

KEITHLEY

Model 776 Programmable Counter/Timer

Instruction Manual

A GREATER MEASURE OF CONFIDENCE

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Keithley Instruments, Inc. • 28775 Aurora Road • Cleveland, OH 44139 • 440-248-0400 • Fax: 440-248-6168 • <http://www.keithley.com>

| | | |
|-----------------------|------------------------------------|---|
| BELGIUM: | Keithley Instruments B.V. | Bergensesteenweg 709 • B-1600 Sint-Pieters-Leeuw • 02/363 00 40 • Fax: 02/363 00 64 |
| CHINA: | Keithley Instruments China | Yuan Chen Xin Building, Room 705 • 12 Yumin Road, Dewai, Madian • Beijing 100029 • 8610-62022886 • Fax: 8610-62022892 |
| FRANCE: | Keithley Instruments Sarl | 3, allée des Garays • 91127 Palaiseau Cedex • 01-64 53 20 20 • Fax: 01-60 11 77 26 |
| GERMANY: | Keithley Instruments GmbH | Landsberger Strasse 65 • 82110 Germering • 089/84 93 07-40 • Fax: 089/84 93 07-34 |
| GREAT BRITAIN: | Keithley Instruments Ltd | The Minster • 58 Portman Road • Reading, Berkshire RG30 1EA • 0118-9 57 56 66 • Fax: 0118-9 59 64 69 |
| INDIA: | Keithley Instruments GmbH | Flat 2B, WILOCRISSA • 14, Rest House Crescent • Bangalore 560 001 • 91-80-509-1320/21 • Fax: 91-80-509-1322 |
| ITALY: | Keithley Instruments s.r.l. | Viale S. Gimignano, 38 • 20146 Milano • 02-48 39 16 01 • Fax: 02-48 30 22 74 |
| NETHERLANDS: | Keithley Instruments B.V. | Postbus 559 • 4200 AN Gorinchem • 0183-635333 • Fax: 0183-630821 |
| SWITZERLAND: | Keithley Instruments SA | Kriesbachstrasse 4 • 8600 Dübendorf • 01-821 94 44 • Fax: 01-820 30 81 |
| TAIWAN: | Keithley Instruments Taiwan | 1 Fl. 85 Po Ai Street • Hsinchu, Taiwan, R.O.C. • 886-3572-9077 • Fax: 886-3572-903 |

Model 776 Programmable Counter/Timer Instruction Manual

Serial Prefix T74

Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation Category II connections require protection for high transient over-voltages often associated with local AC mains connections. The user should assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.


The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.


Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.


When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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1

General Information

1-1. Introduction

This manual provides operating and maintenance information for the Model 776 Programmable Counter/Timer. Section 1 is a general description of the instrument. Section 2 and 3 obtain installation and operating instructions. IEEE programming is explained in Section 4. Maintenance and performance checks are provided in Section 5. The theory of operation is described in Section 6. Section 7 outlines calibration and troubleshooting procedures. Section 8 contains tables of replaceable parts. Section 9 contains schematic and component location diagrams.

Model 776 is a ten digit microprocessor based fully-programmable, three-channel Universal Counter / Timer. The instrument measures with a very high resolution and precision the following parameters: Frequency A, Frequency B, Frequency C, Period A, Pulse-width, Time interval A to B, Total counts B, Ratio A/B, Ratio C/B, Phase A to B and Amplitude peaks. An averaging function is available for improved resolution in time measurement; resolves intervals of pico seconds. Various repetitive tests, no matter how complex, are greatly simplified by utilizing any of the 10 pre-programmed front panel set-up. Set-ups are stored in a non-volatile memory and can be recalled by a simple key stroke.

Model 776 utilizes a combination of two measurement techniques in order to always achieve maximum display resolution. Some functions, such as Frequency measurement function, can be displayed with up to ten digits. Such resolution can be gained from frequencies

as low as 0.01 Hz to more than 225 MHz. The reciprocal technique is being used in low frequency measurements, up to exactly 120 MHz, where the measurement technique is changed to conventional measurement technique. Model 776 measures frequencies of input signals with minimum resolution of nine digits in one second of gate time. With the TCXO time base of the Model 776/2.4G, the displayed result is largely enhanced, both in terms of stability and accuracy.

In Model 776, the traditionally featured decade steps of gate times, are replaced by a more flexible variable gate time. This feature permits a choice from 500 internally pre-selected gate intervals, or any external gate interval which is applied to a rear panel BNC connector. Internal gate times range from 100 μ s to 10 s. External gate expands this range to 1000 s. Trigger level may be selected manually or left to be automatically adjusted, by the instrument, to the optimum level, thus eliminating false triggering on unknown signals.

NOTE

This manual provides a complete description of all features of the 776 Series. Therefore, several of the features that are described in the following paragraphs may not be installed in your instrument.

1-2. Instrument Identification

These Keithley instruments are identified by a serial number, which is located on the rear panel. The two most significant digits (Txx) identify instrument modi-

fication. If this prefix differs from that listed on the title page of this manual, there are differences between this manual and your instrument.

1-3. Configuration

There are two configurations available for the Model 776:

- Model 776 - Two-channel 225 MHz programmable counter/timer.
- Model 776/2.4G - Same as above with 2.4 GHz Channel C and TCXO time base.
- Model 776/2.4G/R - Same as above with rear panel inputs.

1-4. Warranty Information


Warranty information is located on the inside front cover of this instructions manual. Should your Model 776 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

1-5. Manual Addenda

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into this manual.

1-6. Safety Symbols And Terms

The following symbols and terms may be found on an instrument or used in this manual.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

1-7. Inspection

The Model 776 was carefully inspected, both electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (Note: There may be a protective film over the display lens, which can be removed.) Report any damage to the shipping agent immediately. Save the original packing carton for possible future re-shipment. The following items are included with every Model 776 order:

Table 1-1. Model 776 Specifications

| | |
|------------------------------|---------------------------|
| INPUT CHARACTERISTICS | |
| (Channel A & B) | |
| RANGE | |
| DC coupled | : 0 to 225 MHz. |
| AC coupled 1 MΩ | : 30 Hz to 225 MHz. |
| 50 Ω | : 1 MHz to 225 MHz. |
| SENSITIVITY (X1) | |
| 0 to 200 MHz | : 50 mV rms sine wave. |
| 200 MHz to 225 MHz | : 75 mV rms sine wave. |
| 5 ns Minimum Pulse Width | : 75 mVp-p. |
| SIGNAL OPERATING RANGE | |
| (X1) | : -5.00 Vdc to +5.00 Vdc. |
| (X10) | : -50.0 Vdc to +50.0 Vdc. |
| DYNAMIC RANGE (x1) | |
| 0 to 100 MHz | : 75 mV to 5 Vp-p. |
| 100 MHz to 225 MHz | : 150 mV to 2.5 Vp-p. |

