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Symetrix 421 AGC-Leveler

Owner's Manual

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Part number: 530202
Subject to change at our whim, and without notice.

Batteries not included. Ground isn't ground!
Available at finer studios everywhere.

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1. Introduction

The Symetrix 421 is a wide-range AGC-Leveler, a peak limiter, and a downward expander. The 421 reduces the dynamic range of its input signal by the amount of its ratio setting. That is, if the ratio setting is 2:1, then 40 dB of input range turns into 20 dB at the output. A fast peak limiter puts an absolute ceiling on the output level so you know that peaks are held to the level that you set. A downward expander reduces the gain when signal levels fall too low to process, reducing the noise buildup at low signal levels. Speech filters allow reducing the bandpass of the 421 to minimize feedback or amplifier power waste caused by spurious out-of-band signals.

AGC-Levelers can be used anywhere that you might need to reduce the dynamic range of an audio signal over a wide range of signal levels. Possible applications include: tape duplication (especially cassette), driving telephone lines, driving broadcast or STL transmitters, podium or lectern microphones, paging systems, unattended sound systems, and music recording.

The 421 is Listed by Underwriters Laboratories Inc. (UL). Samples of this product have been evaluated by UL and meet the applicable UL Standards for Safety.

We recommend that you read this manual from cover to cover. Somewhere between the confines of the two covers you should find the answers to most (98%) of your questions, both technical as well as musical.

If you're in a hurry (like most of us), or if you really don't believe that someone could write a decent owners manual that you can read and understand, then do us both a favor and read section 6, "Fast First Time Setup." This section will help you get connected, tell you what the knobs do, and send you on your way.

1.1 Manual Sections

This manual contains the following sections:

Chapter 1 *Introduction*, introduces the 421 and the parts of this manual.

Chapter 2 *AGC-Leveler Basics*, lets you know what the 421 does, and how it does it.

Chapter 3 *Technical Tutorial*, a basic and not-so-basic discussion of signal levels, input and output impedances, and connection polarity.

Chapter 4 *Front Panel Overview*, gives a brief look at the controls and switches located on the front panel of the 421.

Chapter 5 *Rear Panel Overview*, gives a brief look at the rear panel of the 421.

Chapter 6 *Fast, First Time Setup*, is a section written especially for people who just can't wait to get their hands on the knobs.

Chapter 7 *Using the* 421, describes the use of the 421 in greater detail.

Chapter 8 *Applications*, describes some of the myriad uses for the 421.

Chapter 9 *Troubleshooting*, tells what to do if the 421 doesn't work.

Chapter 10 *Limited Warranty*, describes the 421's warranty.

Chapter 11 *Repair Information*, tells how to get your 421 repaired.

Chapter 12 *Specifications*, lists the technical specifications of the 421.

Chapter 13 *Service Information*, contains printed circuit board layouts and schematic diagrams for the 421.

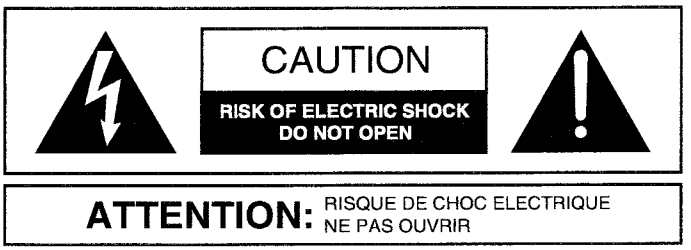
Appendices Contains architects and engineers specifications as well as disassembly instructions.

1.2 Operator Safety Summary

The information in this summary is intended for persons who operate the equipment as well as repair personnel. Specific warnings and cautions are found throughout this manual wherever they may apply; they do not appear in this summary.

The notational conventions used in this manual and on the equipment itself are described in the following paragraphs.

1.2.1 Equipment Markings



No user serviceable parts inside. Refer servicing to qualified service personnel.
Il ne se trouve a l'interieur aucune piece pourvant entre reparée l'usager.
S'adresser a un reparateur compétent.

The lightning flash with arowhead symbol within an equilateral triangle is intended to alert the user of the presence of uninsulated "dangerous voltage" within the product's enclosure that may be of sufficient magnitude to constitute a risk of electric shock to persons.	The exclamation point within an equilateral triangle is intended to alert the user of the presence of important operating and maintenance (servicing) instructions in the literature accompanying the appliance (i.e. this manual).

Caution

To prevent electric shock, do not use the polarized plug supplied with this appliance with any extension cord, receptacle, or other outlet unless the blades can be fully inserted to prevent blade exposure.

1.2.2 Terms

Several notational conventions are used in this manual. Some paragraphs may use Note, Caution, or Warning as a heading. These headings have the following meaning:

Convention	Description
Note	Identifies information that needs extra emphasis. A Note generally supplies extra information to help you use the 421 better.
Caution	*Identifies information that, if not heeded, may cause damage to the* 421 *or other equipment in your system.*
Warning	**Identifies information that, if ignored, may be hazardous to your health or that of others.**

In addition, certain typefaces and capitalization are used to identify certain words. These situations are:

Convention	Meaning
CAPITALS	Controls, switches or other markings on the chassis.
Boldface	Strong emphasis.

1.3 Other Safety Information

Power Source	This product is intended to operate from a power source that does not apply more than 250V rms between the power supply conductors or between either power supply conductor and ground. A protective ground connection, by way of the grounding conductor in the power cord, is essential for safe operation
Grounding	The chassis of this product is grounded through the grounding conductor of the power cord. To avoid electric shock, plug the power cord into a properly wired receptacle before making any connections to the product. A protective ground connection, by way of the grounding conductor in the power cord, is essential for safe operation.
Danger from Loss of Ground	If the protective ground connection is lost, all accessible conductive parts, including knobs and controls that may appear to be insulated, can render an electric shock.
Proper Power Cord	Use only the power cord and connector specified for the product and your operating locale. Use only a cord that is in good condition.
Proper Fuse	The fuse is mounted internally and is not considered user serviceable. The fuseholder accepts American sized fuses (1/4 in dia.) or European sized fuses (5mm dia). For 117 VAC operation, the correct value is 1/2 A, 250VAC, fast blowing (Bussman type AGC) For 230 VAC operation, the correct value is 1/4 A, 250VAC, fast blowing (Bussman type AGC).
Operating Location	Do not operate this equipment under any of the following conditions: explosive atmospheres, in wet locations, in inclement weather, improper or unknown AC mains voltage, or if improperly fused.
Stay Out of the Box	To avoid personal injury (or worse), do not remove the product covers or panels. Do not operate the product without the covers and panels properly installed.
User-serviceable parts	There are no user serviceable parts inside the 421. In case of failure, refer all servicing to the factory or to a qualified repair person.

Notes

2. AGC-Leveler Basics

2.1 Introduction

The AGC-Leveler is a new tool that is now available to the sound contractor. New? Hardly; AGC-Levelers have been around for years. New because of new technology that improves overall operation, and new because of new features that solve real-world sound contracting problems. The missing detail is: nobody has ever packaged all the pieces together in the same box.

The problem of controlling varying audio levels has plagued and puzzled sound engineers since the beginnings of audio. The earliest form of audio level control was an operator turning a rotary attenuator while listening to the program material. This still works today, and given a skilled operator blessed with a certain amount of ESP, can work as well or better than any electronic gain control device that you or I could think up. Of course, most circuit engineers would look upon the last statement as a thinly veiled challenge; as a result, engineers have been thinking up ways to automatically control audio levels for years.

2.2 Definitions

Over the years, some of the following terms have had their definitions "stretched" for one reason or another. To ensure clarity (not to mention correctness), these are the definitions used in this manual:

Compressor	Reduces its gain for signals above a determined threshold. Typical input/output ratios range from 1:1 to 9:1.
Limiter:	Brick wall, high ratio compression. Prevents signal from passing determined threshold level. Typical ratios range from 10:1 or higher.
Leveler:	Another name for a compressor or limiter.
Downward-Expander:	Performs noise reduction by decreasing the signal level as it falls below a determined threshold level. Typical expansion ratios are 1:1.5 to 1:3.
Gate:	Similar to a downward expander except that the gain falls abruptly as the input signal falls below the determined threshold. Typical expansion ratios for a gate are 1:50 or higher (ideally infinite).
AGC	Automatic Gain Control. A compressor with a very low threshold setting and an input/output ratio between 1.1:1 and 4:1. Gain reduction release is signal dependent. Increases its gain for signals falling below the target output level (unity-gain crossover point) and reduces its gain for signals above that level.

2.3 A Bit of History

From an evolutionary standpoint, compressors evolved first, quickly followed by peak limiters and expanders. The gate and downward expander are relative newcomers to the field (late 1960s). Applying a compressor to a varying audio signal for wide-range AGC worked fine...until the signal stopped...at which time the compressor's gain returned to normal (release time) along with the noise inherent in the input source. So, (trumpet fanfare for a great idea!) why not prevent the compressor from releasing (its gain reduction) when there isn't any signal? This is the spark for every audio AGC ever made.

The letters AGC stand for Automatic Gain Control. Functionally, an AGC works like an invisible (and hopefully inaudible) operator who monitors the audio level and imperceptibly raises or lowers the gain to maintain the audio level at some predetermined point. In its most simplistic form, that's all there is to it. (But there is a BUT, as you will see.)

An AGC can also be considered as a special case of an over-threshold compressor having a relatively low ratio (1:1 -> 4:1) and a very low threshold level. Thus, any signal that exceeds the threshold causes some degree of gain reduction. Additional gain, applied after the compressor, brings the signal level back up to line level. If this were all there was to an AGC, we could pack up now and go home.

AGC amplifiers have been with us for many years. In the broadcast world, the old Gates Level-Devil and CBS Labs Audimax are both examples of old (circa 1960) products that performed this function. The feature that sets these guys apart from common-ordinary-garden-variety compressors is: gated, program-controlled release.

If you remember back to the early days of TV, remember when someone at the network screwed up and let the program lapse, the compressor at the local station would release and whoooosh, up would come the noise floor...until the guy at network woke up, in which case it went suuuuuuuuck and back into the program audio. Both the Level-Devil and Audimax fixed this problem by making the release time of the compressor a function of the program audio. That is, they inhibited the gain reduction release if there was no audio present. If audio was present, then the compressor was free to release as much as it wanted, but if there was no audio present, the unit remained at the amount of gain reduction in force before the audio loss.

Similarly, peak limiters have also been around for years. The old Teletronix LA-2 (circa 1962) and UREI LA-3 were both peak limiters that were labeled "leveling amplifiers." Both behaved according to the previously stated definition of a peak limiter. A more recent (relatively) design, the UREI 1176 (circa 1970) combined a peak limiter and a compressor, however, you could only have one or the other (a peak limiter reverts to a compressor when you set the compression ratio below 10:1). A much more recent design, the Symetrix 425 (circa 1991), combines a peak limiter, a compressor, and a downward expander and you can use each section simultaneously. This is equivalent to having three processors wired in series; the first processor is a downward expander, second is a compressor, and last is a peak-limiter. Now you can compress the program subtly, and still have the overload protection that only a peak limiter can provide, and have downward expansion to reduce low-level noise. Figure 2-1 illustrates this concept.

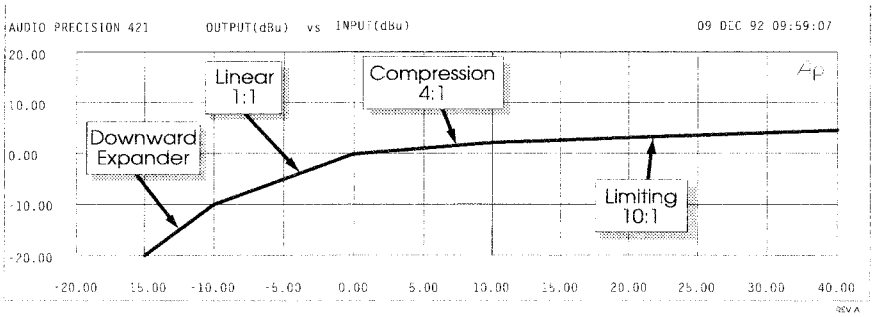


Figure 2-1. Simultaneous downward expansion, compression and limiting.

2.3.1 Silence Detectors Don't Work.

Both the Audimax and the Level-Devil depended upon silence to control the gain-release function. In practice, the silence detector can be fooled by a noisy input signal. Since the AGC/Leveler needs to work at very low threshold levels in order to accommodate a wide range of input levels (ideally, you want the AGC/Leveler to function with signals ranging from near thermal noise to high line level), an ordinary signal-present detector would respond to hum or noise by mistaking it for a valid signal.

If you try using a simple compressor as an AGC, there is no signal-controlled gated-release function. Thus the overall gain is highest anytime that the signal falls below the compressor's

threshold. By itself, this isn't disastrous (perfectly workable with a noiseless input signal), but the sudden change in noise level when a normal-level signal presents itself is a dead giveaway that your compressor is lacking in the IQ department. This is the BUT mentioned earlier.

2.4 A Better Way

As you can see, each different approach works, albeit with drawbacks. A 1990s solution to the problem of random level control would combine the following audio tools:

1. AGC with intelligent gain release.

2. Downward expander for low-level noise reduction.

3. Peak Limiter to establish an absolute peak ceiling.

The Symetrix 421 combines all of these functions and more into a single-rack space package. Figure 2-2 shows the 421's input/output curves. The block diagram can be found in Section 7.

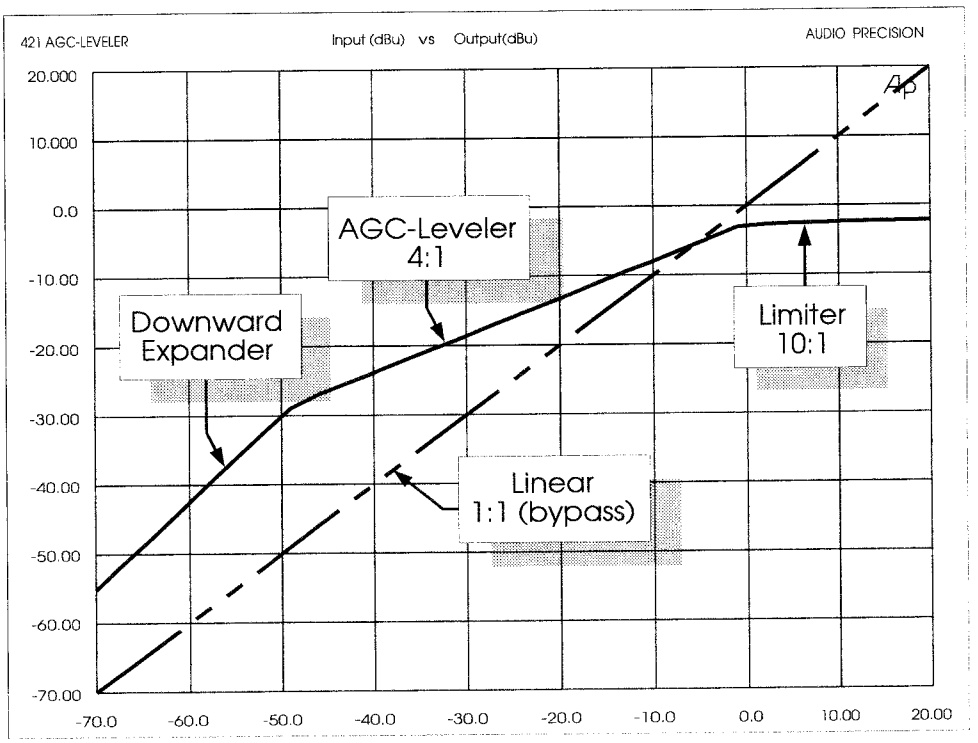


Figure 2-2. Overall 421 input/output curves.

2.4.1 The AGC-Leveler

The 421 uses proprietary circuit techniques to determine the nature of the 421's control signal. If the signal isn't noise (hum, thermal noise, or acoustic feedback), then the 421 allows normal AGC-Leveler release activity. We call this feature ARM (AutoReleaseMonitor). The ARM circuitry provides a high degree of reliability in knowing when to allow the AGC-Leveler to release.

The ARM circuitry makes the action of the 421 less obvious since it can decide whether the input signal is real, thermal noise or feedback. ARMed with this information, the 421 will not release until it knows that it has a real input signal, which effectively eliminates noise pumping or acoustic feedback during program pauses. In sound reinforcement, the ARM considers slight or sustained ringing (acoustic feedback) to be noise; thus the gain remains at

the current setting, which helps keep the sound system from regenerating. If we were using a simple compressor as an AGC and had sufficient gain to cause feedback, the compressor would always keep the sound system at the brink of regeneration (much like the light bulb in a Wein-bridge oscillator). When new program material arrives at the input, the 421 seeks a new gain setting to maintain the new program material at the proper level.

