIN, SINGLE OPAMP, RCA CA3140S
IC716	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
R701	20001-310	RES	CF, 1/4W, 5% 10K
R702	20728-000	POT	SINGLE, LOG, CW, 5K, CTS-200
R703	20041-549	RES	MF, 1/8W, 1% 5.49K
R704	20041-523	RES	MF, 1/8W, 1% 5.23K
R705	20043-100	RES	MF, 1/8W, 1% 100K
R706	20014-182	RES	CC, 1/2W, 5% 820 OHM
R707	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R708	20001-310	RES	CF, 1/4W, 5% 10K
R709	20001-418	RES	CF, 1/4W, 5% 180K
R710	20001-422	RES	CF, 1/4W, 5% 220K
R711	20001-510	RES	CF, 1/4W, 5% 1.0 MEG
R713	20001-310	RES	CF, 1/4W, 5% 10K
R714	20001-447	RES	CF, 1/4W, 5% 470K
R715	20001-310	RES	CF, 1/4W, 5% 10K
R716	20001-522	RES	CF, 1/4W, 5% 2.2 MEG
R717	20001-310	RES	CF, 1/4W, 5% 10K
R718	20001-310	RES	CF, 1/4W, 5% 10K
R719	20001-275	RES	CF, 1/4W, 5% 7.5K
R720	20001-330	RES	CF, 1/4W, 5% 30K
R721	20001-075	RES	CF, 1/4W, 5% 75 OHM
R722	20043-100	RES	MF, 1/8W, 1% 100K
R723	20042-732	RES	MF, 1/8W, 1% 73.2K
R724	20042-732	RES	MF, 1/8W, 1% 73.2K
R725	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R726	20001-310	RES	CF, 1/4W, 5% 10K
R727	20001-010	RES	CF, 1/4W, 5% 10 OHM
R728	20001-322	RES	CF, 1/4W, 5% 22K
R729	20043-150	RES	MF, 1/8W, 1% 150K
R730	20043-150	RES	MF, 1/8W, 1% 150K
R731	20001-422	RES	CF, 1/4W, 5% 220K
R732	20001-451	RES	CF, 1/4W, 5% 510K
R733	20001-256	RES	CF, 1/4W, 5% 5.6K
R734	20042-105	RES	MF, 1/8W, 1% 10.5K
R735	20509-210	POT	TRIM, CERMET, 1T, BECKMAN 72XR1K
R736	20042-100	RES	MF, 1/8W, 1% 10.0K
R737	20042-100	RES	MF, 1/8W, 1% 10.0K
R738	20042-475	RES	MF, 1/8W, 1% 47.5K
R739	20042-523	RES	MF, 1/8W, 1% 52.3K
R740	20042-732	RES	MF, 1/8W, 1% 73.2K
R741	20042-732	RES	MF, 1/8W, 1% 73.2K
R742	20042-732	RES	MF, 1/8W, 1% 73.2K
R743	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R744	20001-310	RES	CF, 1/4W, 5% 10K
R745	20001-010	RES	CF, 1/4W, 5% 10 OHM
R746	20001-275	RES	CF, 1/4W, 5% 7.5K
R747	20014-215	RES	CC, 1/2W, 5% 1.5K
R748	20001-322	RES	CF, 1/4W, 5% 22K
R749	20011-622	RES	CC, 1/4W, 5% 22 MEG
R750	20001-347	RES	CF, 1/4W, 5% 47K
R751	20001-439	RES	CF, 1/4W, 5% 390K
R752	20001-422	RES	CF, 1/4W, 5% 220K
R753	20727-000	POT	SINGLE, LIN, CW, 50K, CTS-200
R754	20001-247	RES	CF, 1/4W, 5% 4.7K
R755	20001-351	RES	CF, 1/4W, 5% 51K
R756	20041-464	RES	MF, 1/8W, 1% 4.64K
R757	20041-909	RES	MF, 1/8W, 1% 9.09K
R758	20001-247	RES	CF, 1/4W, 5% 4.7K
R759	20001-224	RES	CF, 1/4W, 5% 2.4K