Table 1-1. Model 776 Specifications (continued)

| | |
|---|---|
| IMPEDANCE | : 1 M Ω or 50 Ω nominal shunted by less than 45 pF. switchable. |
| LOW PASS FILTER | : -3 dB NOMINAL at 100 KHz. switchable. |
| COUPLING | : AC or DC. switchable. |
| DAMAGE LEVEL (AC or DC) | |
| (X1) | : DC to 2 KHz - 200 V (DC + pk AC); 2 KHz to 100 KHz - 4×10^5 V rms Hz/Freq; Above 100 KHz - 5 V rms. |
| (X10) | : DC to 20 KHz - 200 V (DC + pk AC); 20 KHz to 100 KHz - 4×10^6 V rms Hz/Freq; above 100 KHz - 50 V rms. |
| 50 Ω | : 5 V rms |
| TRIGGER LEVEL CHARACTERISTICS (Channel A and B) | |
| MANUAL TRIGGER (auto trigger off) | |
| (X1) | : -5.00 Vdc to +5.00 Vdc; |
| (X10) | : -50.0 Vdc to +50.0 Vdc. |
| Setting Accuracy | : X1. \pm (35 mV +2% of reading); X10, \pm (350 mV +2% of reading). |
| Resolution (X1) | : 10 mV; (X10): 100 mV. |
| Preset (X1) | : 0.00 Vdc; (X10) 00.0 Vdc. |
| Trigger Slope | : Independent selection of positive or negative slope. switchable. |
| AUTO TRIGGER | |
| Frequency Range | |
| DC Coupled | : 100 Hz to 150 MHz. |
| AC Coupled 1 M Ω | : 100 Hz to 150 MHz. |
| 50 Ω | : 1 MHz to 150 MHz. |
| Auto Trigger Level Range | : \pm 50 Vp-p. |
| Minimum Amplitude | : 100 mV rms sine wave. 280 mVp-p. |
| ATTENUATOR | |
| Manual | : X1 or X10 NOMINAL. selectable. |
| Auto | : Attenuator is automatically enabled when in Auto Trigger Mode. |
| Auto Attenuator Sensitivity | : Attenuator is switched when peak input signal exceeds 5.1 Vp-p. |
| NOTES: | |
| 1. Auto trigger is disabled in the following functions: Totalize B and Frequency C. | |
| 2. Auto trigger function requires that a repetitive signal be present at the input connector. | |
| FREQUENCY A & FREQUENCY B | |
| Measurement Technique | : Reciprocal, below 120 MHz and in User Gate. and in Hold operating modes: Conventional, above 120 MHz. Measurement technique is automatically selected by the instrument. |
| Range | : 0.01 Hz to 225 MHz. |

Table 1-1. Model 776 Specifications (continued)

| | | |
|---|---|--|
| LSD ⁽¹⁾ Displayed Reciprocal | : | $4 \text{ ns} \times \text{frequency}$ gate time. e.g min 9 digits in one second of gate time. |
| Conventional | : | 4/gate time. |
| Resolution | : | $\pm \text{LSD} \pm \frac{(1.4 \times \text{Trig error}^{(2)} \times \text{Frequency})}{\text{gate time}}$ |
| Accuracy | : | $\pm \text{resolution} \pm \text{Time Base error}^{(3)} \times \text{Frequency}$ |
| FREQUENCY C (available with Model 776/2.4G) | | |
| Range | : | 50 MHz to 2.4 GHz. |
| Input Impedance | : | 50 Ω . AC coupled. |
| Sensitivity | : | 15 mV to 2.4 GHz. |
| Dynamic Range | : | 15 mV rms to 4 V rms. |
| VSWR | : | <2:1 (typically 1.5:1). |
| Damage Level | : | AC. 5 V rms; DC. ± 40 V. |
| LSD ⁽¹⁾ Displayed | : | Same as for Frequency A & B. |
| Resolution | : | Same as for Frequency A & B. |
| Accuracy | : | Same as for Frequency A & B. |
| TIME MEASUREMENT - SINGLE SHOT | | |
| PERIOD A, PULSE A, TIME INTERVAL A to B | | |
| Range: | | |
| Period A, Pulse A | : | 5 ns to 2000 s. |
| Time Interval A to B | : | 0 ns to 2000 s. |
| LSD ⁽¹⁾ Displayed | : | |
| Below 20 s | : | 1 ns; |
| Above 20 s | : | $5 \times \text{Time} \times 10^{-10}$ s. |
| Resolution | : | |
| Below 20 s | : | $\pm 2 \text{ LSD} \pm \text{start trigger error}^{(2)} \pm \text{stop trigger error}^{(2)}$; |
| Above 20 s | : | 1 LSD. |
| Accuracy | : | $\pm (\text{Time Base error}^{(3)} \times \text{Time}) \pm \text{Trig level timing error}^{(4)}$ $\pm 1 \text{ ns} \pm \text{resolution}$. |
| Time Delay | : | Active only with Time Measurements - single. First input transition opens the gate. Delay inhibits the consequent transitions. |
| Internal | : | 500 internal pre-programmed delay intervals can be inserted between START and STOP of Time Interval A to B. Inputs during delay are ignored. |
| Internal Range | : | 100 μs to 100 s. |
| Preset Position | : | 1 s. |
| External | : | User selectable delay intervals can be applied through rear panel BNC connector. |
| External Range | : | 100 μs to 2000 s. |

Table 1-1. Model 776 Specifications (continued)