2.4.2 A Smart Downward Expander

The 421s downward expander operates in two modes: NORMAL and AUTO. In normal mode, the downward expander works as previously explained. In AUTO mode, the 421 uses the ARM logic to control the expander's gain. The expander effectively becomes a gate, controlled by the presence of audio, and not by noise (hiss, hum, or feedback). Since the ARM considers feedback or ringing to be noise, the expander cannot be triggered by feedback, especially if the overall system gain is high enough to cause sustained ringing. Without ARMing the expander, any feedback present in the signal keeps the expander's gate open, allowing the feedback to continue. With the gate ARMed, the gain falls rapidly once the real input signal passes which stops any feedback or ringing.

2.4.3 Peak Limiter Provides Absolute Peak Protection.

By its very nature, an AGC-Leveler needs attack and release times that are fast enough to control the dynamics of the signal, and slow enough to follow long-term variations in the signal without destroying the program's dynamics (remember that our mission is to control the dynamic range, and not to remove it). Since AGC/Leveler's are generally limited to about a 4:1 ratio, (any higher and the unit would begin to act more like a limiter than an AGC), it is still possible for high-level signals to still exceed the targeted output level even after being compressed by 3:1 or 4:1. A fast-acting peak-limiter effectively puts a ceiling on the overall output giving you the peace-of-mind that NO peaks will ever escape.

2.4.4 Is Wideband Response Really Necessary?

In many speech-only systems, the only limitation to the overall frequency response of the system is the loudspeakers themselves. The old rock-and-roller's trick of pulling down the last few sliders on a graphic equalizer is not nearly as effective as a sharp-cutoff high- or low-pass filter. Figure 2-3 illustrates the frequency response of a "combining" one-third octave graphic equalizer with the first 5 sliders set to -12 dB and the speech filters of the 421. Notice the poor stopband attenuation of the graphic EQ. (In all fairness to the EQ, this is not how the manufacturer intended it to be used, but it is how many users attempt to create a high-pass filter characteristic using a graphic equalizer.

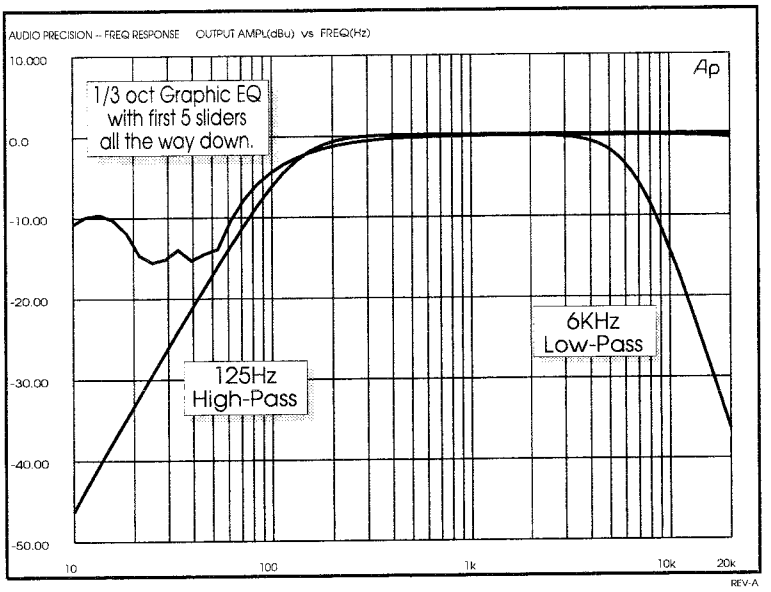


Figure 2-3. Highpass filter using a graphic equalizer.

The 421 has individually switched, sharp-cutoff filters that really work. The low-cut filter (125 Hz, 12 dB/octave) does a great job of removing proximity effect, room or air conditioning rumble, footfalls, p-popping, just plain removing low-frequency junk or protecting horn-loaded paging speakers from stray low-frequency signals. The high-cut filter (6kHz, 24 dB/octave) removes excess hiss and sibilance without causing telephone-quality. Both filters are also useful for stopping acoustic feedback caused by uncontrolled frequency response (sound system response where there is no useful program material).

2.4.5 Automatic Make-up Gain

Another drawback to using a common-ordinary compressor as an AGC is the change in output level as you reset the compression ratio. For many applications, such as channel or group insert compressors or limiters, this doesn't matter. For AGC applications, it makes the unit that much more difficult to use. The 421 adds just the right amount of extra make-up gain via the ratio control to keep the output level constant. Thus, increasing the compression ratio makes the program denser, without affecting the overall level.

Notes

3. Technical Tutorial

This section discusses a multitude of things, all related to getting signals in and out of the 421.

3.1 Matching Levels vs Matching Impedances

In any audio equipment application, the question of "matching" inevitably comes up. Without digging a hole any deeper than absolutely necessary, we offer the following discussion to (hopefully) clarify your understanding of the subject.

Over the years, we have all had impedance matching pounded into our heads. This is important only for ancient audio systems, power amplifiers, and RF. Technically speaking, the reason is power transfer, which reaches a maximum when source and load are matched. Modern audio systems are voltage transmission systems and source and load matching is not only unnecessary, but undesirable as well.

- ❒ Ancient audio systems operate at 600 ohms (or some other impedance value), and must be matched, both at their inputs and at their outputs. Generally speaking, if you are dealing with equipment that uses vacuum tubes, or was designed prior to 1970, you should be concerned about matching. These units were designed when audio systems were based on maximum power transfer, hence the need for input/output matching.
- ❒ Power amplifiers are fussy because an abnormally low load impedance generally means a visit to the amp hospital. Thus, it's important to know what the total impedance of the pile of speakers connected to the amplifier really is.
- ❒ RF systems are matched because we really are concerned with maximum power transfer and with matching the impedance of the transmission line (keeps nasty things from happening). Video signals (composite, baseband, or otherwise) should be treated like RF.

Some folks seem to believe that balanced/unbalanced lines and impedances are related; or even worse that they are associated with a particular type of connector. Not so. Unbalanced signals are not necessarily high-impedance and balanced signals/lines are not necessarily low-impedance. Similarly, although 1/4 inch jacks are typically used for things like guitars (which are high-impedance and unbalanced), this does not predispose them to only this usage. After all, 1/4 inch jacks are sometimes used for loudspeakers, which are anything but high-impedance. Therefore, the presence of 3-pin XLR connectors should not be construed to mean that the input or output is low-impedance (or high-impedance). The same applies to 1/4 inch jacks.

So, what is really important? Signal level, and (to a much lesser degree), the impedance relation between an output (signal source) and the input that it connects to (signal receiver).

Signal level is very important. Mismatch causes either loss of headroom or loss of signal-to-noise ratio. Thus, microphone inputs should only see signals originating from a microphone, a direct (DI) box, or an output designated microphone-level output. Electrically, this is in the range of approximately -70 to -20 dBm. Line inputs should only see signals in the -10 to +24 dBm/dBu range. Guitars, high-impedance microphones, and many electronic keyboards do not qualify as line-level sources.

The impedance relation between outputs and inputs needs to be considered, but only in the following way:

> **Always make sure that a device's input impedance is higher than the output source impedance of the device that drives it.**

Some manufacturers state a relatively high-impedance figure as the output impedance of their equipment. What they really mean is that this is the minimum load impedance that they would like their gear to see. In most cases, seeing a output impedance figure of 10,000 (10K)

ohms or higher from modern equipment that requires power (batteries or AC) is an instance of this type of rating. If so, then the input impedance of the succeeding input must be equal to or greater than the "output impedance" of the driving device.

Symetrix equipment inputs are designed to bridge (be greater than 10 times the actual source impedance) the output of whatever device drives the input. Symetrix equipment outputs are designed to drive 600 ohm or higher loads (600 ohm loads are an archaic practice that won't go away). You don't need to terminate the output with a 600 ohm resistor if you aren't driving a 600 ohm load. If you don't understand the concept of termination, you probably don't need to anyway.

The two facts that you need to derive from this discussion are:

- **Match signal levels for best headroom and signal-to-noise ratio.**

- **For audio, impedance matching is only needed for antique equipment and power amplifier outputs. In all other cases, ensure that your inputs bridge (are in the range of 2 to 200 times the output source impedance) your outputs.**

3.2 Signal Levels

The 421 is designed around studio/professional line levels: +4 dBu or 1.23 volts. The unit is quiet enough to operate at lower signal levels such as those found in semi-pro or musical-instrument (MI) equipment (-10 dBu or 300 millivolts). Conversely, there is sufficient headroom to operate the 421 at +8 levels found in some broadcast applications. The signal level at the sidechain jacks is the same as that found at the input connectors (but the interface point is unbalanced).

3.3 I/O Impedances

The 421 is designed to interface into almost any recording studio or sound reinforcement application. This includes:

- 600 ohm systems where input and output impedances are matched.
- Unbalanced semi-professional equipment applications.
- Modern bridging systems where inputs bridge and outputs are low source impedances (voltage transmission systems).

The 421's input impedance is 30 kilohms balanced, and 15 kilohms unbalanced. The inputs may be driven from any source (balanced or unbalanced) capable of delivering at least -10 dBu into the aforementioned impedances.

The 421's insert jack is an unbalanced I/O point connected to a TRS phone jack. The tip connection is the return, the ring connection is the send. The output source impedance is 1000 ohms, intended to drive a load of 10k ohms minimum. The receive input impedance is 10 kilohms, unbalanced. The gain between the input connectors and the insert-point is -6 dB.

The 421's output impedance is 200 ohms balanced, 100 ohms unbalanced. The output line driver delivers +23 dBm into 600 ohm balanced loads or +17 dBm into 600 ohm unbalanced loads.

3.4 Polarity Convention

The 421 uses the international standard polarity convention of pin 2 hot. Table 3-1 lists the connections used.

If your system uses balanced inputs and outputs, and uses the 421 this way, then the polarity convention is unimportant. If your system is both balanced and unbalanced, then you must pay attention to this, especially when going in and coming out through different connector types (like input on an XLR, output on a phone jack).

XLR	Tip-Ring-Sleeve	Signal
1	Sleeve	Ground
2	Tip	High
3	Ring	Low

Table 3-1. XLR Connector Wiring.

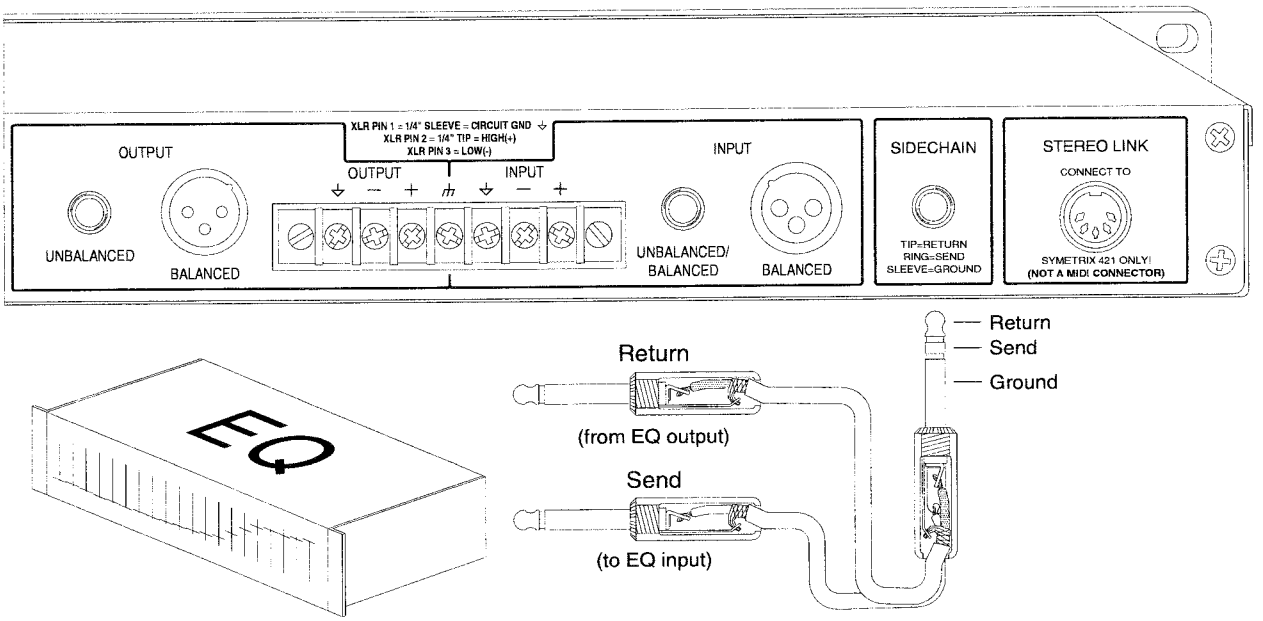


Figure 3-1. Sidechain insert jack connections.

3.5 Input and Output Connections

Figure 3-2 illustrates how to connect the 421 to balanced and unbalanced sources and loads.

To operate the 421 from unbalanced sources, run a 2-conductor shielded cable (that's two conductors plus the shield) from the source to the 421. At the source, connect the low/minus side to the shield, these connect to the source's ground; connect the high/plus side to the source's signal connection. At the 421, the high/plus wire connects to pin 2, the low/minus wire connects to pin 3, and the shield (always) connects to pin 1. This is the preferred method because it makes best use of the 421's balanced input (even though the source is unbalanced). The other alternative shown in Figure 3-2 converts the 421's balanced input into an unbalanced input at the input connector. This works, but is more susceptible to hum and buzz than the preferred method. There is no level difference between either method.

You can drive unbalanced loads with the 421's differentially balanced outputs by using the XLR connector with pin 3 left open. In an emergency (the show must go on), you can ground pin 3, but if you have the choice...leave it open. If you must ground pin 3, it is must be grounded at the 421, rather than at the other end of the cable. The price, regardless of whether or not pin 3 is grounded is 6 dB less output level. This can easily be made up via the TARGET OUTPUT LEVEL control.

Note: If you ground pin 3 of the XLR connector (when driving an unbalanced input from a differentially balanced output), one side of the balanced output stage ends up driving the ground system. This won't harm the 421, but should be avoided if possible. If pin 2 of the XLR is grounded, the output will likely be distorted. If you must ground pin 3, then ensure that it is grounded at the 421. This keeps the current from the output stage, via pin 3, out of the overall ground system, which avoids nasty and unexpected surprises later on.

The 421's sidechain insert jacks are unbalanced I/O points connected to a TRS phone jack. The tip connection is the return, the ring connection is the send (Soundcraft convention). Typically, these connections are used with an external equalizer and Figure 3-1 illustrates the connections used.

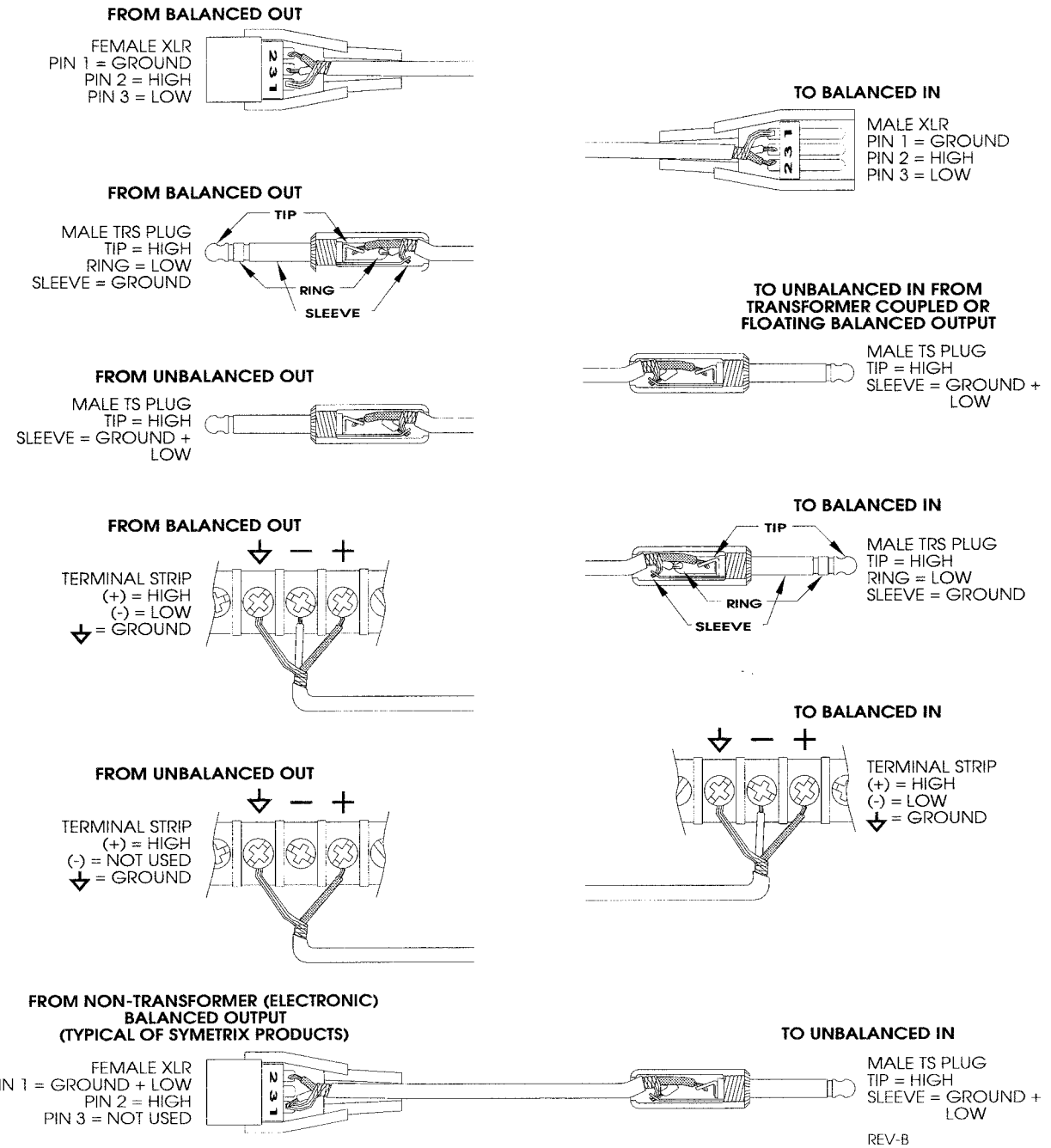
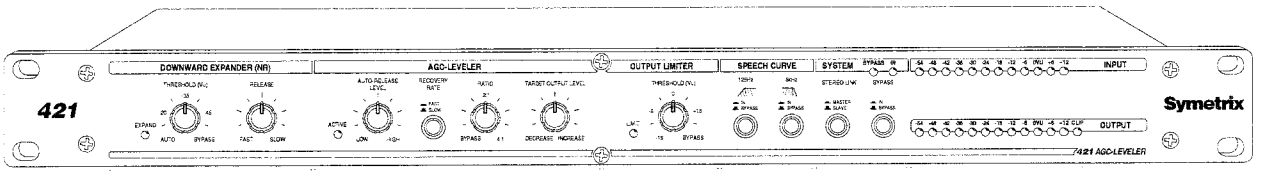


Figure 3-2. Input and output connector wiring. These diagrams represent the majority of connectors used in modern audio equipment. Locate the source connector in the left column and match it up with the destination connector in the right column. Wire your cable according to the diagrams. The "FROM" and "TO" in the drawings refers to the connectors or terminal strip connections and not to the other end of the wire.