R760	20041-931	RES	MF, 1/8W, 1% 9.31K
R761	20041-200	RES	MF, 1/8W, 1% 2.00K
R762	20001-410	RES	CF, 1/4W, 5% 100K
R763	20720-000	POT	SINGLE, LIN, 10K, CTS-200
R764	20042-215	RES	MF, 1/8W, 1% 21.5K
R765	20042-301	RES	MF, 1/8W, 1% 30.1K
R766	20001-268	RES	CF, 1/4W, 5% 6.8K
R767	20041-301	RES	MF, 1/8W, 1% 3.01K
R768	20041-604	RES	MF, 1/8W, 1% 6.04K
R769	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R770	20042-732	RES	MF, 1/8W, 1% 73.2K
R771	20042-732	RES	MF, 1/8W, 1% 73.2K
R772	20042-732	RES	MF, 1/8W, 1% 73.2K
R773	20042-365	RES	MF, 1/8W, 1% 36.5K
R774	20042-732	RES	MF, 1/8W, 1% 73.2K
R775	20042-732	RES	MF, 1/8W, 1% 73.2K
R776	20001-322	RES	CF, 1/4W, 5% 22K
R777	20001-310	RES	CF, 1/4W, 5% 10K
R778	20011-622	RES	CC, 1/4W, 5% 22 MEG
S701	26037-004	SWI	TOGGLE, MIN, 4PDT, C&K 7401
VR701	22003-110	DIO	ZENER, 1W, 10%, 11V, MOTOROLA 1N4741

BOARD #8 TRANSMITTER EQ AND OUTPUT
30415-001-03

C801	21302-647	CAP	TANTALUM, 10%, 6V, 47 MFD
C802	21018-115	CAP	MICA, 1%, 500V, CD15 150 PF
C803	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C804	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C805	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C806	21018-124	CAP	MICA, 1%, 500V, CD15 240 PF
C807	21602-310	CAP	POLYCARBONATE, 2%, .01 MFD
C808	21019-033	CAP	MICA, 2%, 500V, CD15 33 PF
C810	21401-268	CAP	POLYESTER, RAD, 100V, 10%, .0068 MFD
C811	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C813	21307-547	CAP	TANTALUM, 10%, 35V, 4.7 MFD
C814	21017-010	CAP	MICA, 1/2 PF, 500V, CD15 10 PF
C815	21107-410	CAP	CERAMIC, 20%, 50V, .1 MFD
C824	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C825	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C826	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C827	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C828	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C829	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C830	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C831	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C832	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C833	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C834	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C835	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C836	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C837	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C838	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C839	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C840	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C841	21304-622	CAP	TANTALUM, 10%, 15V, 22 MFD
CR801	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR802	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR803	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR804	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR805	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR806	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR807	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR808	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR809	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR810	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR811	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR812	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR813	25102-002	LED	GREEN, MONSANTO MV5253
CR814	25102-001	LED	RED, MONSANTO MV5753
IC801	24206-202	IC	LIN, DUAL OPAMP, T.I. TL072
IC802	24206-202	IC	LIN, DUAL OPAMP, T.I. TL072
IC803	24206-202	IC	LIN, DUAL OPAMP, T.I. TL072
IC804	24206-202	IC	LIN, DUAL OPAMP, T.I. TL072
IC805	24206-202	IC	LIN, DUAL OPAMP, T.I. TL072
IC806	24501-302	IC	DIGITAL, RCA CD4011BE
Q801	23202-101	TRA	SIG, NPN, FAIRCHILD 2N4400
Q802	23202-101	TRA	SIG, NPN, FAIRCHILD 2N4400
Q803	23002-101	TRA	SIG, PNP, FAIRCHILD 2N4402
Q804	23002-101	TRA	SIG, PNP, FAIRCHILD 2N4402
Q805	23202-101	TRA	SIG, NPN, FAIRCHILD 2N4400
Q806	23202-101	TRA	SIG, NPN, FAIRCHILD 2N4400
Q807	23002-101	TRA	SIG, PNP, FAIRCHILD 2N4402
Q808	23002-101	TRA	SIG, PNP, FAIRCHILD 2N4402