| TIME MEASUREMENTS AVERAGED | |
|---|---|
| PERIOD A AVERAGED | |
| Range | : 8 ns to 10 s. |
| LSD ⁽¹⁾ Displayed | : $4 \text{ ns} \times \frac{\text{Period}}{\text{gate time}}$ e.g min 9 digits in 1 second of gate time. |
| Resolution | : $\pm \text{LSD} \pm \frac{(1.4 \times \text{Trig error}^{(2)} \times \text{Period})}{\text{gate time}}$ |
| Accuracy | : $\pm \text{resolution} \pm (\text{Time Base error}^{(3)} \times \text{Period})$. |
| Number of Periods Averaged | : $N = \frac{\text{gate time}}{\text{Period}}$ |
| PULSE A, TIME INTERVAL A to B AVERAGED | |
| Range | |
| Pulse A | : 5 ns to 10 s |
| Time Interval A to B | : -3 ns to 10 s (A and B signals must have the same repetition rate). |
| LSD ⁽¹⁾ Displayed | : $4 \text{ ns} / \sqrt{N}$. |
| Resolution | : $\pm (1 \text{ LSD} + 10 \text{ ps})$. |
| Accuracy | : $\pm (\text{Time Base Error}^{(3)} \times \text{Time}) \pm 1 \text{ ns} \pm \text{resolution} \pm \text{Trigger Level Timing Error}^{(4)} \pm (\text{Trigger error}) / \sqrt{N}$ |
| Dead Time Stop to Start | : 20 ns minimum. |
| Number of Samples Averaged | : $N = \text{gate time} \times \text{Frequency}$. |
| PHASE A to B AVERAGED | |
| Range | : 0 to 360° x (1 - 20 ns x Frequency A). |
| example | : 0 to 359.99° at 1 KHz; 0 to 180.0° at 25 MHz. |
| Frequency Range | : 0.1 Hz to 25 MHz. A and B signals must have the same frequency. |
| LSD ⁽¹⁾ Displayed | : $4 \text{ ns} \times 360^\circ \times \frac{(1 + \sqrt{N})}{\text{gate time}}$ or 0.01°, whichever is greater. |
| Resolution | : $\pm 1 \text{ LSD}$. |
| Accuracy | : $\pm \text{resolution} \pm (1 \text{ ns} \times \text{Frequency A} \times 360^\circ) \pm \text{Trigger Level Timing Error}^{(4)} \times \text{Frequency A} \times 360^\circ \pm \frac{(\text{Trigger error}^{(2)} \times \text{Frequency A} \times 360^\circ)}{\sqrt{N}}$ |
| Number of Cycles Averaged | : $N = \text{gate time} \times \text{Frequency A}$. |
| Minimum Amplitude | : 100 mV rms sine wave. |
| TOTALIZE B | |
| Frequency Range | : 0 to 120 MHz. |
| Totalizing Range | : 0 to 10 ¹⁶ - 1. |
| Gate Modes | |
| Infinite | : Totalizing on B indefinitely. |
| Gated by A | : Totalizing on B between a pair of two consecutive transitions of the opposite direction on A. |
| Gated by AA | : Totalizing on B between a pair of two consecutive transitions of the same direction on A. |
| Gating Transition | : Positive or Negative transitions, selectable. |
| Dead Time Stop to Start ⁽⁷⁾ | : 20 ns min from stop transition to the next start transition. |

Table 1-1. Model 776 Specifications (continued)

| | |
|------------------------------------|--|
| LSD displayed | : 1 count of channel B input signal. |
| Resolution | : 1 LSD. |
| Accuracy | |
| Infinite | : Same as LSD. |
| Gated by A, Gated by AA | : $\pm \frac{\text{pulse repetition rate B} \times \text{Trigger error}^{(2)} \text{ A}}{\text{total counts B}}$ |
| RATIO A/B | |
| Frequency Range | |
| A | : 0.01 Hz to 225 MHz; |
| B | : 0.01 Hz to 125 MHz. |
| LSD ⁽¹⁾ displayed | : $\frac{4 \times \text{Ratio}}{\text{Frequency A} \times \text{gate time}}$ |
| Resolution | : $\pm \text{LSD} \pm \frac{\text{Trigger error B}^{(2)} \times \text{Ratio}}{\text{gate time}}$ |
| Accuracy | : Same as resolution. |
| RATIO C/B | |
| Frequency Range | |
| C | : 50 MHz to 2.4 GHz; |
| B | : 10 Hz to 225 MHz. |
| LSD ⁽¹⁾ displayed | : $\frac{4 \times \text{Ratio}}{\text{Frequency B} \times \text{gate time}}$ |
| Resolution and Accuracy | : $\pm \text{LSD}$. |
| V PEAK A | |
| Function | : Displays simultaneously, with 3 digits each, the maximum and minimum peaks of Channel A input signal. Decimal points and polarity are automatically displayed. |
| Frequency range | |
| Slow Rate | : 40 Hz to 10 MHz; |
| Fast Rate | : 100 Hz to 10 MHz. |
| Dynamic Range | : 280 mV p-p to 51 V p-p. |
| Resolution x1 | : 10 mV; x10: 100 mV. Attenuator is activated automatically if either the positive or the negative peaks of the input signal exceeds ± 5.1 V or when the peak to peak voltage exceeds 5.1 V. |
| Accuracy | : $\pm \text{resolution} \pm 0.1(V_{\text{pos pk}} - V_{\text{neg pk}}) \pm 35 \text{ mV}$. |
| GATE TIME | |
| Internal Gate Time | : 500 pre-programmed gate time intervals. |
| Internal Range | : 100 μs to 10 s or one period of the input, which ever is longer. |
| Preset Position | : 1 s. |
| External Gate Time | : User selectable gate time intervals, ranging from 100 μs to 1000 s. |
| External Range | : 100 μs to 2000 s. External gate not available with Time measurements - single shot. Totalize B and Phase A to B. |
| External Input | : Rear panel BNC connector; accepts TTL level signals. |
| External Gate Delay ⁽⁶⁾ | : <10 μs . |

Table 1-1. Model 776 Specifications (continued)

| | |
|-----------------------------------|--|
| EXTERNAL ARMING (TRIGGER) | |
| Function | : Arms the instrument when set to HOLD mode. |
| Input | : Via Rear panel BNC. |
| Impedance | : 1 K Ω nominal. |
| Level | : TTL. |
| Logic | : Positive true. |
| Minimum Pulse Width | : 10 μ s. |
| Trigger Delay ⁽⁵⁾ | : <50 μ s. |
| STANDARD TIME BASE | |
| Frequency | : 10 MHz. |
| Aging Rate | : <1 x 10 ⁻⁷ /month. |
| Temperature Stability | : <5 x 10 ⁻⁶ , 0 to 50 °C. |
| Line Voltage | : <1 X 10 ⁻⁷ for 10% change (short term). |
| Clock IN/OUT | : Selected with an internal switch. |
| External Time Base Input | : Rear Panel BNC accepts 10 MHz TTL. |
| Time Base Out | : 10 MHz approx 2 V from a 51 Ω source. |
| TCXO TIME BASE | |
| (available with Model 776/2.4G) | |
| Frequency | : 10 MHz. |
| Aging Rate | : <1 x 10 ⁻⁷ /month; <1 x 10 ⁻⁶ /year. |
| Temperature Stability | : <1 x 10 ⁻⁶ , 0 to 50 °C. |
| Line Voltage | : <1 x 10 ⁻⁷ for 10% change (short term). |
| Clock IN/OUT | : Selected with an internal switch. |
| External Time Base Input | : Rear Panel BNC accepts 5 or 10 MHz TTL. Selected via an internal switch. |
| Time Base Out | : 10 MHz approx 2 V from a 51 Ω source. |
| GPIB INTERFACE | |
| Programmable Controls | : All front panel controls except POWER switch. |
| Multiline Commands | : DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD. |
| Uniline Commands | : IFC, REN, EOI, SRQ, ATN. |
| Interface Functions | : SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1. |
| Data Output Format Reading | : With prefix 18 ASCII characters plus terminator; Without prefix - 14 ASCII characters plus terminator. |
| Gate/Delay Time and Trigger Level | : With prefix - 9 ASCII characters plus terminator; Without prefix - 5 ASCII characters plus terminator. |
| Data Output | |
| Single Shot | : One reading processed after trigger. |
| Normal Mode | : Approximately four readings/second, formatted. |
| Fast Mode | : Up to 100 reading/second, formatted. |
| Address Selection | : Front panel programming. Address is stored in a non-volatile memory. |
| GENERAL | |
| Display Rate | |
| Normal | : Approximately four measurements per second; |
| Hold | : Single shot measurement, taken with each press of RESET; |
| Fast | : Up to 100 measurements per second. |