Notes

4. Front Panel Overview



DOWNWARD EXPANDER:

THRESHOLD — Determines the level below which the downward expander operates, which reduces the gain at a 1:2 dB ratio.

At the max CCW setting of the control, the threshold setting is automatic; determined by the setting of the AUTORELEASE LEVEL control. In this case, the downward expander acts more like a gate (very high ratio) NOTE: the silence detector thinks that acoustic feedback is silence!

At the max CW setting, the threshold setting is low enough that all signals are above threshold, therefore the expander is bypassed.

RELEASE — Determines the rate of decay for the downward expander.

LED — Activity indicator, tells when the downward expander is active.

AGC-LEVELER:

AUTO-RELEASE LEVEL — Determines the level that the input signal must exceed to allow the AGC-Leveler to release. If the signal level is below this threshold (activity LED OFF), then the AGC release function is not allowed; the AGC allows the signal level to fall to zero. This keeps the AGC-Leveler from "undoing" fades, etc.

Another way to understand this control is to think of it in terms of the minimum signal level required to make the AGC-Leveler try to maintain the Target Output Level. Once the signal falls below the AUTO-RELEASE LEVEL setting, the AGC-Leveler allows the signal to decrease. When the input signal crosses the AUTO-RELEASE LEVEL setting, the AGC-Leveler once again tries to maintain constant output level.

RECOVERY RATE — Switch that sets the basic recovery-time. Fast for speech, slow for music or music/speech. Fast might work for music in special applications.

RATIO — Determines the input/output ratio, like on any other gain-reduction device. Unlike other devices, the 421 computes the additional make-up gain needed for the ratio setting and applies it to the VCA so that the output level doesn't change with the setting of the ratio control.

TARGET OUTPUT LEVEL — Sets the approximate output level desired from the 421.

LED — Indicates leveling activity. If the LED is off, then the gain of the AGC-Leveler is frozen at the last setting. The signal level where the gain is frozen is determined by the AUTO-RELEASE LEVEL control.

OUTPUT LIMITER:

THRESHOLD — Sets the threshold of the peak (ceiling) limiter. This works in conjunction with the leveler's ratio and target output level controls. The way this works is: the 421 will not allow the peak limiter to be set higher than the setting of the target output level control. If you think about it, it would make no sense if you allowed peaks past the target output level, so that's the way it is.

LED — Indicates activity in the peak limiter.

SPEECH CURVE:

125 HZ — 12 dB/octave rolloff for speech applications.

6KHZ — 24 dB/octave rolloff for speech applications.

SYSTEM:

STEREOLINK — Sets master/slave relationship between 2 units. **The "normal" (master/single-unit) setting is IN.**

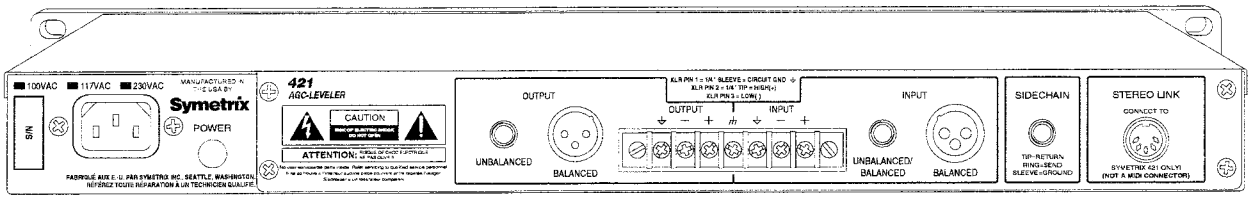
BYPASS — Hard-wire bypasses the 421. If STEREOLINKED, all linked (slave) units revert to bypass as well. Has no effect on any slave that has been STEREOLINKED (STEREOLINK switch OUT).

METERING:

INPUT — Indicates the input signal level to the 421. VU calibrated peak-meter.

OUTPUT — Indicates the output signal level of the 421. VU calibrated peak-meter.

5. Rear Panel Overview



serial number	Do yourself a favor and write this number down in a safe place (how about the front of this manual?). While you're at it, do us a favor and return your completed warranty card. Not only does it establish your warranty, it helps give us a clue to your equipment wants, needs, and desires.
power connector	IEC power receptacle. Connect the power cord to an appropriate source of AC power. Observe the marked power supply voltage on rear panel.
Outputs	1/4" TRS, wired for unbalanced operation (ring connected to circuit ground). XLR-male, differentially balanced. All outputs paralleled.
Screw Terminals	Barrier strip with #6 screw connections. Contains all input and output connections as well as chassis and circuit ground connections. The screw terminal inputs and outputs are wired in parallel with their respective connectors.
Inputs	1/4" TRS, XLR-female, balanced bridging. All inputs paralleled.
Sidechain	1/4" TRS, ring = send, tip = return (Soundcraft convention).
StereoLink	5-pin DIN female connector. Used to link two 421s for stereo operation. Refer to section 6.1 for additional information.

5.1 Grounding

The 421 can be configured to conform to serveral different grounding conventions (float circuit, ground circuit) via connections on barrier strip. The factory-supplied configuration has the chassis connected to the circuit ground via a 10 ohm resistor paralleled with a 0.1 mfd capacitor. The U-ground (third wire/safety ground) connection to the power cord is directly connected to the chassis.

In most installations, the factory grounding configuration works best. In some instances (high RF levels, or Consultant's specification), it may be necessary to directly connect the circuit ground to the chassis. This can be accomplished via the connections found on the terminal strip located on the rear panel.

Notes

6. Fast First Time Setup

Follow these instructions to get your 421 up-and-running as quickly as possible. The intent of this section is fast setup. If you need something clarified, then you'll find the answer elsewhere in this manual.

6.1 Connections

Connect the 421 as a "through" device; that is, breaking either the input or output connections (NOT disconnecting the AC power since that results in a BYPASS condition) must result in silence. Use any combination of the input and output connections. All of the input connections are paralleled. The XLR output connector and the balanced screw terminal outputs are paralleled. The unbalanced output is paralleled from the + screw terminal output. The 421 wants line level signals, such as those found at the output of a CD player, cassette machine, mixer output, mixer channel insert jack, etc. Figure 6-1 shows a basic hookup.

To stereo-link two 421s, interconnect the STEREOLINK jacks found on the rear panels of the units using a five-pin DIN male to DIN male patch cord (Symetrix p/n 037010). This looks like a MIDI cable, and a MIDI cable may actually work if all five pins are actually connected to each other.

> **Note:** Although the stereo-interconnect cable *looks* like a MIDI cable, **it isn't**. There is nothing remotely resembling MIDI inside or between two 421s. If you connect either connector to a MIDI device, it *probably* won't harm anything, it *definitely* won't work, and it *may* allow you to communicate with a nearby galaxy (if it does, please call us and let us know which one! Be sure to record the conversation.).

Decide which unit is the master and which unit is the slave (using force only if absolutely necessary) and set the front panel MASTER/SLAVE switches accordingly. In stereo-mode, the slave unit's controls are disabled and only the master unit controls affect operation. Figure 6-2 shows how to stereo-link two 421s.

Note: If there is no master unit connected via the StereoLink connectors, the slave unit (any unit with its MASTER/SLAVE switch in the OUT position) remains in bypass mode, regardless of the setting of its bypass switch.

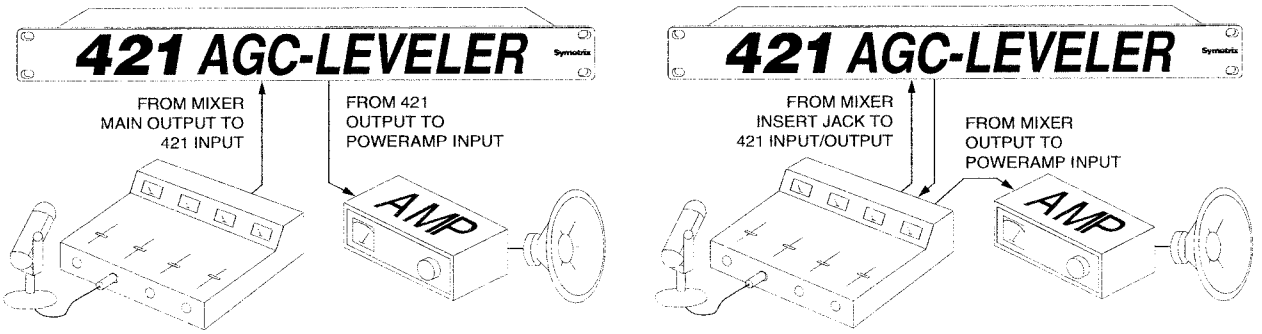


Figure 6-1. Basic 421 hookup.

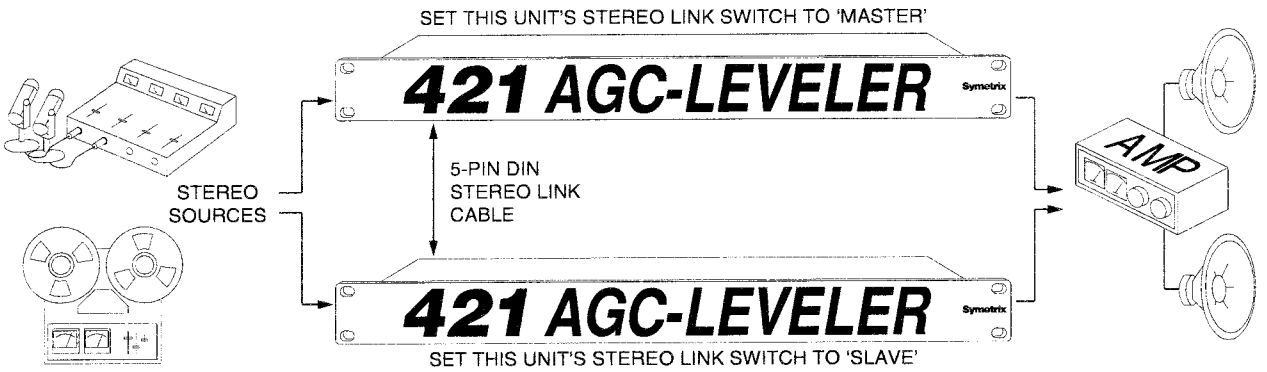


Figure 6-2. Stereo interconnection.

6.2 Initial Setup

Set the front panel controls as follows:

Downward Expander:		**Speech Curve:**	
THRESHOLD	bypass	125 HZ	out
RELEASE	12:00	6 KHZ	out
AGC-Leveler:		**System:**	
AUTO-RELEASE LEVEL	12:00	MASTER/SLAVE	in
RECOVERY RATE	in	BYPASS	in
RATIO	4:1		
TARGET OUTPUT LEVEL	12:00		

Apply an input signal to the 421. Observe the input meter; there should be activity. Observe the output meter; there should also be activity. The input meter reads the actual input signal, the output meter reads the actual output signal. Both meters are peak responding and are calibrated in VU (0 VU = +4 dBu = 1.23V RMS).

Set the AGC-Leveler by first adjusting the TARGET OUTPUT LEVEL control for the output level required. Next, decrease the setting of the RATIO control until you obtain the desired amount of dynamic range reduction. Speech tolerates higher ratios than music although speech squashed at 4:1 sounds a bit unnatural. The difference between the two meters visually shows what the 421 is doing. Remember that a 1:1 ratio setting amounts to BYPASS for the AGC-Leveler. Set the RECOVERY RATE switch as required by the program material (starting point: fast for speech, slow for music, slow for mixed speech and music).

In sound reinforcement applications, set the AUTO-RELEASE LEVEL control to limit the pickup "range" of the microphone. Lower (more CCW) settings will increase the pickup range (the level setting is lower, therefore the AGC-Leveler will track lower level signals), and higher settings will force the user to be more "on-mike."

In recording, broadcast or tape duplication applications, the AUTO-RELEASE LEVEL control sets the minimum signal level that the AGC-Leveler will track. If the input signal were music, with a long fade, the AGC-Leveler interprets the fade as a decrease in signal level and raises the gain to try to maintain the level set by the TARGET OUTPUT LEVEL control. In effect, the AGC-Leveler "undoes" the fade, which may or may not be allowable. The AUTO-RELEASE LEVEL control sets how far the signal level can fall before the AGC-Leveler stops trying to raise the gain. More CCW settings lower this level, which may be what you want if you're trying to recreate the long piano chord heard at the end of the Beatles song, *A day in the life.*

Set the downward expander during program pauses to minimize noise buildup by adjusting the THRESHOLD control until the expand activity LED illuminates. Set the RELEASE control for the desired release rate.

Use the AUTO position of the downward expander THRESHOLD control for situations where the input signal is noisy (hum, hiss, or feedback). In AUTO mode, the expander tracks the AGC-Leveler's AutoRelease monitor. When the AGC-Leveler releases, the expander begins working, at the rate set by the RELEASE control. If the input signal contains acoustic feedback, the AutoRelease monitor ignores it, which effectively stops the feedback before it has a chance to grow into something ugly or potentially damaging.

Set the output limiter by adjusting the THRESHOLD control either for the absolute maximum output level desired (as read on the threshold control's panel scale) or as indicated on the peak-responding output meter.

Set the SPEECH CURVE switches as necessary and as required by the situation. The 125 Hz switch removes boominess and some of the proximity effect caused by close-talking a single-D cardioid microphone (such as a Shure SM-58), without making voices sound thin. The 6kHz switch removes sibilance and high-frequency feedback without causing "telephone voice."

Note: Do not use pink noise or sine-waves for setup. It simply will not work (the ARM circuitry will think your signal is noise). Use speech or music.

Notes

7. Using the 421

This section is intended for more advanced users. If AGC-Levelers are new to you, we recommend that you start out by using the procedure found in "Fast, First-Time Setup."

7.1 Block Diagram

Figure 7-1 is the block diagram of the 421. Please take a moment and take note of the following:

1. All input connectors are paralleled. The polarity standard used is pin-2 hot.
2. All output connectors are paralleled, with the exception of the unbalanced TRS output connector (which is paralleled on the tip connection only). The polarity standard is pin-2 hot.
3. Bypass mode is relay-controlled, hard-wire.
4. The slope of the 125 Hz highpass filter is 12 dB/octave.
5. The slope of the 6kHz lowpass filter is 24 dB/octave.