Q809 THRU Q816	23403-101	TRA	FET, SILCONIX J111
Q817	25001-000	IC	OPTOISOLATOR, MONSANTO MCT-26
Q818	25001-000	IC	OPTOISOLATOR, MONSANTO MCT-26
Q819	23202-101	TRA	SIG, NPN, FAIRCHILD 2N4400
R801	20042-210	RES	MF, 1/8W, 1% 21.0K
R802	20042-475	RES	MF, 1/8W, 1% 47.5K
R803	20042-887	RES	MF, 1/8W, 1% 88.7K
R804	20043-110	RES	MF, 1/8W, 1% 110.0K
R805	20042-210	RES	MF, 1/8W, 1% 21.0K
R806	20042-105	RES	MF, 1/8W, 1% 10.5K
R807	20041-464	RES	MF, 1/8W, 1% 4.64K
R808	20042-422	RES	MF, 1/8W, 1% 42.2K
R809	20042-226	RES	MF, 1/8W, 1% 22.6K
R810	20042-287	RES	MF, 1/8W, 1% 28.7K
R811	20042-226	RES	MF, 1/8W, 1% 22.6K
R812	20042-150	RES	MF, 1/8W, 1% 15.0K
R813	20001-218	RES	CF, 1/4W, 5% 1.8K
R814	20042-150	RES	MF, 1/8W, 1% 15.0K
R815	20001-310	RES	CF, 1/4W, 5% 10K
R816	20042-100	RES	MF, 1/8W, 1% 10.0K
R817	20820-001	POT	CONTROL, 10T, 100K, BOURNS 3501S-1-104
R818	20042-150	RES	MF, 1/8W, 1% 15.0K
R819	20042-150	RES	MF, 1/8W, 1% 15.0K
R820	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R821	20001-147	RES	CF, 1/4W, 5% 470 OHM
R822	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R823	20001-147	RES	CF, 1/4W, 5% 470 OHM
R824	20043-100	RES	MF, 1/8W, 1% 100.0K
R825	20042-143	RES	MF, 1/8W, 1% 14.3K
R826	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R827	20001-382	RES	CF, 1/4W, 5% 82K
R828	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R829	20727-000	POT	SINGLE, LIN, CW, 50K, CTS-270
R830	20042-150	RES	MF, 1/8W, 1% 15.0K
R831	20042-150	RES	MF, 1/8W, 1% 15.0K
R836	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R837	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K
R838	20001-320	RES	CF, 1/4W, 5% 20K
R839	20001-320	RES	CF, 1/4W, 5% 20K
R840	20043-100	RES	MF, 1/8W, 1% 100.0K
R841	20043-499	RES	MF, 1/8W, 1% 499.0K
R842	20000-947	RES	CF, 1/4W, 5% 4.7 OHM
R843	20000-947	RES	CF, 1/4W, 5% 4.7 OHM
R844	20001-227	RES	CF, 1/4W, 5% 2.7K
R845	20042-150	RES	MF, 1/8W, 1% 15.0K
R846	20042-150	RES	MF, 1/8W, 1% 15.0K
R847	20000-947	RES	CF, 1/4W, 5% 4.7 OHM
R848	20000-947	RES	CF, 1/4W, 5% 4.7 OHM
R849	20001-227	RES	CF, 1/4W, 5% 2.7K
R850	20001-322	RES	CF, 1/4W, 5% 22K
R851	20014-122	RES	CC, 1/2W, 5% 220 OHM
R852	20014-122	RES	CC, 1/2W, 5% 220 OHM
R853	20014-122	RES	CC, 1/2W, 5% 220 OHM
R854	20001-347	RES	CF, 1/4W, 5% 47K
R855	20001-510	RES	CF, 1/4W, 5% 1.0 MEG
R856	20001-347	RES	CF, 1/4W, 5% 47K
R857	20001-347	RES	CF, 1/4W, 5% 47K
R858	20014-210	RES	CC, 1/2W, 5% 1K