Table 1-1. Model 776 Specifications (continued)

| | |
|-------------------------------------|---|
| Arming | : Each channel is armed by it's own signal |
| Reset | : Clears display and re-cycles measurement. |
| Trigger Level Outputs | : DC Outputs via rear panel terminals. not adjusted for attenuators. |
| Accuracy | : DC (X1) $\pm 35 \text{ mV} \pm 2\%$ of trigger level reading. |
| Output Impedance | : 1 K Ω , 1%. |
| Display | : 10 digits seven segments LED, 0.56" high. 2 digits for exponent. |
| Displayable Digits | : Selectable from 3 to 10 most significant digits. |
| Gate | : LED indicator lights when gate is open. |
| Stored Set-ups | : Ten measurement set-ups. including trig levels, gate/delay time, input conditioning and measurement rate may be stored in memory and subsequently recalled. When AC mains power is removed, a non-volatile memory preserves the stored set-ups for a typical period of 3 years. |
| Operating Temperature | : 0 to 50 °C ambient, 0 to 80% relative humidity. |
| Storage Temperature | : -25 to 65 °C. |
| Power Requirements | : 115/230 V rms $\pm 10\%$ (rear panel switch select) 48-60 Hz, 30 W maximum. |
| Warm-Up | : 1 hour to rated accuracy and stability. |
| Dimensions | : 3.5" x 8.3" x 15.4" (H x W x D) 89 x 211 x 391 m"m. |
| Rack Mount Dimensions | : 3.5" x 19" (H x W) 89 x 483 m"m. |
| Weight: | approximately 8 lb (3.5 kg). |
| Accessories Furnished: | Power Cord, Operating Manual. |
| DEFINITION OF TERMS | |
| (1) LSD | : Unit value of least significant digit. Calculation should be rounded as follows 1 to <5 Hz becomes 1 Hz, 5 ns to <10 ns becomes 10 ns etc. |
| (2) Trigger Error | : $\frac{\sqrt{(e_i^2 + e_n^2)}}{\text{Input slew rate at trigger point}}$ Where: e_i is the rms noise voltage of the counter's input channel (250 μV typ.) e_n is the rms noise of the input signal for 225 MHz band-width. |
| (3) Time Base Error | : Maximum fractional frequency change in time base frequency due to all errors: e.g aging, temperature, line voltage etc. |
| (4) Trigger Level Timing Error (x1) | : $\frac{18\text{mV}}{\text{Input slew rate at start trigger point}} \pm \frac{18\text{mV}}{\text{Input slew rate at stop trigger point}}$ |
| 5) External arming (trigger) delay | : Delay from the positive going slope of the arming signal to the internal gate open signal. |
| (6) External gate delay | : Delay from the positive going slope of the gating signal to the internal gate open signal. |
| (7) Dead Time | : Minimum time between measurement which the counter is busy in performing the measurement. The counter will not at this time respond to any input transition. |

- Model 776 Programmable Counter/Timer with line cord.
- Model 776 Instructions Manual.

If an additional manual is required, order:

- Keithley part number 776-901-00.

1-8. Specifications

Instrument specifications are listed in Table 1-1. These specifications are the performance standards or limits against which the instrument is tested.

NOTE

All specifications in the following table apply after a warm-up period of 1 hour and at ambient temperature of $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

2

Installation

2-1. Introduction

This section contains information and instructions necessary for the installation and shipping of the Model 776. Details are provided for power connection, grounding safety requirements, installation information, and re-packing instructions for storage or shipment.

2-2. Performance Checks

The instrument was carefully inspected for mechanical and electrical performance before shipment from the factory. It should be free of physical defects and in perfect electrical order upon receipt. Check the instrument for damage in transit and perform the electrical procedures outlined in Section 5. If there is indication of damage or deficiency, see the warranty in this manual and notify your local Keithley field engineering representative or the factory.

CAUTION

It is recommended that the operator be fully familiar with the specifications and all sections of this manual. Failure to do so may compromise the warranty and the accuracy which Keithley has engineered into your instrument.

2-3. Power Requirements

The instrument may be operated from any one of the following sources: a. 103.5 to 126.5 Volts (115 Volts nominal) b. 207 to 253 Volts (230 Volts nominal).

The instrument operates over the power mains frequency range of 48 to 63 Hz. Always verify that the operating power mains voltage is the same as that specified on the rear panel voltage selector switch.

CAUTION

Failure to switch the instrument to match the operating line voltage will damage the instrument and may void the warranty.

The instrument should be operated from a power source with its neutral at or near ground (earth potential). The instrument is not intended for operation from two phases of a multi-phase ac system or across the legs of a single-phase, three-wire ac power system. Crest factor (ratio of peak voltage to rms) should be typically within the range of 1.3 to 1.6 at 10% of the nominal rms mains voltage.

2-4. Grounding Requirements

To insure the safety of operating personnel, the U.S. O.S.H.A. (Occupational Safety and Health) requirement and good engineering practice mandate that the instrument panel and enclosure be "earth" grounded. All Keithley instruments are provided with an Underwriters Laboratories (U.L. and V.D.E) listed three-conductor power cable, which when plugged into an appropriate power receptacle, grounds the instrument.

The long offset pin on the male end of the power cable carries the ground wire to the long pin of the receptacle on the rear panel of the instrument.

CAUTION

To avoid operator shock hazard do not exceed the power mains voltage frequency rating which limits the leakage current between case and power mains. Never expose the instrument to rain, excessive moisture, or condensation.

2-5. Installation And Mounting

The instrument is fully solid state and dissipates only a small amount of power. No special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 50°C, when the relative humidity exceeds 80% or condensation appears anywhere on the instrument. Avoid operating the instrument close to strong magnetic fields which may be found near high power equipment such as motors, pumps, solenoids, or high power cables. Use care when rack mounting to locate the instrument away from sources of excessive heat or magnetic fields. Always leave 4 cm (1.5 inches) of ventilation space on all sides of the instrument.

2-6. Bench Mounting

The instrument is shipped with plastic feet, tilt stand in place and ready for use as a bench or portable instrument. See outline drawing Figure 2-1 for dimensions.

2-7. Rack Mounting

The instrument may be rack mounted in a standard 19 inch EIA rack. The instrument may be rack mounted in Rack Mount Kit option Rack.

2-8. Portable Use

The instrument may be used in applications requiring portability. A tilt stand consisting of two retractable legs is provided with each unit.

2-9. Short Term Storage

If the instrument is to be stored for a short period of time (less than three months), place cardboard over the panel and cover the instrument with suitable pro-

TECTIVE covering such as a plastic bag or strong kraft paper. Place power cable and other accessories with the instrument. Store the covered voltmeter in a clean dry area that is not subject to extreme temperature variations or conditions which may cause moisture to condense on the instrument.