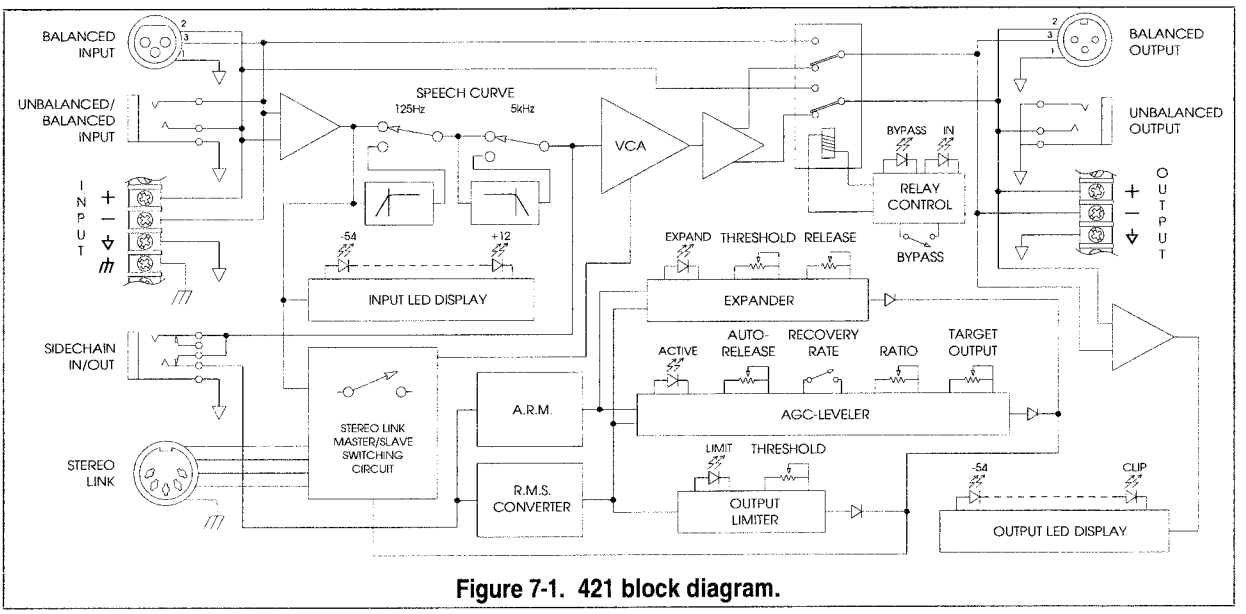


Figure 7-1. 421 block diagram.

7.2 Installation

The 421 may be installed free-standing or rack mounted. No special ventilation requirements are necessary.

Mechanical	One rack space (1.75 inches) required, 10 inches depth (including connector allowance). Rear chassis support recommended for road applications.
Electrical	105-125 VAC, 50-60Hz, 15 watts maximum.
Connectors	XLR-3 female for inputs, XLR-3 male for outputs, both connectors paralleled with TRS females and terminal strip. TRS female for sidechain. DIN-5 female for STEREOLINK. Pin 2 of the XLR connectors is "Hot."
SIDECHAIN	This is both an input and output on the same connector (tip = input/return, ring = output/send).
STEREOLINK	Interconnect the two stereo link jacks with 5-pin DIN male-male cable. (See previous note in Chapter 6.)

7.3 Using the Sidechain Jacks

The sidechain is a patch point in the control circuit of a dynamic range processor, which provides access to the part of the circuitry that tells the VCA what to do. The 421's sidechain signal is routed through a TRS jack located on the rear panel that provides both a send and return via the same jack. The sidechain connection affects all three processors in the 421. The wiring diagram for the sidechain in/out connector is reproduced on the back panel of the 421. The TRS jack is connected as follows: tip = return, ring = send, sleeve = ground.

Refer to the block diagram. Notice the SIDECHAIN connections that come from the balanced input stage. They allow access to the control circuit's input signal. The control signal is derived from, but kept totally separate from, the audio signal path. This means the control signal can be processed outside the 421 without actually processing the signal that's going through the VCA (the audio signal itself). This presents some very interesting possibilities for changing or improving the operation of the dynamic range processor.

The best use of the sidechain is to make the action of the 421's AGC-Leveler/limiter/expander frequency dependent, that is, to make it respond more (or less) to certain frequencies in the audio signal. Because the audio signal and the control signal remain completely separate (even while the control circuit tells the VCA whether to turn the gain up or down), you can equalize the sidechain without changing the EQ in the main audio path.

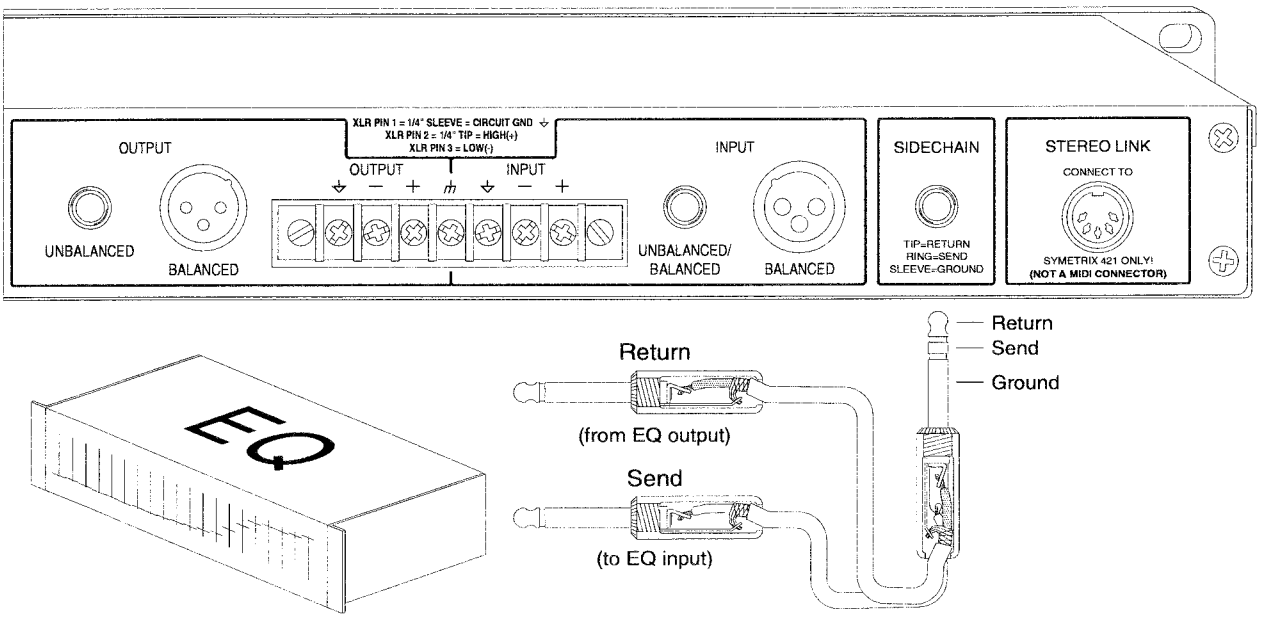


Figure 7-2 Basic sidechain hookup

Removing unwanted frequencies from the control signal before it actually reaches the VCA prevents those frequencies from being used to create gain changes. Perhaps most importantly, this happens without actually equalizing the signal being processed through the 421.

To make the 421's processors more sensitive to high frequencies, use an equalizer (graphic or parametric) to boost the high frequencies in the sidechain signal. This increases the sensitivity of the control circuits to those particular frequencies so the AGC-Leveler/limiter/expander responds more to those frequencies than any others. If the offending frequencies produce a control signal of greater amplitude than the desired frequencies they will control how the AGC-Leveler/limiter/expander behaves with the rest of the signal as well. However, if the offending signals are of significantly greater amplitude than the rest of the signal, careful adjustment of the corresponding threshold control (combined with the boost provided by the EQ in the sidechain) will make the compressor/limiter/expander respond only to the boosted frequencies.

Keep in mind that the threshold levels become a function of the amount of overall gain through the equalizer, including the boost. This technique can be used with any frequency that can be controlled by the equalizer.

Cutting a frequency creates the inverse effect, making the 421 *less* sensitive to the frequencies that were removed from the control signal.

In normal mode (not AUTO mode), the expander only discriminates between different levels (not different sounds); it can be fooled by signals whose levels are nearly the same, even if the frequency content of those signals is fundamentally different. When the 421's expander is used to shut out unwanted sounds, any signal exceeding the threshold setting triggers the expander. When this happens, it's often possible to eliminate the false triggering by equalizing the control signal.

For example, if low frequency signals transmitted through a desk or podium are triggering the 421's expander unnecessarily you can use the sidechain equalizer to do one of the following:

- ❒ Use an equalizer in the sidechain to remove the low frequencies from the control signal.
- ❒ Use the equalizer to boost the voice-range frequencies in the control signal.

When the offending frequencies are removed or minimized, the relative level of the desired frequencies increases and the expander can now tell the difference between the wanted and unwanted signals. Use this technique in any situation where levels are nearly the same, but the fundamental frequencies involved are different.

> **NOTE** The ability of the expander to discriminate between wanted and unwanted signals is partially determined by mic technique. Be particularly careful of high frequency sounds entering the side or rear pattern of a cardioid mic. Most cardioid mics exhibit a sharply rising off-axis response characteristic at higher frequencies. Check the off-axis curve (the lower one) in the manufacturer's literature. If there's only a 3dB to 6dB difference between the on-axis (frontal) response and the off-axis (side or rear) response in the 5kHz to 10kHz reason, high frequency sounds will be picked up by the side or back of your mic.
>
> Use the mic's directional pattern to keep other sources as far off-axis as possible - do everything you can do to extract all the source-to-source discrimination possible through good mic technique. The sounds picked up by individual mics must be primarily the sound of the desired signal, or the expander won't be able to tell the difference.
>
> **Hint:** You can save time, and make life easier by listening to the output of the equalizer (instead of the 421 output) that you're using in the sidechain. Doing this allows you to hear the signal that will control the 421, and perhaps to find the range that you wish to emphasize or de-emphasize more easily.

7.4 Optimizing Control Settings

When searching for an optimum control setting, here are a few rules-of-thumb to follow:

The FAST setting of the RECOVERY RATE switch is best suited for speech signals. Use the SLOW setting for musical or noisy signals or if you want the gain changes to be as unobtrusive as possible.

The RATIO control determines how much of the input signal's dynamic range makes it through to the output. The 4:1 setting is pretty obtrusive and is probably not a usual setting unless you really want to hear the effect of a parameter change. We recommend that you start at 4:1 (so you can hear the effect) and then find a more esthetic setting.

The AUTORELEASE LEVEL control determines the signal level needed to cause gain release in the AGC-Leveler section of the 421. A suggested method of setting it is: with no signal present (microphone live, but no speech), increase the setting of the AUTORELEASE LEVEL control until the green "ACTIVE" LED extinguishes. Then, further increase the control setting slightly.

For musical signals, use the SLOW setting of the RECOVERY RATE switch. Set the AUTORELEASE LEVEL control as low as possible, so that the "ACTIVE" LED is extinguished during silent periods.

When using the AUTO setting of the downward expander, first set the AUTORELEASE LEVEL control in the AGC-Leveler section of the 421. Now use the expander's RELEASE control to prevent expander action during short pauses.

When using the 421 in a PA situation, ensure that feedback can not occur if the AGC-Leveler reaches a state of zero gain reduction. Do this by forcing auto-recovery to occur by quickly turning the AUTORELEASE LEVEL control in the clockwise direction (causing the LED to illuminate). Once release occurs, you can return to your desired setting. If necessary, reduce the RATIO setting or the TARGET OUTPUT LEVEL setting to eliminate the feedback. If you need a bit more gain, you may be able to achieve it by increasing the target level until the system rings, then use the downward expander in the AUTO mode to lower the system gain when there is no signal. You may have to tolerate a small amount of ringing on the tail of a word, but this is probably preferable to inaudibility.

7.5 StereoLink and Bypass Switching

The STEREO LINK and BYPASS switches interract. In stereo mode, the designated master unit takes over all functions of the slave, including in/bypass switching.

If the STEREO LINK switch is in the "out" position, the 421 is in slave-mode. In slave mode, the 421 gets its mode commands via the link cable from the master unit. This includes in/bypass switching.

Note

If there is no master unit connected via the STEREO LINK connectors, the slave unit remains in bypass mode, regardless of the setting of its BYPASS switch. If there is a master unit, then the BYPASS switch on the master determines the in/bypass status of the slave.

8. Applications

An AGC-Leveler has many applications in the recording studio, in auditoriums or theatres, in commercial or industrial PA systems, in tape duplication, or in broadcast. Here are some of the applications that we've come up with here at Symetrix. If you think of an unusual idea for using the 421, please share it with us. If it's really unique, we'll send you something useful (in our opinion) for your trouble.

8.1 Broadcast Telephone Line Driver

Sometime or another, every broadcast engineer ends up having to send audio down a leased telephone line (as opposed to a dial-up line). Of course, you need to keep the levels hot, but if you hit the line too hard the phone company frowns, etc. It's good practice to ensure that there is a hard limit to any signal that ends up going down a phone line. Again, the 421 is well suited to the task of being an unobtrusive, yet unyielding guardian of the audio level.

As a starting point, use the SLOW recovery rate, low ratio (2:1 or lower), and a low AUTORELEASE LEVEL setting. Set the target level control for the desired average level into the line, and then dial in enough peak limiting to keep the peaks under control. You may want to back the target level off slightly so that you don't need as much peak limiting (peak limiters are more inaudible if you only limit occasional peaks).

8.2 Conference or Courtroom Recording

If you're recording conferences or courtroom proceedings, you are faced with the same problem as the lectern microphone. Worse yet, you're trying to record this on tape, which does not have infinite headroom.

Best bet. Put a separate 421 on each microphone and record each microphone separately on a multitrack tape machine.

More practical. Separate the microphones into two groups: audience and front. Put a 421 on each group, record them separately on each track of a stereo machine.

Workable. Put a 421 between the mixer output and the tape machine.

8.3 Foreground Music

The CD changer has put canned music into a new era. One problem, of course, is the ASCAP and BMI clearance (not insurmountable). A bigger problem is one of dynamic range. An average CD has far too much dynamic range to be useful for background or foreground music. The 421 helps you reduce the overall dynamic range, while retaining some semblance of the music's original dynamics. You can link two units together for stereo (which prevents image-shifts caused by unequal amounts of gain reduction in the left and right channels). Start with the ratio control around 2:1 to 3:1, and use the SLOW recovery rate setting. Try a fairly low (CCW) setting of the AUTORELEASE LEVEL control to keep fades from making your music disappear.

8.4 Americans with Disabilities Act.

The American Disabilities Act (ADA) of 1990 (Public Law 101-336) affects any of us who supply equipment to or operate public gathering places. There are five major aspects (Titles) to this law, all of which have staged implementation dates.

Title I deals with employment issues, Title II deals with public services, Title III deals with public accomodations and services operated by private entities, Title IV deals with telecommunicatons, and Title V deals with miscellaneous issues. Of partitular interest to sound system providers or installers is Title III which says that many of the places where you find sound systems must provide assistive listening devices for persons with sensory

impairment[1]. Some of the solutions employed are: headphone jacks at certain seats, low powered AM or FM transmitters broadcasting to Walkman (R) type radios or to facility-supplied radios, and infrared transmission systems. Regardless of the transmission method, these systems all require a signal of reduced dynamic range so that the users can hear both the softest and loudest parts of a performance. The 421 is ideally suited to this application. Try moderate to high ratios (2:1 and up), and long release time. Pick an AutoRelease level that keeps the AGC action somewhat unobtrusive. Use the peak limiter to keep the transmitter out of clipping.

8.5 Lectern-mounted Microphones

A common and thoroughly vexing problem is that of the ubiquitous lectern microphone. A staple of hotels, public meeting places, courtrooms, and churches, the podium microphone gets used and misused by one and all.

Anyone who uses a microphone has their own idea of how and where to place the microphone (relative to their lips, of course) and how they should speak into it. Some get their cues from TV (which any self-respecting audio person knows is usually wrong), and some just make it up as they go. Some stick the mike near their navel, just like on TV (or is it that TV-news-types have their vocal chords somewhere new?), and others try to use it for a snack. You get the idea. What this means to you is roller-coaster audio levels. Try the 421. It will do for a lectern or other announce microphone what no compressor has ever done before: consistent audio levels *with* increased freedom from feedback.

Some hints: use moderate ratios (1:1.5 to 3:1) unless you want a really "in your face" sound. Use either or both of the speech filter switches. The AUTORELEASE LEVEL affects the size of the microphone's "pickup circle." More CCW settings expand the circle, allowing the 421 to raise lower level voices more (remember, it won't keep them from sounding distant or off-mike!). Higher settings restrict the pickup range of the microphone, so a weak talker won't be picked up as well unless they move-in on the microphone to cause the gain to readjust to their voice level. In noisy environments, try a higher (more CW) setting. You can use the downward expander in AUTO mode to gate the mike off when idle. Ensure that the TARGET OUTPUT LEVEL isn't high enough to cause feedback when the AGC-Leveler has fully released (you can force a release by quickly turning the AUTORELEASE LEVEL control and then returning it to its former setting.

8.6 Live PA

Have you ever mixed live sound for someone who just can't play at the right level? They're usually too soft when playing rhythm, and too loud when playing leads. A 421 can help you out. Connect the 421 into the mixer's channel insert jack, use a relatively low RATIO setting, use the expander if you need to. Remember that lower ratio settings mean more difference between soft and loud, and higher ratio settings will try to make the signal more or less the same volume. This trick also works on microphones that get sung into and used for announcements. The 421 keeps the announcements audible without the worry of forgetting to bring the fader down during a song. Again, use a low RATIO setting, around 2:1. If you try this on a submix, be careful because the large number of microphones involved makes it that much easier to push the sound system into feedback.