BOARD #9   CLOCK, DELAY 1&2, VCA 2, "OR", INTEGRATOR, CLIPPER, LP FILTER
30390-000 03 (+ECO 246)

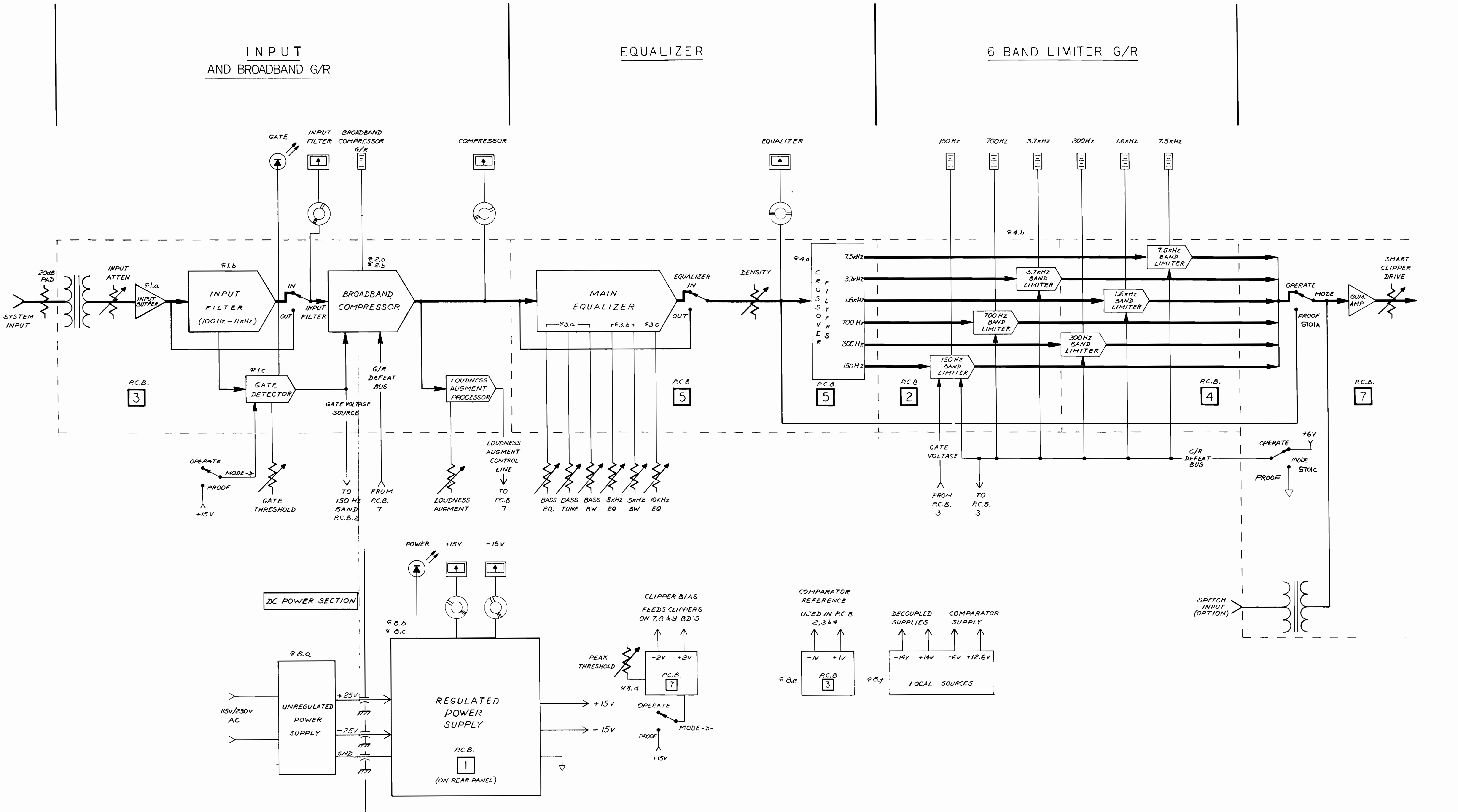
A901	30385-000	ASY	MODULE, INTEGRATOR, 9000A
C901	21106-410	CAP	CERAMIC, 20%, 25V, .1 MFD
C902	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C903	21103-447	CAP	CERAMIC, 20%, 12V, .47 MFD
C904	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C905	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C906	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C907	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C908	21018-122	CAP	MICA, 1%, 500V, CD15 220 PF
C909	21022-210	CAP	MICA, 1%, 500V, CD19 1000 PF
C910	21106-410	CAP	CERAMIC, 20%, 25V, .1 MFD
C911	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C912	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C913	21019-118	CAP	MICA, 2%, 500V, CD15 180 PF
C914	21023-191	CAP	MICA, 2%, 500V, CD19 910 PF
C915	21305-610	CAP	TANTALUM, 10%, 20V, 10 MFD
C916	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C917	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C918	28506-000	CAP	MICA, 1%, CD15FD(414)F03, 414 PF
C919	21601-222	CAP	POLYCARBONATE, 1%, .0022 MFD
C920	21601-310	CAP	POLYCARBONATE, 1%, .01 MFD
C921	21305-610	CAP	TANTALUM, 10%, 20V, 10 MFD
C922	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C923	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C924	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C925	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C926	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C927	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C928	21205-647	CAP	ALUM, RAD 16V 47 MFD
C929	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C930	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C931	21020-047	CAP	MICA, 5%, 500V, CD15 47 PF
C932	21307-510	CAP	TANTALUM, 10%, 35V, 1 MFD
C933	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
C934	21106-350	CAP	CERAMIC, 20%, 25V, .05 MFD
CR901	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR902	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR903	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR904	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR905	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR906	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR907	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR908	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR909	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR910	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR911	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR912	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR913	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR914	