2-10. Long Term Storage Or Re-Packing For Shipment

If the instrument is to be stored for a long period or shipped, proceed as directed below. If you have any questions contact your local Keithley field engineering representative or the Keithley Service Department at the factory.

If the original Keithley supplied packaging is to be used proceed as follows:

1. If the original wrappings, packing material, and container have been saved, re-pack the instrument and accessories originally shipped to you. If the original container is not available, one may be purchased through the Keithley Service Department at the factory.
2. Be sure the carton is well sealed with strong tape or metal straps.
3. Mark the carton with the model number and serial number with indelible marking. If it is to be shipped, show sending address and return address on two sides of the box; cover all previous shipping labels.

If the original container is not available, proceed as follows:

1. Before packing the unit, place all accessories into a plastic bag and seal the bag.
2. For extended storage or long distance shipping only, use U.S. government packing method II C and tape a two-unit bag of desiccant (per MIL-D-3464) on the rear cover.
3. Place a 13 cm (5 inch) by 30 cm (12 inch) piece of sturdy cardboard over the front panel for protection.
4. Place the counter into a plastic bag and seal the bag.
5. Wrap the bagged instrument and accessories in one inch thick flexible cellular plastic film cushioning material (per PPP-C-795) and place in a barrier bag (per MIL-B-131). Extract the air from bag and heat seal.
6. Place bagged instrument and accessories into a 250 mm (10 inch) x 360 mm (14 inch) x 508 mm (20 inch)

fiber board box (per PPP-B-636 type CF, class WR, variety SW, grade V3C). Fill additional spaces with rubberized hair or cellular plastic cushioning material. Close box in accordance with container specifications. Seal with sturdy water resistant tape or metal straps.

7. Mark container "DELICATE INSTRUMENT", "FRAGILE", etc. Mark instrument model and serial number and date of packaging. Affix shipping labels as required or mark according to MIL-STD-129.

NOTE

If the instrument is to be shipped to Keithley for calibration or repair, attach a tag to the instrument identifying the owner. Note the problem, the symptoms, and service or repair

desired. Record the model and serial number of the instrument. Show the work authorization order as well as the date and method of shipment. **ALWAYS OBTAIN A RETURN AUTHORIZATION NUMBER FROM THE FACTORY BEFORE SHIPPING THE INSTRUMENT TO KEITHLEY.**

2-11. Safety

Be fully acquainted and knowledgeable with all aspects of this instruction manual before using the instrument to assure operator safety and protection against personnel shock hazard.

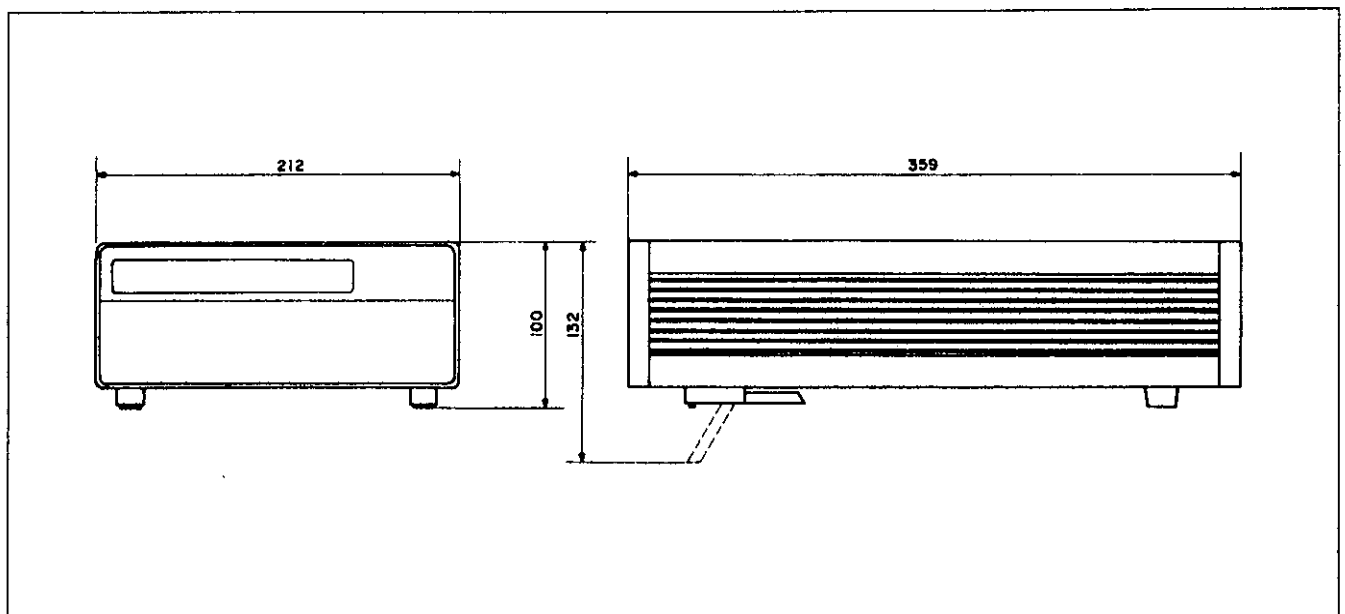


Figure 2-1. Model 776 - outline dimensions.

Notes

3

Operating Instructions

3-1. Introduction

Model 776 operation is divided into two general categories: basic bench operation, and IEEE-488 operation. Basic bench operation, which is covered in this section, consists of using the Model 776 to perform basic frequency, time, peak voltage, and phase measurements. IEEE programming can also be used to greatly enhance the capability of the instrument in applications such as automatic test equipment. These aspects are covered in details in Sections 3 and 4.

3-2. Front Panel Familiarization

The front panel layout of the Model 776 is shown in Figure 3-1. The front panel is generally divided into three sections: controls, connectors, display and indicators. The following paragraphs describe the purpose of each of these items in details.

3-2-1. Controls

All the front panel controls except **[POWER]** are momentary contact switches. Many controls include an annunciator light to indicate the selected mode. Controls which do not have an annunciator light, when pressed, will cause an immediate reaction on the display. The controls are divided into functional groups for easier operation. Front panel controls are divided to the following functional groups: Power, Mode, Functions, Display Modifiers, and Input Setting.

1. POWER. The **[POWER]** switch controls the AC power to the instrument. Pressing and releasing the

switch once turns the power on. Pressing and releasing the switch a second time turns the power off.

2. MODE. There are two push-buttons in the MODE section: **[CLR/LCL]** (clear/local), and **[2nd/EXE]** (second/execute). The **[2nd]** push-button is used to select secondary functions. Normally, the secondary functions are marked below the push-buttons. To help distinguish between normal and secondary functions, all secondary functions are printed in yellow. Pressing the **[2nd/EXE]** push-button will cause the instrument to display the following reading:

2nd ?