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1 For additional information on the ADA, contact one or more of the following:
US Justice Department, (202)-514-0301, (202) 223-0101
US Equal Employment Opportunity Commission, (800)-669-EEOC
American Speech and Language Association, (301) 897-5700
International Accessibility Board, (800) 872-2253

8.7 Mixdown

You can use the 421 during mixdown for a number of different things.

voice over — Let the 421 ride the level of the announcer, while you set the basic announcer to music-bed ratio.

Let the 421 ride the music-bed, while you ride the announcer's level.

music — Process background vocals with the 421. It will keep them consistently hot, without making them sound squashed (unless that's what you want), and without the risk of noise buildup that a plain-Jane compressor would cause.

Try using the 421 on individual instruments, as a way of keeping their level more consistent, without radically altering their timbre.

8.8 Paging Systems

Just like the poor lectern mike, paging systems suffer from the same ills. It really doesn't matter if the audio begins life in a telephone system, or if you have a dedicated paging mike. Every user has their own idea of how to use the mike. You can fight them (successfully) and win with the 421 AGC-Leveler.

8.9 Secondary Sound System Feeds

Many sound systems derive secondary feeds for ancillary systems that serve related areas of a facility. In arenas or large stadiums, this might be the outer concourses, PA shadow zones, concession areas, rest rooms, dressing rooms, etc. In a church, it might be the lobby or cry room. In a TV studio, it could be the IFB (interrupted foldback) system.

Any and all of these situations benefit from the 421's effortless gain-riding ability.

8.10 Tape Duplication (especially in churches)

Anytime you change recording media, especially between a professional format and a consumer format (how about DAT to consumer cassette?), patch a 421into the recording chain to perform a gentle squeeze, and for peak limiting. Try 2:1 RATIO, set the TARGET OUTPUT LEVEL control for the average level that you need and use the limiter to control the peaks.

Many churches record the Pastor's message (sermon) and make it available on tape by the end of the service. Considering the speed with which this must occur, a 421 might be just the thing to keep the average levels hot, while still preventing overload.

8.11 Teleconferencing

Many teleconference users want to record the content of the conference. Of course, audio levels are all over the map (one participant shouts, another is timid...). Try a 421 between the audio mixer and the tape machine, and another between the telephone interface and the tape machine. Using separate 421s and separate tape tracks will help if and when someone tries to transcribe the conference. Keeping things separate also helps negate the 421s tendency to bring the telephone interface's leakage (trans-hybrid loss) up to the same level as the caller, which isn't a good idea. In spite of this, the 421 helps out by keeping the signal levels more consistent from caller to caller, which is a good idea. Figure 8-1 illustrates the hookup.

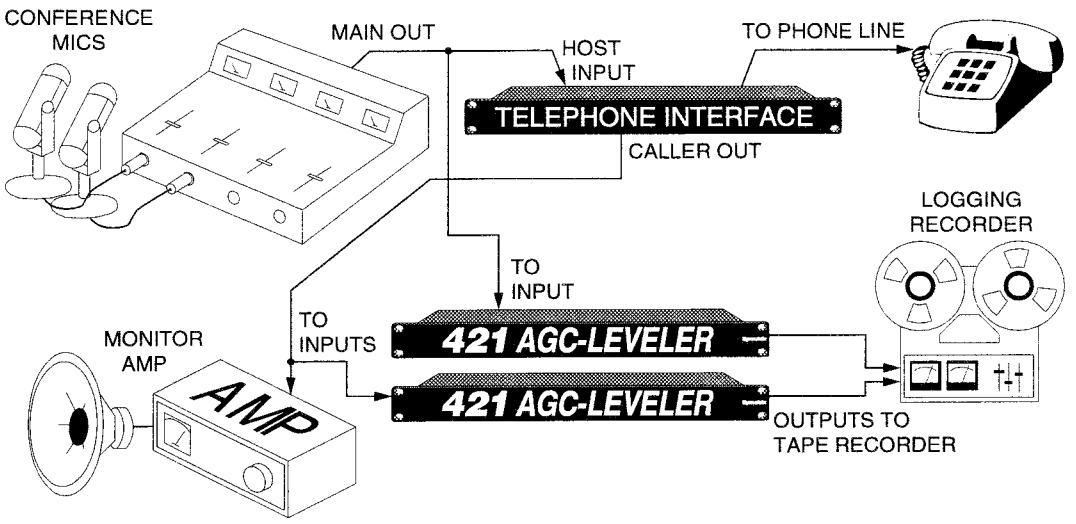


Figure 8-1. Teleconferencing setup.

8.12 Theatre and Auditorium Cue Systems

An auditorium cue system consists of a microphone(s) mounted in the audience area of a theatre or auditorium that feeds an amplifier that drives speakers located in the backstage areas of the hall. The potential dynamic range in this application is tremendous, ranging from an empty room to an audience on their feet making a plea for an encore.

A 421 can work wonders keeping this sort of system under control; keeping the level high enough to be audible, and low enough to not be annoying. The downward expander can reduce the level when the room is very quiet, to eliminate electronic noise, yet open up if someone speaks.

8.13 Post Production

A 421 can be invaluable in post production. How about:

transfer — Use the 421 when transferring location sound tapes. If you keep the ratio low, you'll gain consistency, with a minimum loss of dynamic range.

mix — Use multiple 421s to keep various mix elements audible...Try one on FX or Foley, and on dialog.

mastering — If you're creating something that will be heard in a specific environment, consider using a 421 to preprocess your mix for that environment. For instance, suppose you're making a point-of-purchase video that will heard in a noisy department store, over a semi-ordinary television set. Give the dialog a good dose of 2.5k to 5k presence boost to make it cut through the noise. Then process the overall mix through the 421 with a 3:1 ratio. This will keep the overall level hot but consistent, and the combination of presence boosting and overall level control will make your product audible in spite of the environment that it is presented in.

Be sure to check the previous section entitled "Mixdown" for additional tips and hints.

9. Troubleshooting Chart

No output	Check cables and connections. Are inputs driven by outputs, and outputs driving inputs? Verify cables by patching input and output connections together, at the unit. **CAUTION: *Do this only at low signal levels (and/or with the system gain turned down)!*** Check for AC power presence. Check input by plugging headphones halfway into the sidechain jack and listening for input signal (this verifies that the unit is receiving signal). Check output by plugging headphones into output jack. Check downward expander threshold setting; it may be too high for the current signal level.
Stuck in bypass mode	Check setting of the StereoLink (master/slave) switch. In single-unit (mono) systems, the switch should be in the IN position.
No limiter action	Check threshold control setting. Signal levels may be too low.
Distortion	If you're using the sidechain, remove the plug and recheck. If the distortion disappears, then check the sidechain cable, and whatever processor it is patched into. Ensure that the sidechain send (ring connection) goes to the sidechain processor's input, and that the sidechain return (tip) goes to the sidechain processor's output (sounds stupid, but VERY important).
No LED display	Is the unit plugged in, and turned on?
No LEDs at turn on	Is the AC outlet feeding the 421 OK? Is the fuse OK?
Unit unplugged, functions normally	Call us!

Note: *Repeated fuse blowing is a sure sign of electronic distress. Unplug the unit, (which puts it into hard-wire bypass mode) and make arrangements for repair.*

Warning: the fuse is located internally and lethal voltages are present inside the chassis. The fuse is not considered user serviceable. If the fuse is blown, the 421 more than likely needs repair.

Notes

10. 421 AGC-Leveler Limited Warranty

This Symetrix product is designed and manufactured for use in professional and studio audio systems. Symetrix, Inc. (Symetrix) warrants that this product, manufactured by Symetrix, when properly installed, used, and maintained in accordance with the instructions contained in the product's operator's manual, will perform according to the specifications set forth in the operator's manual.

Symetrix expressly warrants that the product will be free from defects in material and workmanship for one (1) year. Symetrix' obligations under this warranty will be limited to repairing or replacing, at Symetrix' option, the part or parts of the product which prove defective in material or workmanship within one (1) year from date of purchase, provided that the Buyer gives Symetrix prompt notice of any defect or failure and satisfactory proof thereof. Products may be returned by Buyer only after a Return Authorization number (RA) has been obtained from Symetrix and Buyer will prepay all freight charges to return any products to the Symetrix factory. Symetrix reserves the right to inspect any products which may be the subject of any warranty claim before repair or replacement is carried out. Symetrix may, at its option, require proof of the original date of purchase (dated copy of original retail dealer's invoice). Final determination of warranty coverage lies solely with Symetrix. Products repaired under warranty will be returned freight prepaid via United Parcel Service by Symetrix, to any location within the Continental United States. Outside the Continental United States, products will be returned freight collect.

The foregoing warranties are in lieu of all other warranties, whether oral, written, express, implied or statutory. Symetrix, expressly disclaims any IMPLIED warranties, including fitness for a particular purpose or merchantability. Symetrix's warranty obligation and buyer's remedies hereunder are SOLELY and exclusively as stated herein.

This Symetrix product is designed and manufactured for use in professional and studio audio systems and is not intended for other usage. With respect to products purchased by consumers for personal, family, or household use, Symetrix **expressly disclaims all implied warranties, including but not limited to warranties of merchantability and fitness for a particular purpose.**

This limited warranty, with all terms, conditions and disclaimers set forth herein, shall extend to the original purchaser and anyone who purchases the product within the specified warranty period.

Warranty Registration must be completed and mailed to Symetrix within thirty (30) days of the date of purchase.

Symetrix does not authorize any third party, including any dealer or sales representative, to assume any liability or make any additional warranties or representation regarding this product information on behalf of Symetrix.

This limited warranty gives the buyer certain rights. You may have additional rights provided by applicable law.

Limitation of Liability

The total liability of Symetrix on any claim, whether in contract, tort (including negligence) or otherwise arising out of, connected with, or resulting from the manufacture, sale, delivery, resale, repair, replacement or use of any product will not exceed the price allocable to the product or any part thereof which gives rise to the claim. In no event will Symetrix be liable for any incidental or consequential damages including but not limited to damage for loss of revenue, cost of capital, claims of customers for service interruptions or failure to supply, and costs and expenses incurred in connection with labor, overhead, transportation, installation or removal of products or substitute facilities or supply houses.

Notes

11. Repair Information

Should you decide to return your 421 to Symetrix for service, please follow the following instructions.

11.1 Return Authorization

Symetrix will service any of its products for a period of five years from the date of manufacture. However, no goods will be accepted without a Return Authorization number.

BEFORE SENDING ANYTHING TO SYMETRIX, CALL US FOR AN RA NUMBER. JUST ASK, WE'LL GLADLY GIVE YOU ONE! CALL (206) 787-3222 WEEKDAYS, 8AM TO 4:30 PM PACIFIC TIME.

11.2 In-Warranty Repairs

To get your unit repaired under the terms of the warranty:

1. Call us for an RA number.

2. Pack the unit in its original packaging materials.

3. Include your name, address, etc. and a brief statement of the problem. Your daytime telephone number is very useful if we can't duplicate your problem.

4. Put the RA number on the outside of the box.

5. Ship the unit to Symetrix, freight prepaid.

Just do those five things, and repairs made in-warranty will cost you only the one-way freight fee. We'll pay the return freight.

If you choose to send us your product in some sort of flimsy, non-Symetrix packaging, we'll have to charge you for proper shipping materials. If you don't have the factory packaging materials, then do yourself a favor by using an oversize carton, wrap the unit in a plastic bag, and surround it with bubble-wrap. Pack the box full of Styrofoam peanuts. Use additional bubble-wrap if you must ship more than one unit per carton. Be sure there is enough clearance in the carton to protect the rack ears (you wouldn't believe how many units we see here with bent ears). We won't return the unit in anything but original Symetrix packaging. Of course, if the problem turns out to be operator inflicted, you'll have to pay for both parts and labor. In any event, if there are charges for the repair costs, you will pay for return freight. All charges will be COD unless you have made other arrangements (prepaid, Visa or Mastercard).

11.3 Out-of-Warranty Repairs

If the warranty period has passed, you'll be billed for all necessary parts, labor, packaging materials, and any applicable freight charges.

Remember, you must call for an RA number before you send the unit to Symetrix.

Notes

12. Specifications

General

Type	Integrated leveler, peak limiter, and downward expander.
Inputs	TRS phone, XLR-female, screw terminals, 30k balanced bridging, +24 dBu maximum level.
Outputs	XLR-male, screw terminals, 200 ohm source impedance, differentially balanced, +23 dBm maximum level.
	TRS phone, unbalanced, +17 dBm maximum level. (wired tip = hot, ring & sleeve = shield/ground)
Bypass	Relay controlled, hard-wire bypass in either power-off or bypass conditions.
Sidechain	TRS phone, unbalanced send and receive, 1000 ohm source impedance, 10k input impedance. Tip = receive, Ring = send.
Approvals	Listed by Underwriters Laboratories Inc, control number 2T38.

Sonics

Frequency Response	20 - 50 kHz, +4 dBm
Harmonic Distortion	< ..05% 20-20 kHz, +4 dBm, 30 kHz bandwidth.
	Typically < .01% @ 1000 Hz.
Residual Noise	-90 dBu, 20 kHz noise bandwidth, rms responding meter.

Downward Expander

Ratio	1:2
Threshold	-50 VU (bypass) to -20 VU
AutoThreshold	interlocked to AGC-Leveler ARM circuitry
Attack Time	1 ms
Release Time	program dependent, 1-7 seconds depending on amount and duration.

Leveler

Ratio	1:1 to 4:1
AutoRelease Threshold	-70 dBu to -30 dBu
Attack Time	approximately 1 ms
Release Time	Fast: 16 dB/500 ms program dependent
	Slow: 16 dB/200 ms program dependent
	Release rate occurs only during ARM allowed release.
Target output range	+/- 20 dB

Peak Limiter

Ratio	10:1
Threshold	-15 VU to +20 VU (bypass)
Attack Time	500 µS for 90% gain reduction
Release Time	approximately 1 second

Speech Curve

Type	Switch selected cutoff filters allow tailoring LF and/or HF response for speech applications.
Frequencies	LF = 125Hz, 12 dB/octave, 2-pole Butterworth HF = 6kHz, 24 dB/octave, 4-pole

Input/Output Metering

Type	LED Bargraph, 12 steps + clip
Range (min to max)	66 dB
Ballistics	peak
Calibration	0 dB = 0 VU = +4 dBm = 1.23V

Power

Connector	IEC 3-pole
Voltage, etc.	105-125 VAC, 50-60 Hz, 15 watts maximum
Fuse	0.5A fast blow, internal.
Grounding	Safety ground (U ground) connected to chassis; I/O connector grounds connected to circuit ground; circuit ground connected to chassis via 20-ohms paralleled with .01-mfd. Circuit ground may be strapped to chassis ground via rear-panel barrier strip.

Note: many of the front panel controls are calibrated relative to the VU scale so that they correlate with the metering.

In the interest of continuous product improvement, Symetrix Inc. reserves the right to change, alter, or modify these specifications at any time, without prior notice.

13. PCB Layouts and Schematics

Note: The printed circuit board layouts and schematics in this section are intended for use only by qualified personnel.

Caution: *These servicing instructions are for use only by qualified personnel. To avoid electric shock do not perform any servicing other than that contained in the operating instructions portion of this manual unless you are qualified to do so. Refer all servicing to qualified service personnel.*

These schematics and layouts are provided for reference use only, for use by qualified service personnel and for use in answering certain technical questions that are beyond the scope and intent of this manual. The schematics and layouts in this manual were accurate at the time that this manual was written. Your actual product may contain changes not shown on these drawings. The inclusion of this material in this manual in no way obligates Symetrix to provide updated information or to inform users of any changes, past or pending.

A complete service manual is available from the factory for a nominal charge. Please contact the Symetrix Service Department at the address listed in Section 11 of this manual.

13.1 Troubleshooting Hints

If you are attempting repair of your 421, the following tips and hints may be useful, especially if you are not familiar with operational amplifiers.

The first thing that you should check are the power supplies. Their nominal voltage should be within 5% of the noted value on the schematic. The IC regulators used are current limited and short-circuit protected; their output voltage drops under excessive load (like something downstream that draws excessive current).

In audio amplifiers that utilize operational amplifiers as their active gain element, the two feedback resistors establish the working gain of the circuit. In Symetrix equipment, and other equipment using bipolar (separate plus and minus) power supplies, the nominal DC output voltage of each stage should be at or very near zero volts.

If an opamp's output is at or near one of the power supply rails, this usually means that the opamp has failed. The exception to this rule is when the circuit configuration uses the opamp as a DC amplifier or as a comparator.

When used as a DC amplifier, the output should follow the input signal (modified by the circuit's gain equation).

When used as a comparator, the opamp's output swings between the two supply rails and there should be no intermediate output state.