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR915	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR916	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR917	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR918	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR919	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR920	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR921	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR922	22101-000	DIO	SIGNAL, FAIRCHILD 1N4148
CR923	22201-400	DIO	RECTIFIER, 1A, MOTOROLA 1N4004
IC901	24502-302	IC	DIGITAL, FLIP-FLOP, RCA CA4013BE
IC902	24502-302	IC	DIGITAL, FLIP-FLOP, RCA CA4013BE
IC903	24503-302	IC	DIGITAL, RCA CD4049UBE
IC904	24702-302	IC	SPECIAL FUNCTION, RETICON SAD-1024
IC905	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC906	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC907	24011-102	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. A
IC908	24006-102	IC	LIN, SINGLE OPAMP, RCA CA3140S
IC909B	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC910	24401-101	IC	MULT DISCRETE, NATIONAL LM3019
IC911	24011-102	IC	LIN, SINGLE OPAMP, RCA CA3080S, GD. A
IC912	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC913	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
IC914A	24202-102	IC	LIN, MULT OPAMP, RAYTHEON RC4558T
L901	29504-000	MSE	INDUCTOR, 50 mh, MILLER 70F502AF
Q901	23001-101	TRA	SIG, PNP, MOTOROLA 2N4125
R901	20042-453	RES	MF, 1/8W, 1% 45.3K
R902	20041-634	RES	MF, 1/8W, 1% 6.34K
R903	20001-239	RES	CF, 1/4W, 5% 3.9K
R904	20509-250	POT	TRIM, CERMET, 1T, BECKMAN 72XR5K
R905	20001-447	RES	CF, 1/4W, 5% 470K
R906	20001-315	RES	CF, 1/4W, 5% 15K
R907	20001-315	RES	CF, 1/4W, 5% 15K
R908	20042-422	RES	MF, 1/8W, 1% 42.2K
R909	20042-422	RES	MF, 1/8W, 1% 42.2K
R910	20001-439	RES	CF, 1/4W, 5% 390K
R911	20042-499	RES	MF, 1/8W, 1% 49.9K
R912	20042-499	RES	MF, 1/8W, 1% 49.9K
R913	20041-205	RES	MF, 1/8W, 1% 2.05K
R914	20042-100	RES	MF, 1/8W, 1% 10.0K
R915	20041-887	RES	MF, 1/8W, 1% 8.87K
R916	20509-150	POT	TRIM, CERMET, 1T, BECKMAN 72XR500 OHM
R917	20042-316	RES	MF, 1/8W, 1% 31.6K
R918	20043-154	RES	MF, 1/8W, 1% 154K
R919	20042-768	RES	MF, 1/8W, 1% 76.8K
R920	20042-255	RES	MF, 1/8W, 1% 25.5K
R921	20042-255	RES	MF, 1/8W, 1% 25.5K
R922	20043-140	RES	MF, 1/8W, 1% 140K
R923	20043-140	RES	MF, 1/8W, 1% 140K
R924	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K
R925	20001-310	RES	CF, 1/4W, 5% 10K
R926	20001-010	RES	CF, 1/4W, 5% 10 OHM
R927	20001-275	RES	CF, 1/4W, 5% 7.5K
R928	20043-150	RES	MF, 1/8W, 1% 150K
R929	20043-150	RES	MF, 1/8W, 1% 150K
R930	20001-322	RES	CF, 1/4W, 5% 22K
R931	20001-422	RES	CF, 1/4W, 5% 220K
R932	20509-510	POT	TRIM, CERMET, 1T, BECKMAN 72XR1MEG
R933	20001-227	RES	CF, 1/4W, 5% 2.7K
R934	20042-453	RES	MF, 1/8W, 1% 45.3K