The reading is blinking indicating that the counter is ready for a consequent press of another push-button which was assigned a second function. Pressing the **[2nd/EXE]** push-button again will restore normal operation. The **[CLR/LCL]** push-button when pressed, and the instrument was in remote operation (but not in remote lockout condition LLO), restores local operation. When the instrument is in local operation, pressing this push-button clears the display and arms the counter for the next measurement cycle.

3. FUNCTION. The three FUNCTION push-buttons control the type of measurement. Each push-button is used to select one of three functions.

FREQ. - The FREQ push-button places the instrument in one of three frequency measurement functions: Frequency A, Frequency B or Frequency C. Consecutive pressing of the **[FREQ]** push-button will toggle

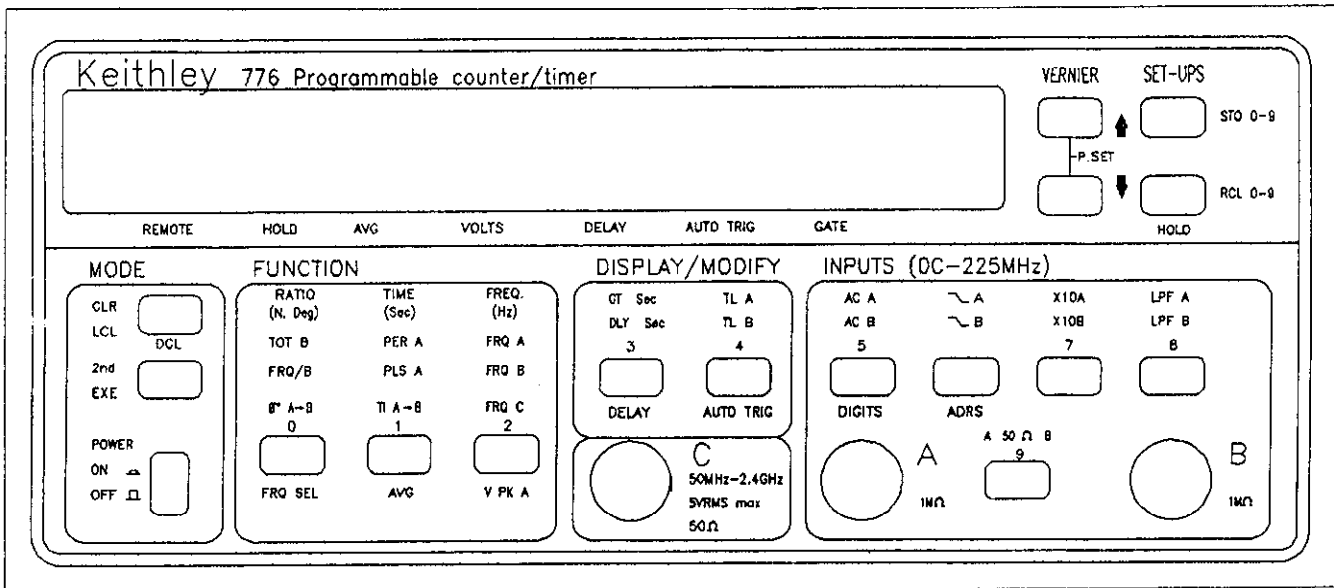


Figure 3-1. Front Panel Controls, Indicators and Connectors

between frequency A, Frequency B and Frequency C functions.

TIME - The TIME push-button sets the Model 776 up to measure one of three time measurement functions: Period A, Pulse A or Time Interval A to B. Consecutive pressing of the [TIME] push-button will toggle between these three functions.

RATIO - The RATIO push-button places the instrument in one of three ratio measurement functions: Totalize B (infinite, gated by A, or gated by AA), FRQ/B (C/B or A/B), or Phase A relative to B. Consecutive pressing of the [RATIO] push-button will toggle between Totalize B, FRQ/B, and Phase A to B functions.

4. DISPLAY/MODIFY. The two DISPLAY/MODIFY push-buttons modify the display from normal frequency, time or ratio reading to another reading such as trigger level, gate time, totalize mode, V peak mode, or delay time.

5. INPUTS. There are 5 push-buttons at the INPUTS section. These buttons select functions which adjust input signal properties before it is applied to the actual input. Push-buttons control attenuation, coupling, slope, input impedance, and low pass filter to suppress high frequency noise.

6. VERNIER. The two push-buttons in the VERNIER section are used as a digital potentiometer. The VERNIER operates in conjunction with the following functions: Trigger level, Gate time, Delay time, Digits, Address, Totalize mode, Vpeak mode, Analog out, and

Offset. The two push-button also set these parameters to a pre-set position.

7. SET-UPS. There are two push-buttons in the SET-UPS section. One is used to store a complete front panel set-up. The other button is used to recall a stored set-up.

3-2-2 Connectors

The connectors are used to connect the Model 776 to the unknown signal.

1. CHANNEL A. The CHANNEL A connector is used when making measurement which are related to channel A.

2. CHANNEL B. The CHANNEL B connector is used when making measurements which are associated with channel B.

3. CHANNEL C. The CHANNEL C connector is used for high frequency measurements, up to 2.7 GHz with a 50 Ω input impedance. Although this terminal is always installed, the internal circuitry to operate this function is optional and may not be installed on your model.

NOTE

If front panel connectors are present on a Model 776/2.4G/R unit, they are not functional.

3-2-3. Display And Indicators

1. DISPLAY. The function of the display is to show the result of the processed measurement. The display consists of a 10 digit mantissa and a single digit exponent.

The exponent uses a leading minus to indicate negative values. The sign on the exponent changes to + for zero or positive values. The display is also used to indicate information other than the measurement such as the gate time or the trigger level.

2. INDICATORS. There are 30 indicators located on the front panel. The indicators are used to point at a selected function or signal to the user that the instrument is set to a special function like auto trigger or remote operation.

3-3 Rear Panel Familiarization

Figure 3-2 shows the rear panel layout of the model 776.

3-3-1. Connectors and Terminals

1. AC RECEPTACLE. Power is applied, through the supplied power cord, to the 3-terminal AC receptacle. Note that the selected power supply voltage is marked on the rear panel above the line voltage selector switch.

2. LINE SWITCH. The LINE VOLTAGE SELECTOR switch selects one of the primary voltage which are marked on both sides of the switch.

3. LINE FUSE. The line fuse provides protection for the AC power line input. For information on replacing this fuse, refer to Section 5.

4. IEEE-488 CONNECTOR. This connector is used to connect the instrument to the IEEE-488 bus.

5. TRIGGER LEVEL OUTPUTS. These three terminals are used for monitoring, by an external DMM or oscilloscope, the DC voltage coming from channels A and B trigger level circuits.

6. CLOCK. This BNC connector is used to output the internal clock as a reference to another instrument. The same input may be connected to an external reference. The function of this input/output is marked above the connector.