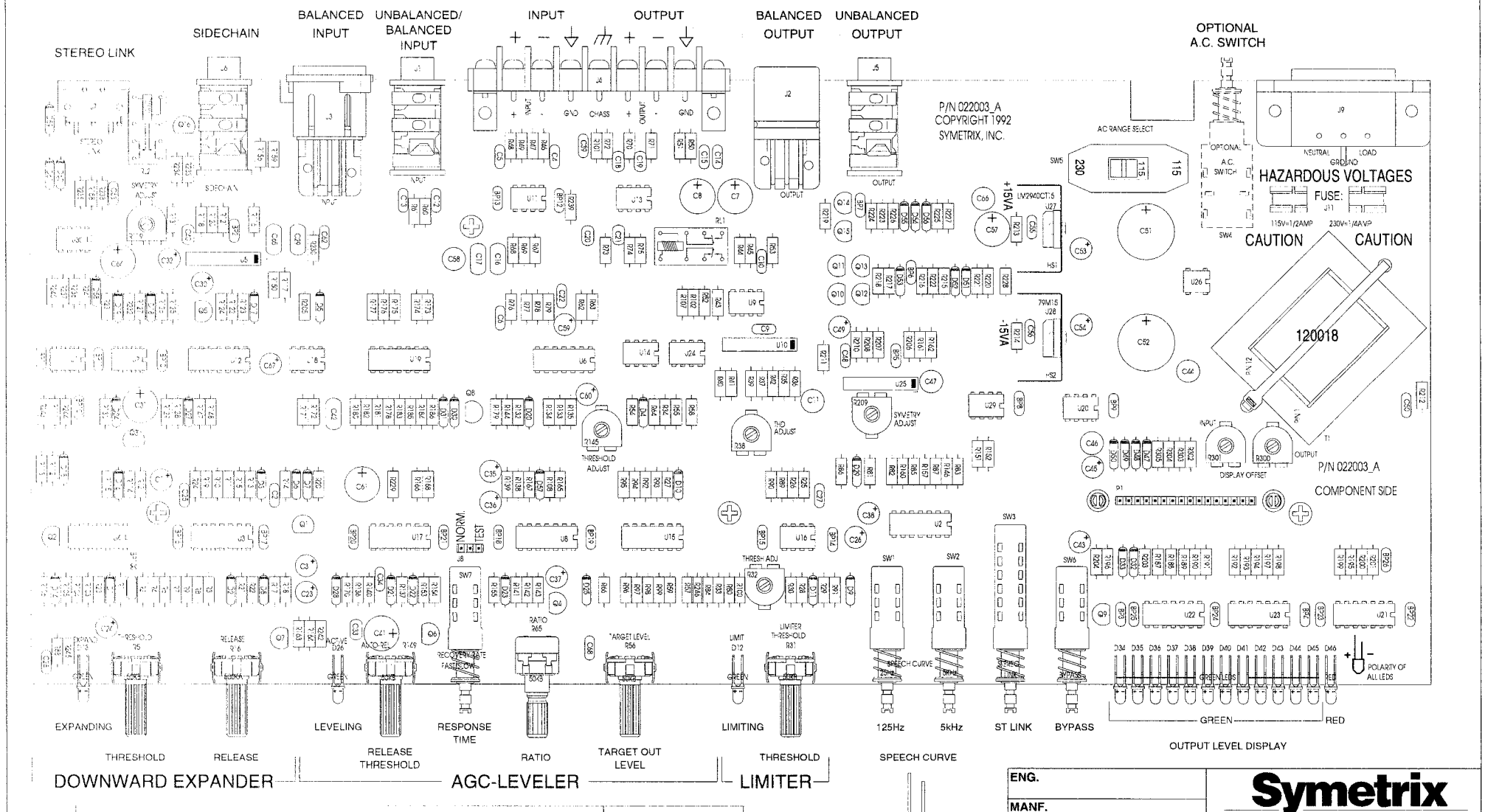
Units using substantial amounts of digital circuitry are probably best serviced at the factory.

13.2 Additional Reading

You can find additional information on the design and applications of operational amplifiers in the following text:

"Audio IC Op-Amp Applications," Walter G. Jung, Copyright 1987, *Howard W. Sams & Company*, Indianapolis, IN.

Notes



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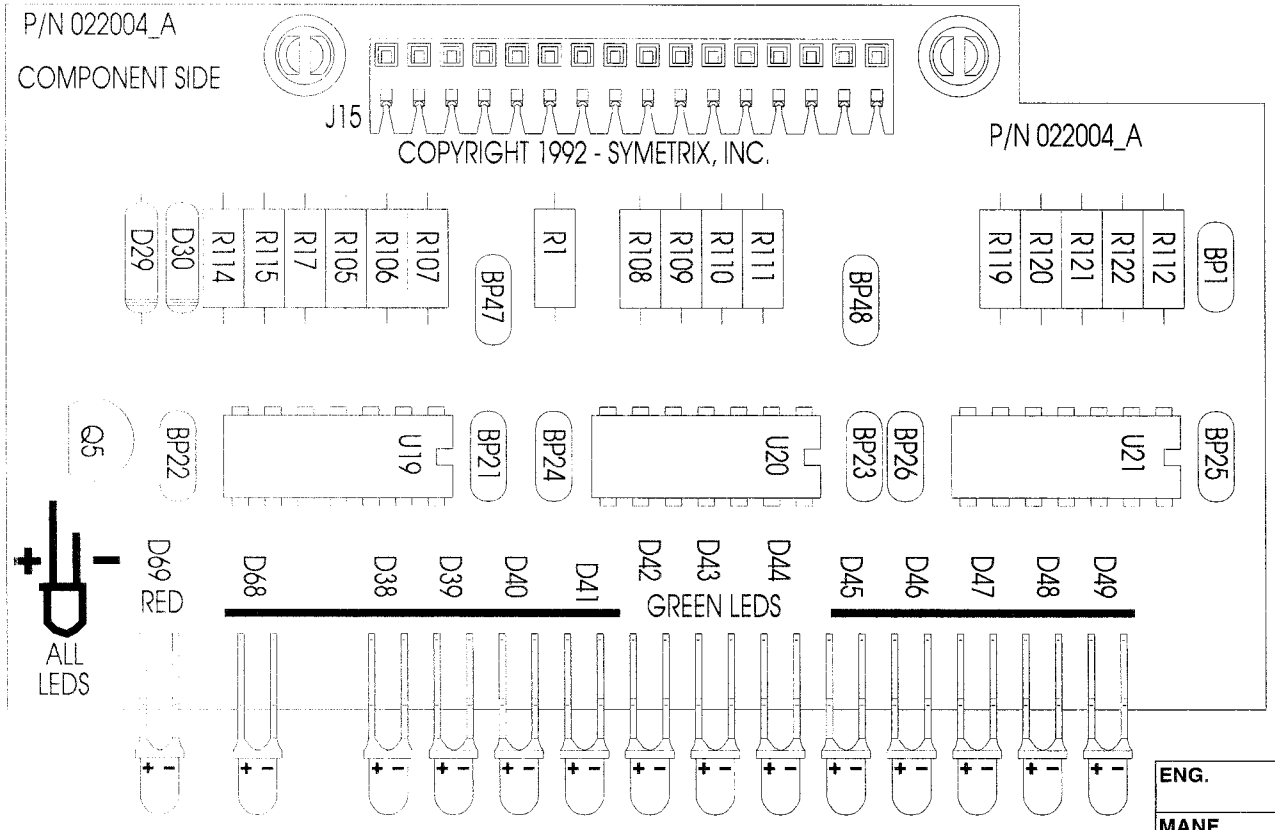
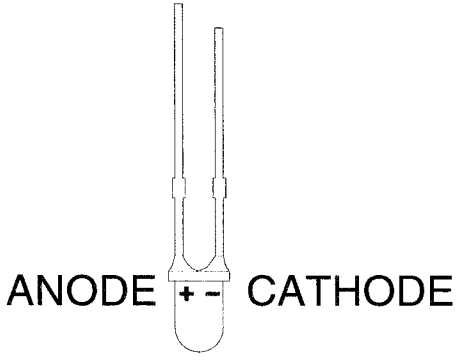
DATE PRINTED		DWG NO. 022003-ASY DWG REV. A
DRAWN BY	James Husted	DATE 4/10/92 SHEET 1 OF 1

REV#	REVISIONS:	DATE	REV#	REVISIONS:	DATE
A	FIRST PRODUCTION RELEASE	11/10/92			





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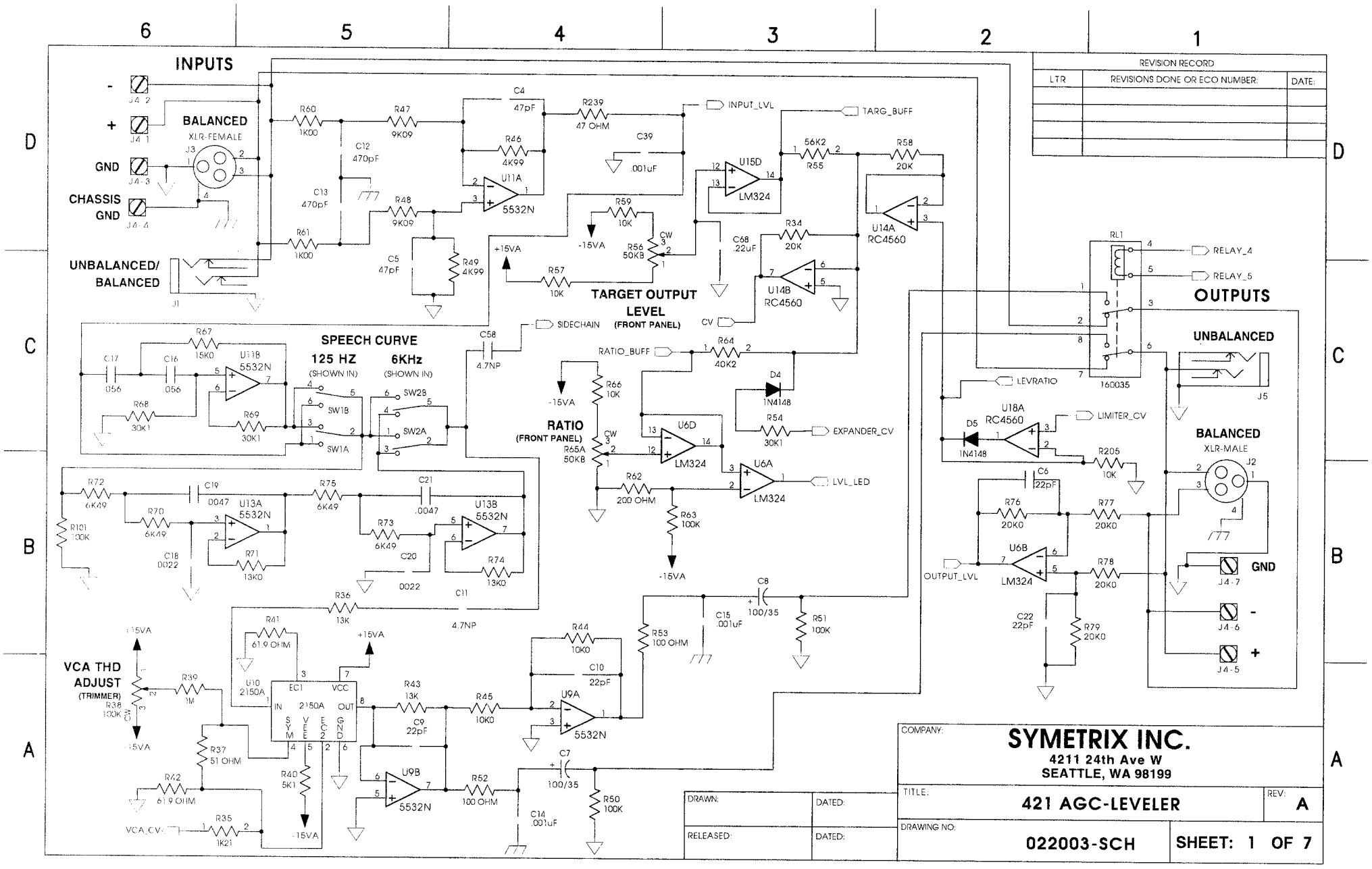
DRAWN BY	James Husted	DWG REV.	A
		DATE	4/13/92
		SHEET 1 OF 1	



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LTR	REVISIONS DONE OR ECO NUMBER:	DATE:

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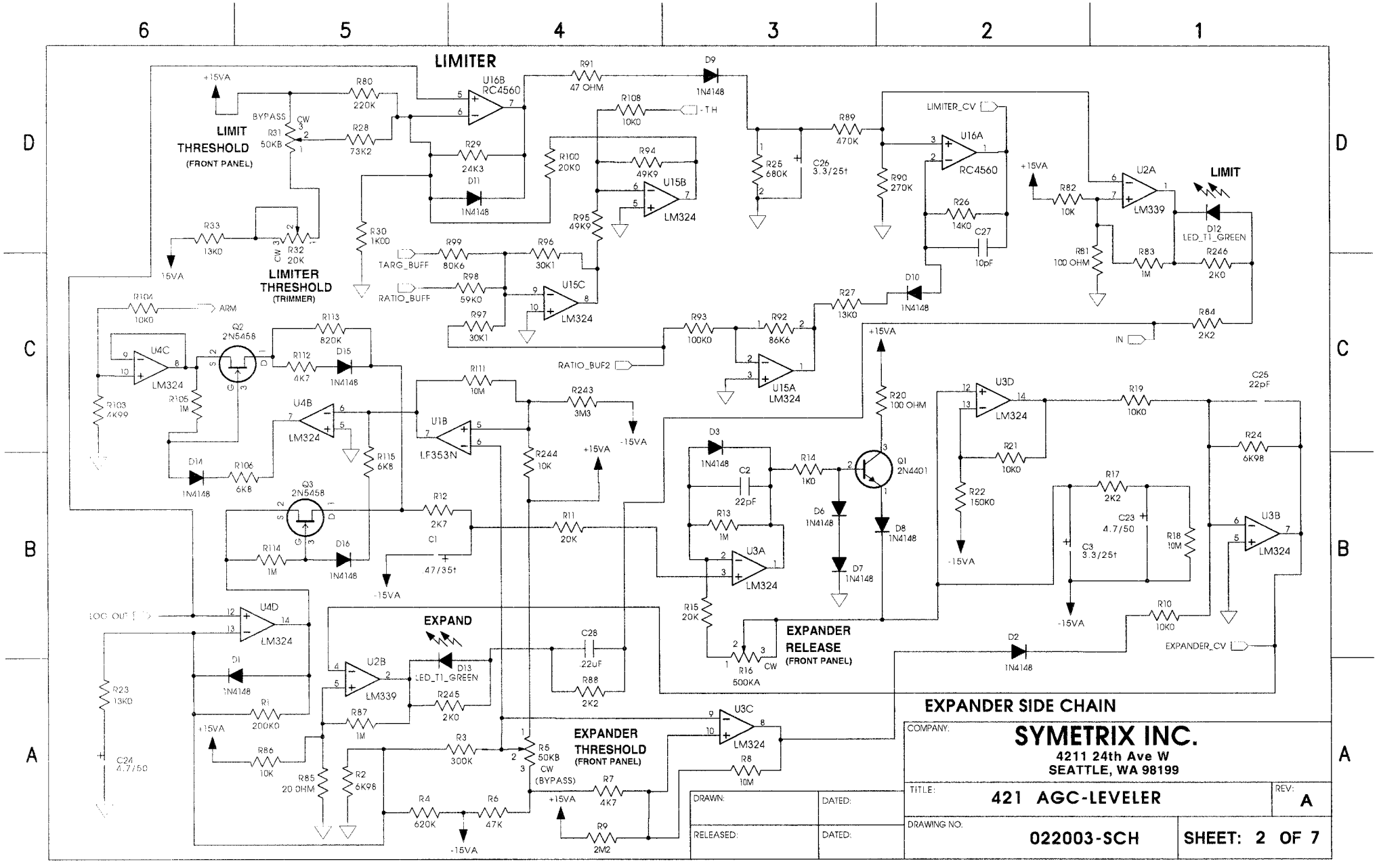
DRAWN:	DATED:	DRAWING NO:	**022003-SCH**
RELEASED:	DATED:	SHEET:	**1 OF 7**