R935	20001-239	RES	CF, 1/4W, 5%	3.9K
R936	20509-250	POT	TRIM, CERMET, 1T, BECKMAN 72XR5K	
R937	20001-447	RES	CF, 1/4W, 5%	470K
R938	20042-100	RES	MF, 1/8W, 1%	10.0K
R939	20001-410	RES	CF, 1/4W, 5%	100K
R940	20001-315	RES	CF, 1/4W, 5%	15K
R941	20001-315	RES	CF, 1/4W, 5%	15K
R942	20042-221	RES	MF, 1/8W, 1%	22.1K
R943	20042-221	RES	MF, 1/8W, 1%	22.1K
R944	20042-110	RES	MF, 1/8W, 1%	11.0K
R945	20043-140	RES	MF, 1/8W, 1%	140K
R946	20043-140	RES	MF, 1/8W, 1%	140K
R947	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K	
R948	20001-310	RES	CF, 1/4W, 5%	10K
R949	20001-010	RES	CF, 1/4W, 5%	10 OHM
R950	20001-339	RES	CF, 1/4W, 5%	39K
R951	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K	
R952	20509-310	POT	TRIM, CERMET, 1T, BECKMAN 72XR10K	
R953	20001-510	RES	CF, 1/4W, 5%	1.0 MEG
R954	20042-750	RES	MF, 1/8W, 1%	75.0K
R955	20042-825	RES	MF, 1/8W, 1%	82.5K
R956	20042-110	RES	MF, 1/8W, 1%	11.0K
R957	20043-392	RES	MF, 1/8W, 1%	392K
R958	20043-432	RES	MF, 1/8W, 1%	432K
R959	20042-100	RES	MF, 1/8W, 1%	10.0K
R960	20042-232	RES	MF, 1/8W, 1%	23.2K
R961	20042-232	RES	MF, 1/8W, 1%	23.2K
R962	20042-255	RES	MF, 1/8W, 1%	25.5K
R963	20042-464	RES	MF, 1/8W, 1%	46.4K
R964	20042-127	RES	MF, 1/8W, 1%	12.7K
R965	20001-433	RES	CF, 1/4W, 5%	330K
R966	20042-309	RES	MF, 1/8W, 1%	30.9K
R967	20042-750	RES	MF, 1/8W, 1%	75.0K
R968	20042-750	RES	MF, 1/8W, 1%	75.0K
R969	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K	
R970	20001-356	RES	CF, 1/4W, 5%	56K
R971	20001-227	RES	CF, 1/4W, 5%	2.7K
R972	20001-247	RES	CF, 1/4W, 5%	4.7K
R973	20509-250	POT	TRIM, CERMET, 1T, BECKMAN 72XR5K	
R974	20043-402	RES	MF, 1/8W, 1%	402K
R975	20042-243	RES	MF, 1/8W, 1%	24.3K
R976	20041-348	RES	MF, 1/8W, 1%	3.48K
R977	20042-324	RES	MF, 1/8W, 1%	32.4K
R978	20042-243	RES	MF, 1/8W, 1%	24.3K
R979	20001-410	RES	CF, 1/4W, 5%	100K
R980	20041-178	RES	MF, 1/8W, 1%	1.78K
R981	20042-280	RES	MF, 1/8W, 1%	28.0K
R982	20001-447	RES	CF, 1/4W, 5%	470K
R983	20509-350	POT	TRIM, CERMET, 1T, BECKMAN 72XR50K	