7. EXTERNAL ARMING/GATE/DELAY. A BNC connector which may receive one of three signals: arming pulse, external gate signal or external delay pulse. This input is useful when gate or delay times other than the internal times are required, or to take one reading with model 776 in synchronization with other equipment.

8. CHANNEL A, CHANNEL B, CHANNEL C (Not shown). These connectors, only present on a Model 776/2.4G/R, are used to connect the unit to the unknown signal. If front panel connectors are present, they are not functional.

3-4. Power-Up Procedure

The basic procedure of powering up the Model 776 is described below.

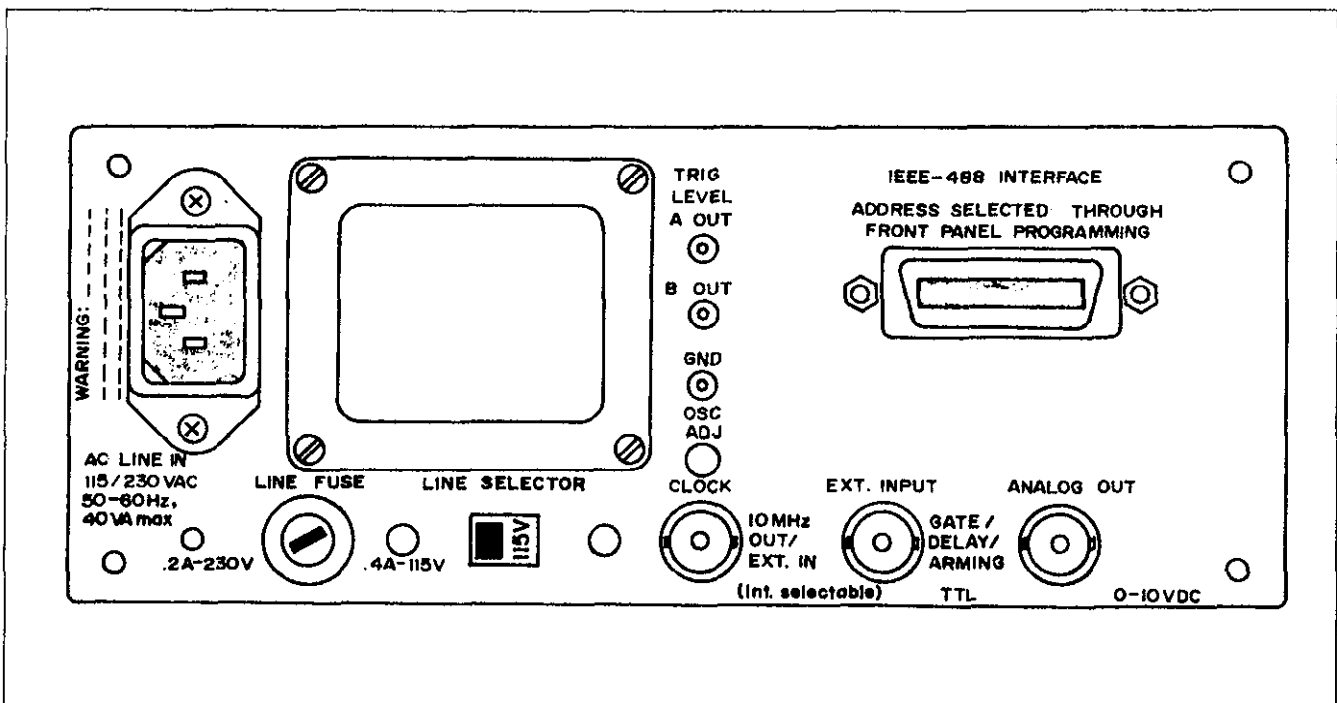


Figure 3-2. Rear Panel Connectors and Terminals.

1. Connect the female end of the power cord to the AC mains receptacle on the rear panel. Connect the other end of the power cord to a grounded AC outlet.

CAUTION

Be sure the power line voltage agrees with the indicated value on the rear panel of the instrument. Failure to heed this warning may result in instrument damage.

WARNING

The instrument is equipped with a 3-wire power cord designed to be used with grounded outlets. When the proper connections are made, the instrument chassis is connected to the power line ground. Failure to use a properly grounded outlet may result in personal shock hazard.

2. Turn on the power by pressing and releasing the POWER switch on the front panel.
3. The instrument will then begin operation by performing a display and indicator test which takes approximately one second. All mode and IEEE indicators will turn on and the display will appear as follows:

8.8.8.8.8.8.8.8.8.± 8.

4. To verify that all display segments are operating, compare the instrument's display with the above during the test.
5. Following the display test, the instrument proceeds by displaying the options installed. When no option is installed, the instrument will display the following message:

776

If option 2.4G (2.4 GHz C Channel input + TCXO) is installed, the instrument will display the following message:

776-2.4G

6. Once the model number and the installed options are displayed, the instrument will perform ROM and RAM tests. If all these tests are passed, the display will show the software revision level for about 1 second similar to the example below:

SoFt 1.1

7. Following the software revision level, the instrument will display the previously selected IEEE primary address which is set through front panel programming and stored in the non-volatile memory. For example, with the rear panel switch set to address 25, the display will show:

IE Adr 25

8. Following these display messages, the instrument will go into the normal operating mode and begin displaying readings. The instrument will be set to the previously programmed front panel set-up.

3-5. Software Reset

One, who is not yet fully familiar with the front panel operation of the Model 776, may find himself locked in a "dead-end" situation where nothing operates the way it should. The fastest way to restore the counter to a known condition is by resetting the instrument's software. This can be done by pressing the [2nd/EXE] push-button and then pressing the [DCL] push-button (second function to the [CLR/LCL] push-button). The instrument will then be set to its factory selected default. Table 3-1 summarizes these defaults.

NOTE

Software reset has no effect on any of the front panel set-ups which were previously stored in the memory locations 0 through 9. The software reset also has no effect on the programmed GPIB address.

3-6. Display Messages

The Model 776 has several display messages associated with basic front panel operation. The instrument has also a few front panel indications that flag front panel programming error. These messages are discussed in the following. Note that the instrument has a number of additional display messages which are associated with IEEE-488 programming.

3-6-1. IEEE-488 Error Messages

The counter incorporates a number of display messages which are associated with errors made through the GPIB interface. These messages are discussed in detail in Section 4 of this manual. However, there is one message which should be explained at this point because it may interfere with normal front panel operation. A remote enable or a device dependent command, sent to the counter through the bus, turns on the REMOTE light

| FUNCTION | DEFAULT STATE |
|----------------------|----------------------|
| Function | Frequency A |
| Display/Modify | Normal reading |
| Gate/Delay | Time 1.0 s |
| Trigger Levels A & B | 0.00 V |
| Coupling | DC |
| Slope | Positive going |
| Attenuators | Off |
| Filters | Off |
| Impedance | 1 MΩ |
| Averaging | Off |
| Auto Trigger | Off |
| Delay | Off |
| Sampling Rate | Normal - 3 reading/s |
| Ratio Mode | A/B |
| V Peak A | Rate Fast |
| Totalize Mode | Infinite |
| Displayed Digits | 10 |
| IEEE Status | Local |

Note: The Model 776 and 776/2.4G/R have a default gate time of 1 second. The Model 776/2.4G/R has a default gate time of 100ms.