LIMITER
LIMIT THRESHOLD (FRONT PANEL)
LIMITER THRESHOLD (TRIMMER)
EXPAND
EXPANDER THRESHOLD (FRONT PANEL)
EXPANDER RELEASE (FRONT PANEL)
EXPANDER SIDE CHAIN
LIMIT
LIMIT
+15VA
-15VA
-TH
ARM
IN
LOG OUT
LIMITER_CV
EXPANDER_CV
TARG_BUFF
RATIO_BUFF
RATIO_BUF2
U16B RC4560
U16A RC4560
U15A LM324
U15B LM324
U15C LM324
U1B LF353N
U2A LM339
U2B LM339
U3A LM324
U3B LM324
U3C LM324
U3D LM324
U4A LM324
U4B LM324
U4C LM324
U4D LM324
Q1 2N4401
Q2 2N5458
Q3 2N5458
R80 220K
R28 73K2
R31 50KB
R29 24K3
R33 13K0
R32 20K
R30 1K00
R100 20K0
R108 10K0
R91 47 OHM
R94 49K9
R95 49K9
R99 80K6
R96 30K1
R98 59K0
R97 30K1
R89 470K
R25 680K
R90 270K
R26 14K0
R27 13K0
R82 10K
R81 100 OHM
R83 1M
R246 2K0
R84 2K2
R104 10K0
R103 4K99
R105 1M
R113 820K
R112 4K7
R106 6K8
R115 6K8
R111 10M
R243 3M3
R244 10K
R93 100K0
R92 86K6
R20 100 OHM
R14 1K0
R19 10K0
R21 10K0
R22 150K0
R24 6K98
R17 2K2
R18 10M
R10 10K0
R12 2K7
R11 20K
R114 1M
R13 1M
R15 20K
R16 500KA
R23 13K0
R1 200K0
R87 1M
R245 2K0
R88 2K2
R86 10K
R85 20 OHM
R2 6K98
R3 300K
R5 50KB CW (BYPASS)
R7 4K7
R4 620K
R6 47K
R9 2M2
R8 10M
C1 .47/35t
C2 22pF
C26 3.3/25t
C27 10pF
C28 .22uF
C24 4.7/50
C23 4.7/50
C3 3.3/25t
C25 22pF
D1 1N4148
D2 1N4148
D3 1N4148
D6 1N4148
D7 1N4148
D8 1N4148
D9 1N4148
D10 1N4148
D11 1N4148
D12 LED_T1_GREEN
D13 LED_T1_GREEN
D14 1N4148
D15 1N4148
D16 1N4148
SYMETRIX INC.
4211 24th Ave W
SEATTLE, WA 98199
421 AGC-LEVELER
022003-SCH
SHEET: 2 OF 7
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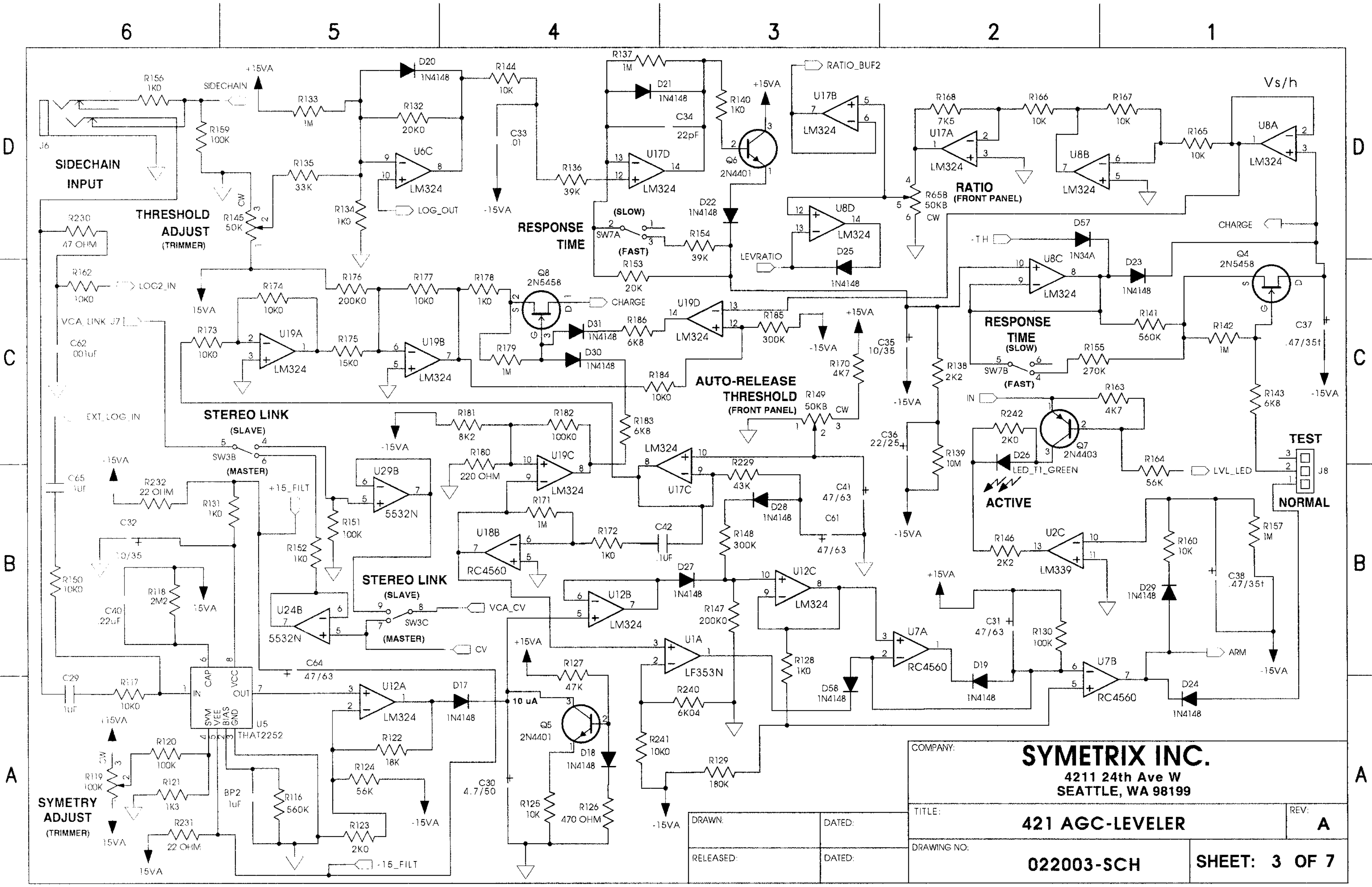
SIDECHAIN INPUT
THRESHOLD ADJUST (TRIMMER)
RESPONSE TIME
(SLOW)
(FAST)
RATIO (FRONT PANEL)
Vs/h
RATIO_BUF2
LOG_OUT
LOG2_IN
VCA_LINK J7
EXT_LOG_IN
CHARGE
LEVRATIO
-TH
AUTO-RELEASE THRESHOLD (FRONT PANEL)
STEREO LINK
(SLAVE)
(MASTER)
VCA_CV
CV
+15_FILT
-15_FILT
IN
LVL_LED
LED_T1_GREEN
ACTIVE
TEST
NORMAL
J8
ARM
10 uA
SYMETRY ADJUST (TRIMMER)
THAT2252
COMPANY:
SYMETRIX INC.
4211 24th Ave W
SEATTLE, WA 98199
TITLE:
421 AGC-LEVELER
REV:
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DRAWING NO:
022003-SCH
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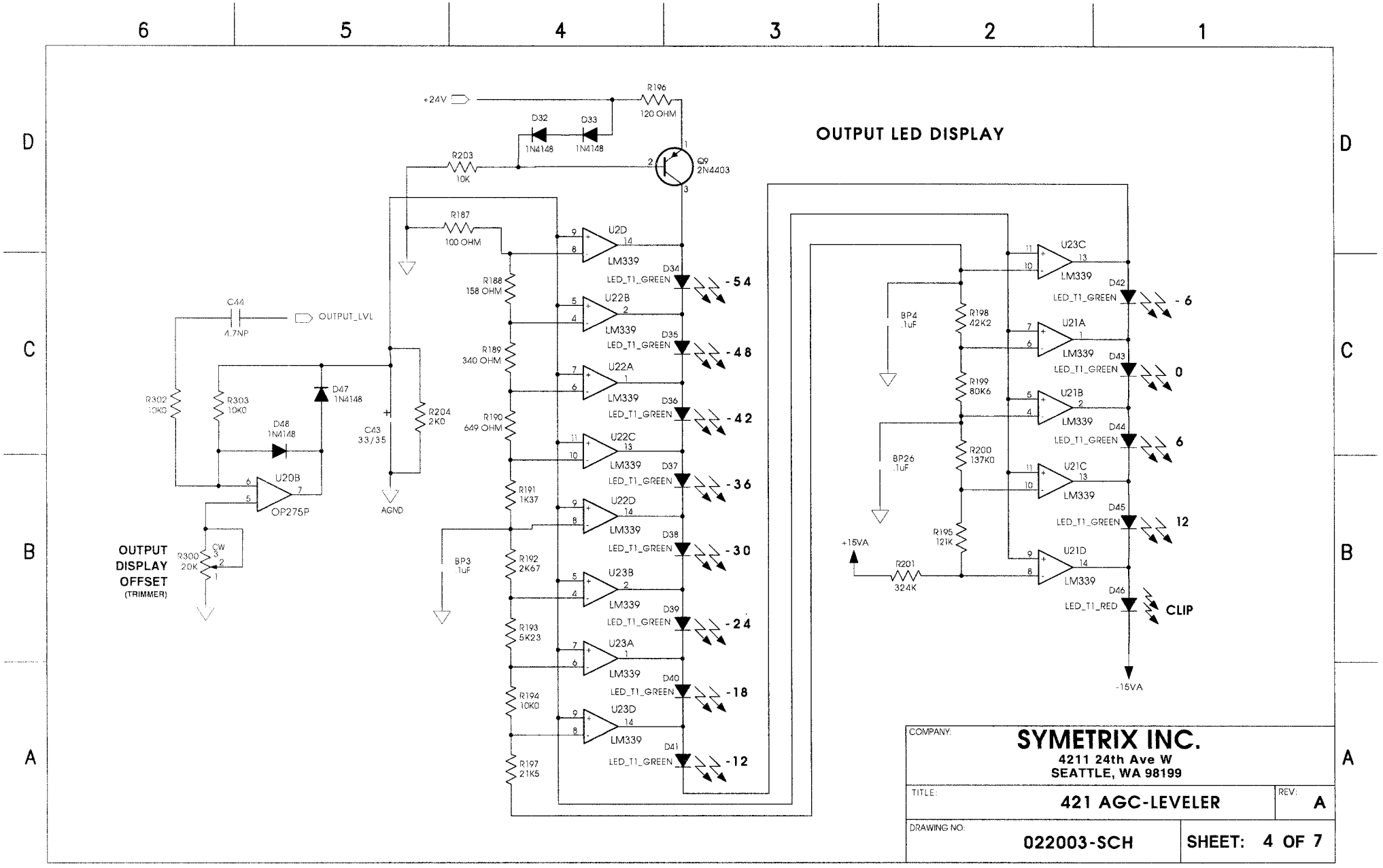

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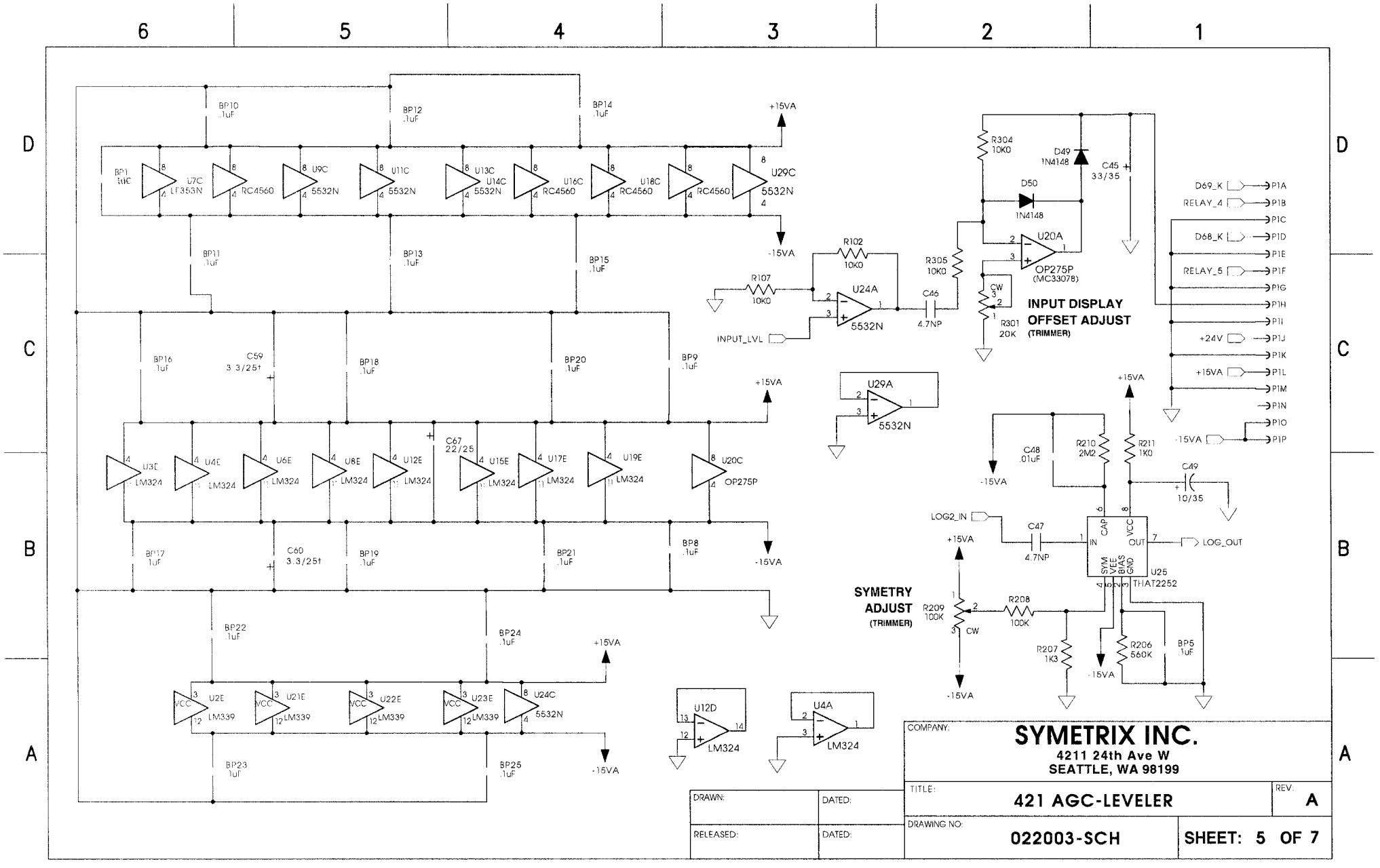
6
5
4
3
2
1
D
C
B
A
BP10 .1uF
BP12 .1uF
BP14 .1uF
+15VA
BP1 .1uF
U7C LF353N
RC4560
U9C 5532N
U11C 5532N
U13C U14C 5532N
U16C RC4560
U18C RC4560
RC4560
U29C 5532N
-15VA
BP11 .1uF
BP13 .1uF
BP15 .1uF
R102 10K0
R107 10K0
U24A 5532N
C46 4.7NP
R305 10K0
R304 10K0
D49 1N4148
D50 1N4148
C45 33/35
U20A OP275P (MC33078)
CW
R301 20K
INPUT DISPLAY OFFSET ADJUST (TRIMMER)
INPUT_LVL
D69_K
RELAY_4
D68_K
RELAY_5
+24V
+15VA
-15VA
P1A
P1B
P1C
P1D
P1E
P1F
P1G
P1H
P1I
P1J
P1K
P1L
P1M
P1N
P1O
P1P
BP16 .1uF
C59 3 3/25t
BP18 .1uF
BP20 .1uF
BP9 .1uF
U29A 5532N
C67 22/25
U3E LM324
U4E LM324
U6E LM324
U8E LM324
U12E LM324
U15E LM324
U17E LM324
U19E LM324
U20C OP275P
C48 .01uF
R210 2M2
R211 1K0
C49 10/35
LOG2_IN
C47 4.7NP
LOG_OUT
U25 THAT2252
CAP
VCC
IN
OUT
SYM
VEE
BIAS
GND
SYMETRY ADJUST (TRIMMER)
R209 100K
R208 100K
R207 1K3
R206 560K
BP5 .1uF
BP17 .1uF
C60 3.3/25t
BP19 .1uF
BP21 .1uF
BP8 .1uF
BP22 .1uF
BP24 .1uF
U2E LM339
U21E LM339
U22E LM339
U23E LM339
U24C 5532N
BP23 .1uF
BP25 .1uF
U12D LM324
U4A LM324
COMPANY:
SYMETRIX INC.
4211 24th Ave W
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TITLE:
421 AGC-LEVELER
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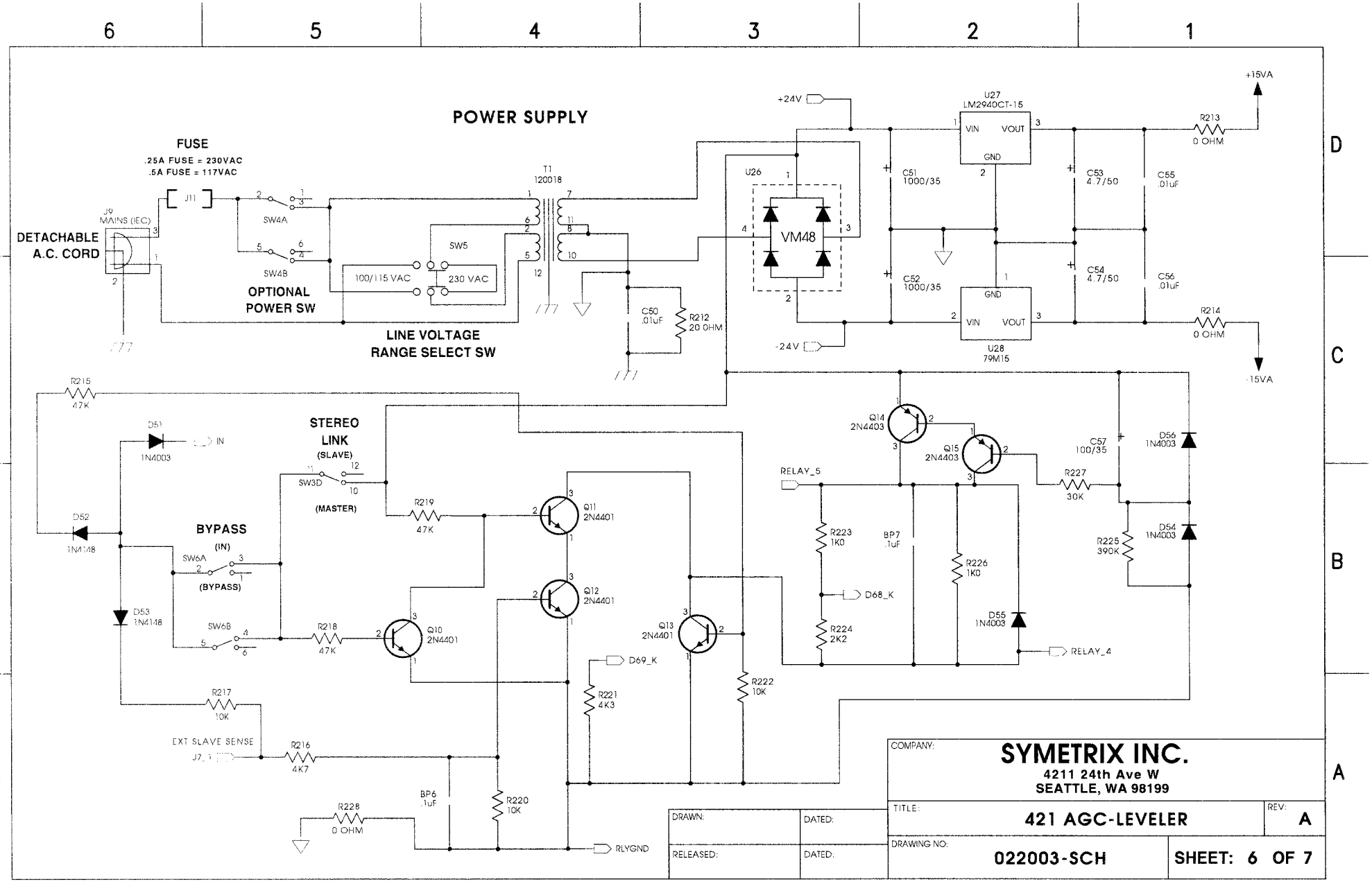