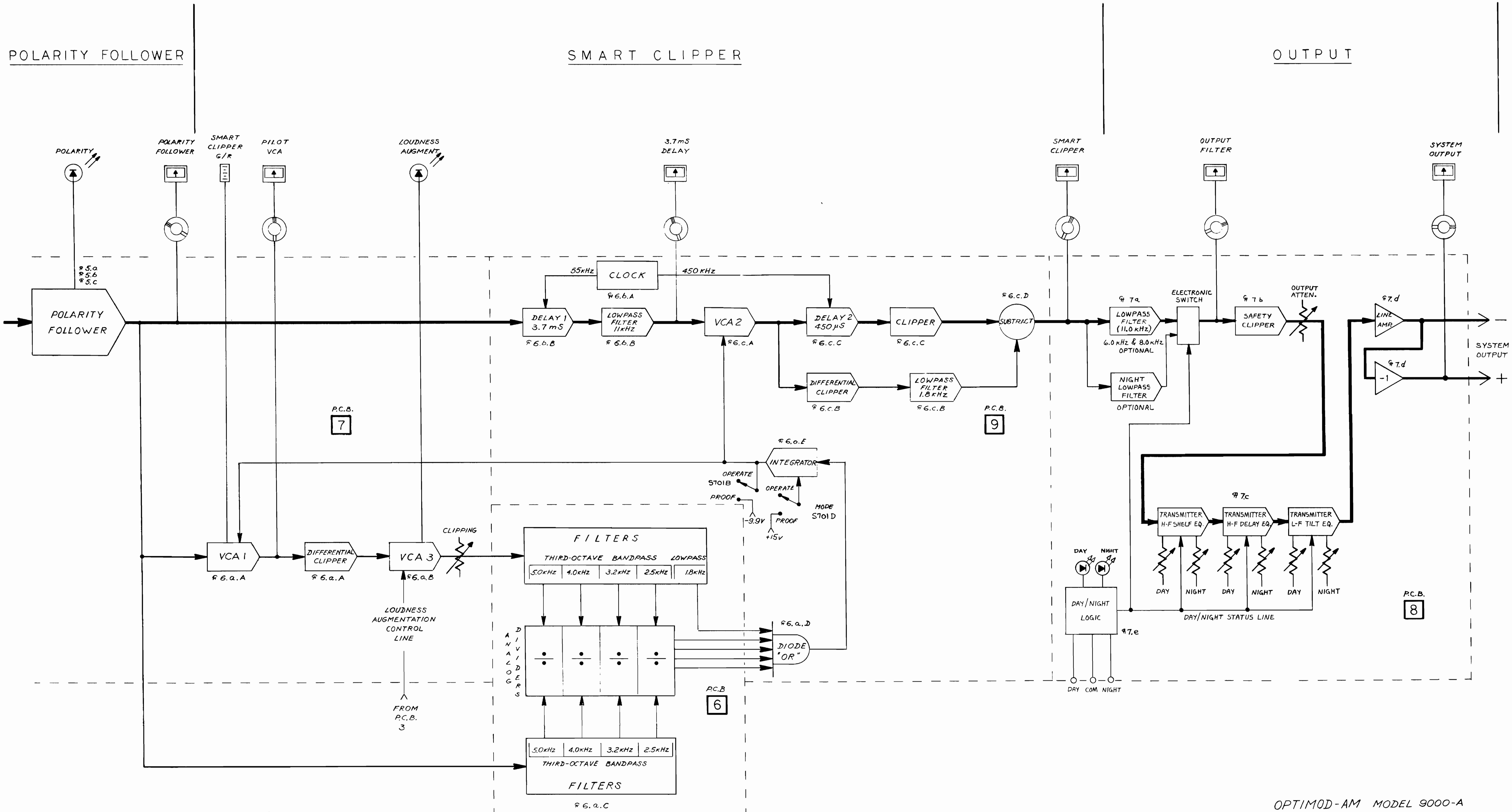
OPTIMOD-AM MODEL 9000A/1

SYSTEM BLOCK DIAGRAM

C



INPUT
AND BROADBAND G/R
EQUALIZER
6 BAND LIMITER G/R
SYSTEM INPUT
20dB PAD
INPUT ATTEN
INPUT BUFFER
INPUT FILTER (100Hz – 11kHz)
GATE
INPUT FILTER
BROADBAND COMPRESSOR G/R
BROADBAND COMPRESSOR
GATE DETECTOR
GATE THRESHOLD
GATE VOLTAGE SOURCE
G/R DEFEAT BUS
COMPRESSOR
LOUDNESS AUGMENT. PROCESSOR
LOUDNESS AUGMENT
LOUDNESS AUGMENT CONTROL LINE
TO P.C.B 7
TO 150 Hz BAND P.C.B. 2
FROM P.C.B. 7
OPERATE
MODE
PROOF
+15V
P.C.B. 3
MAIN EQUALIZER
EQUALIZER IN
OUT
BASS EQ.
BASS TUNE
BASS BW
5kHz EQ
5kHz BW
10kHz EQ
P.C.B. 5
DENSITY
CROSSOVER FILTERS
7.5kHz
3.7kHz
1.6kHz
700 Hz
300 Hz
150 Hz
150 Hz BAND LIMITER
700 Hz BAND LIMITER
3.7kHz BAND LIMITER
300Hz BAND LIMITER
1.6kHz BAND LIMITER
7.5kHz BAND LIMITER