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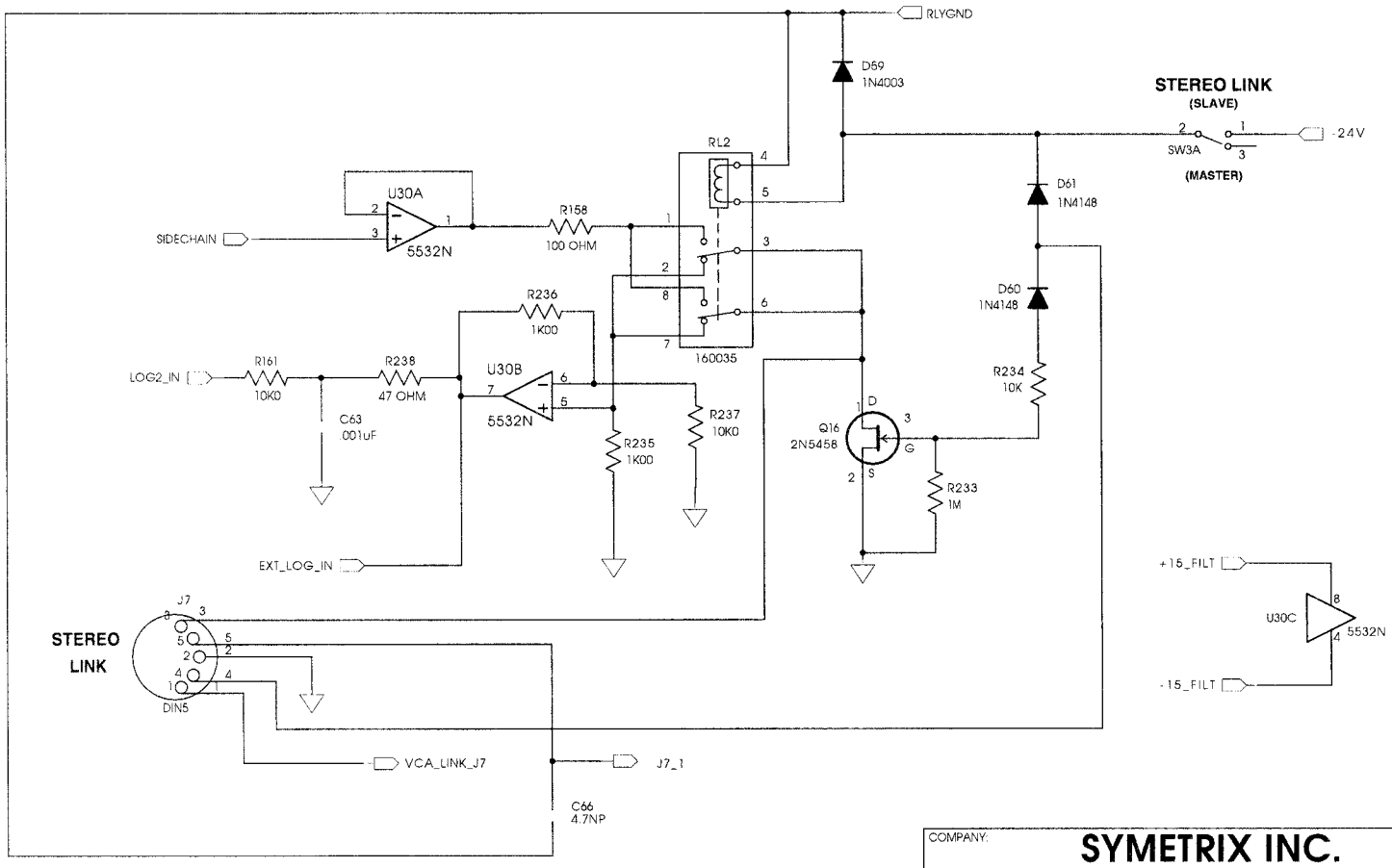

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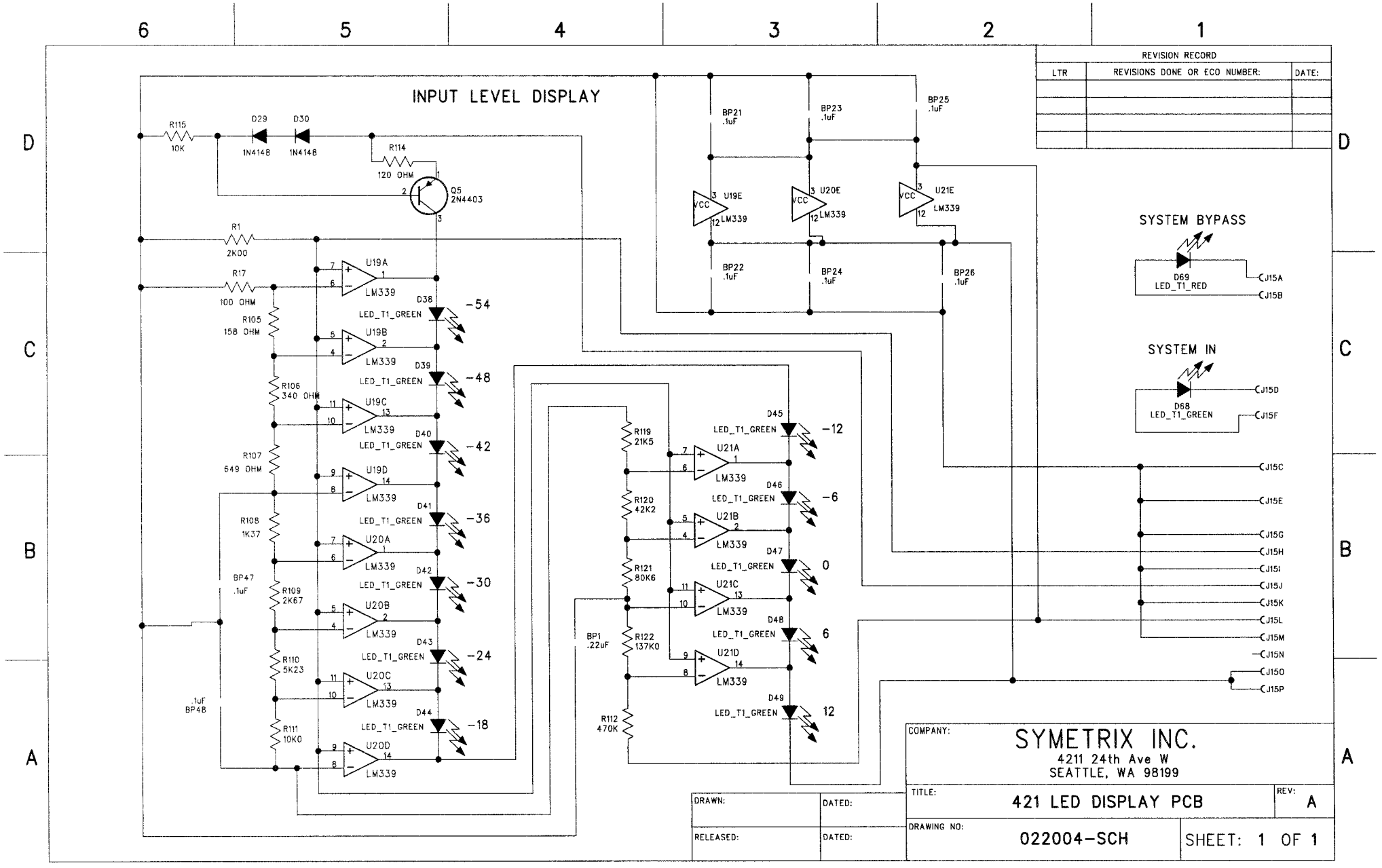
INPUT LEVEL DISPLAY
REVISION RECORD
LTR
REVISIONS DONE OR ECO NUMBER:
DATE:
SYSTEM BYPASS
SYSTEM IN
D69 LED_T1_RED
D68 LED_T1_GREEN
J15A
J15B
J15C
J15D
J15E
J15F
J15G
J15H
J15I
J15J
J15K
J15L
J15M
J15N
J15O
J15P
R115 10K
D29 1N4148
D30 1N4148
R114 120 OHM
Q5 2N4403
R1 2K00
R17 100 OHM
R105 158 OHM
R106 340 OHM
R107 649 OHM
R108 1K37
R109 2K67
R110 5K23
R111 10K0
BP47 .1uF
BP48 .1uF
U19A LM339
U19B LM339
U19C LM339
U19D LM339
U20A LM339
U20B LM339
U20C LM339
U20D LM339
D38 LED_T1_GREEN -54
D39 LED_T1_GREEN -48
D40 LED_T1_GREEN -42
D41 LED_T1_GREEN -36
D42 LED_T1_GREEN -30
D43 LED_T1_GREEN -24
D44 LED_T1_GREEN -18
BP21 .1uF
BP22 .1uF
BP23 .1uF
BP24 .1uF
BP25 .1uF
BP26 .1uF
U19E LM339
U20E LM339
U21E LM339
R119 21K5
R120 42K2
R121 80K6
R122 137K0
R112 470K
BP1 .22uF
U21A LM339
U21B LM339
U21C LM339
U21D LM339
D45 LED_T1_GREEN -12
D46 LED_T1_GREEN -6
D47 LED_T1_GREEN 0
D48 LED_T1_GREEN 6
D49 LED_T1_GREEN 12
COMPANY:
SYMETRIX INC.
4211 24th Ave W
SEATTLE, WA 98199
TITLE:
421 LED DISPLAY PCB
REV: A
DRAWN:
DATED:
RELEASED:
DATED:
DRAWING NO:
022004-SCH
SHEET: 1 OF 1

Appendix A. Architects and Engineers Specification

The Automatic Gain Control (AGC) shall be a single channel model that reduces the dynamic range of wide range, wideband audio signals, provide peak limiting, downward expansion and bandpass limiting filters. The AGC shall occupy one rack space (1U).

The AGC shall be capable of controlling audio signals ranging from -70 dBu to +24 dBu and reducing their range by an input/output ratio ranging from 1:1 to 4:1. The input/output ratio shall be adjustable via a front-panel control. Response speed switching shall be provided to accommodate speech and music sources. A target output level control shall be provided to shift the level of the output signal over a nominal +/- 20 dB range. The release time of the AGC shall be controlled by the presence of input signal and the signal sensor shall be capable of discriminating between music, speech, random noise, and pure tones. The threshold level of the signal sensor shall be adjustable via a front panel control and the presence of signals above the threshold setting shall be indicated via a green LED.

The AGC shall also contain an integral peak limiter having at least a 10:1 ratio and adjustable threshold level. A green LED indicator shall be provided to indicate peak limiter activity. The peak limiter threshold shall determine the absolute maximum output amplitude of the AGC-Leveler regardless of other conditions.

The AGC shall also contain an integral downward expander having a 1:2 expansion ratio with threshold and release time controls. Furthermore, the downward expander shall be capable of operating automatically via the signal sensor circuitry. A green LED indicator shall be provided to indicate downward expander circuit activity.

Bandpass limiting filters shall be provided having a lowpass characteristic of 24 dB/octave at 6kHz and a highpass characteristic of 12 dB/octave at 125Hz. Both filters shall be capable of being used individually or simultaneously.

The AGC shall provide identical peak responding input and output level meters. These meters shall be capable of responding to signals ranging from -54 VU to +12 VU (-50 dBu to +16 dBu). An output clipping indicator shall be provided.

The AGC shall provide facilities for stereo-coupling two units via a shielded 5-pin DIN male-to-male cable. A front panel switch shall designate which unit is the master and which unit is the slave.

The inputs shall be active balanced bridging designs terminated with 3-pin XLR (AES/IEC standard wiring), 1/4" TRS female, and screw terminals. The input circuitry shall incorporate RFI filters. The outputs shall be active balanced designs having equal source impedances and terminated with 3-pin XLR (AES/IEC standard wiring), and screw terminals. A separate 1/4" TRS jack shall provide an unbalanced output.

The balanced inputs shall accommodate +24 dBu signals without distortion, and the balanced outputs shall be capable of delivering +23 dBm into a 600 ohm load.

Overall frequency response shall be 20 - 20 kHz, +0 -1 dB, measured at +4 dBm output. There shall be no more than .02% harmonic distortion, measured under the following conditions: +4 dbu input, +4 dBm output, BYPASS switch out, 1000 Hz. Residual noise output shall be no greater than -90 dBm, measured with a 20 kHz noise bandwidth.

When the unit is inoperative (either by loss of power, or via the BYPASS switch), the inputs and outputs shall be wired together. There shall be no transients transmitted to the output terminals during either turn-on, turn-off, or bypass operation.

Access to the AGC's sidechain shall be provided via a single 1/4" TRS female connector. The ring connection shall be the sidechain output and the tip connection shall be the sidechain return.

The AGC shall be capable of operating by means of its own built-in power supply connected to 117V nominal AC (105-130V) 50/60 Hz (230V nominal, 207-253V AC, 50 Hz where

applicable). The AGC shall be Listed by Underwriters Laboratories Inc. (UL) or other equivalent nationally recognized safety testing agency.

The unit shall be a Symetrix Incorporated model 421 AGC-Leveler.

Appendix B. Disassembly Instructions

The following instructions are only for qualified service personnel.

> **Caution**: These servicing instructions are for use by qualified personnel only. To avoid electric shock do not perform any servicing other than that contained in the operating instructions portion of this manual unless you are qualified to do so. Refer all servicing to qualified service personnel.
>
> **Warning**: ***Lethal voltages are present inside the chassis. Perform all service work with the unit disconnected from all AC power.***

Top Cover Removal

1. Ensure that the 421 is disconnected from the AC power source.
2. Remove four 6-32 x 1/2 inch screws from the rear-panel.
3. Remove two 6-32 x 1/2 inch screws from each side of the chassis.
4. Remove one 6-32 x 1/2 inch screw from the top-middle of the front panel. Use caution to prevent the screwdriver from slipping and marring the front panel.
5. Lift the top cover free of the chassis.

Circuit Board Removal

1. Ensure that the 421 is disconnected from the AC power source.
2. Remove the top cover using the procedure described previously.
3. Remove the four screws from the four corners of the front panel.
4. Remove four 6-32 x 1/4 inch SEMS machine screws from the printed circuit board. Three are located near the front panel, the remaining screw is located between the output relays.
5. Disconnect the green safety ground wire at the chassis screw terminal by removing the nut. Ensure that this wire is reconnected when reassembling the 421.

Notes