P.C.B. 2
P.C.B. 4
GATE VOLTAGE
FROM P.C.B. 3
TO P.C.B. 3
G/R DEFEAT BUS
OPERATE
MODE
PROOF
S701A
S701C
+6V
SUM. AMP
SMART CLIPPER DRIVE
P.C.B. 7
SPEECH INPUT (OPTION)
DC POWER SECTION
POWER
+15V
-15V
115V/230V AC
UNREGULATED POWER SUPPLY
+25V
-25V
GND
REGULATED POWER SUPPLY
P.C.B. 1
(ON REAR PANEL)
+15V
-15V
CLIPPER BIAS
FEEDS CLIPPERS ON 7,8 & 9 BD'S
PEAK THRESHOLD
-2V
+2V
P.C.B. 7
OPERATE
MODE
PROOF
+15V
COMPARATOR REFERENCE
USED IN P.C.B. 2,3 & 4
-1V
+1V
P.C.B. 3
DECOUPLED SUPPLIES
COMPARATOR SUPPLY
-14V
+14V
-6V
+12.6V
LOCAL SOURCES



SYMBOLS & ABBREVIATIONS

¶ – PARAGRAPH REFERENCES TO CIRCUIT DESCRIPTION IN MANUAL
P.C.B. – PRINTED CIRCUIT BOARD
VCA – VOLTAGE CONTROLLED AMPLIFIER

OPTIMOD-AM MODEL 9000-A
BLOCK DIAGRAM

ORBAN ASSOC., INC
SAN FRANCISCO, CA 94107

DOC 60109 -000-03