Table 3-1. Default States After Software Reset

and enables remote operation. In this case, all front panel push-buttons, except [LCL], are disabled. An attempt to press one of these push-buttons will cause the following message to be displayed:

PrESS LcL

This message indicates that the instrument will ignore any front panel programming sequence unless the [CLR/LCL] push-button is pressed and the REMOTE light turns off.

3-6-2. Error Indication

There are several error indications that are caused by either an incorrect front panel programming or insufficient input level conditioning which is otherwise required by the instrument for normal signal processing. These indications are either visible (blinking LED) or audible (beeper) and are described in the following.

1. AUDIBLE ALARM. The AUDIBLE ALARM will sound when attempting an incorrect sequence of front panel programming. This could occur under the following conditions:

1. Any two front panel push-buttons are pressed simultaneously except the two [VERNIER] push-buttons.
2. The instrument is in **FREQ** or **RATIO** or **TIME AVG** function and the operator attempts to turn the delay on.
3. The instrument is in **FREQ** or **RATIO** function and the operator attempts to turn the **AVG** function on.
4. The instrument is in remote condition (**REMOTE LED** on) and any front panel push-button except [CLR/LCL] is pressed.
5. The [VERNIER] push-buttons were pressed and the instrument was not in **DISPLAY/MODIFY** mode of operation.
6. The instrument was in **DISPLAY/MODIFY** mode of operation and the [VERNIER ↑] or [VERNIER ↓] push-buttons were pressed continuously until a parameter limit was reached. Parameter limits are summarized in Table 3-2.

2. GATE ERROR. The gate error is indicated on the front panel by the **GATE LED**. This error will occur when the counter is in **FREQ** or **TIME AVG** function and when the signal was removed from the input connector in the middle of the measurement process or when a radiated random noise was sensed by the input circuitry. The **GATE LED** will then blink once but no result will be registered on the display.

3. GATE TIME ERROR. The gate time error is indicated on the front panel by the **GT LED**. The gate time error occurs in **FREQ** or **TIME AVG** functions when the period of the input signal is larger than the period of the gate time. The gate error will also occur in **Phase A to B** function when the gate time is not sufficient to permit the minimum resolution of 1 degrees. When one of the conditions above occurs, the gate time LED (**GT**) will blink for a couple of times and then resume a search routine. This sequence will repeat itself until a proper signal is found or until the gate time was readjusted to satisfy the required conditions.

4. TRIGGER LEVEL ERROR. The trigger level error occurs when the instrument is set to **AUTO TRIG** or **V PEAK A** modes and the input signal is either absent or below the specified auto trigger limits. The trigger level LED (either **TL A** or **TL B**) then blinks, for a couple of times. The counter then resumes a new search routine. This sequence will repeat itself until a signal has been found or until the auto trigger mode was turned off.

3-7. Control Selection

Selecting the various front panel operating modes is simply a matter of pressing, once or twice, the appropriate push-button as described in the following paragraphs.

| FRONT PANEL NOMENCLATURE | PARAMETER | LOW LIMIT | HIGH LIMIT |
|--------------------------|------------------------|-------------|--------------------|
| TL A | Trigger Level A | -5.00 | +5.00 |
| TL B | Trigger Level B | -5.00 | +5.00 |
| GT | Gate Time | 100 μ s | 100 s / USER GATE |
| DLY | Delay Time | 100 μ s | 100 s / USER DELAY |
| DIGITS | No of displayed digits | 3 | 10 |
| ADRS | GPIB address | 0 | 30 |

Table 3-2. Front Panel Programming Limits

3-8. Selecting A Function

The Model 776 must be set up for the proper measuring function, with one of the three Function push-buttons. There are 17 different available functions in the FUNCTION block summarized in the following. To simplify the operating instruction for these functions, the functions are divided in the following table into three operational groups.

FUNCTIONS SUMMARY

Group 1

1. FREQUENCY A
2. FREQUENCY B
3. FREQUENCY C
4. PERIOD A
5. PULSE WIDTH A
6. TIME INTERVAL A TO B
7. PHASE A RELATIVE TO B

Group 2

8. PERIOD AVERAGED A
9. PULSE WIDTH AVERAGED A
10. TIME INTERVAL A TO B AVG

Group 3

11. TOTALIZE B (infinitely)
12. TOTALIZE B GATED BY A
13. TOTALIZE B GATED BY AA
14. RATIO A/B
15. RATIO C/B
16. V PEAK A - FAST RATE
17. V PEAK A - SLOW RATE

The letter after the function indicates the input connector where this measurement may be performed. For

example, FREQUENCY C can only be measured if the signal is applied to the C Channel input connector. Similarly, V PEAK A can only be measured at the Channel A input connector. Some functions require that both Channel A and B be connected for a successful measurement - functions like Time Interval A to B, Ratio FRQ/B, or Totalize B by A.

Selecting a function from the first group is described in the following:

1. First bring the Model 776 to a known state as described in paragraph 3-5. This is done by pressing first the [2nd/EXE] push-button and then pressing the [DCL] push-button. The instrument will then default to a factory pre-selected state and the light next FRQ A will illuminate; indicating that Frequency A function is now selected.

2. To select Frequency B press the [FREQ] push-button once. The light next to FRQ B illuminates; indicating that Frequency B is now selected.

3. To select Frequency C press the [FREQ] push-button again. The light next to FRQ C illuminates; indicating that Frequency C is now selected. Note that this procedure assumes that option 52 (2.4 GHz C Channel is installed).

4. To select Period A press the [TIME] push-button once. The light next to PER A illuminates; indicating that Period A is now selected.

5. To select Pulse A press the [TIME] push-button again. The light next to PLS A illuminates; indicating that Pulse A is now selected.

6. To select Time Interval A to B press the [TIME] push-button again. The light next to TI A to B illuminates; indicating that Time Interval A to B is now selected.

7. To select Phase A relative to B press the **[RATIO]** push-button again. The light next to Phase A to B illuminates; indicating that Phase A to B function is now selected. Select a function from the second group as described in the following:

8. To select Period Averaged A press the **[TIME]** push-button until the light next to PER A illuminates. Press the **[2nd]** push-button and then press the **AVG.** push-button (second function to the **[TIME]** button). Observe that the **AVG** light illuminates; indicating that the Period Averaged A function is now selected.

9. To select Pulse Averaged A press the **[TIME]** push-button until the light next to PLS A illuminates. Press the **[2nd]** push-button and then press the **AVG.** push-button (second function to the **TIME** button). Observe that the **AVG** light illuminates; indicating that the Pulse Averaged A function is now selected.

10. To select Time Interval Averaged A to B press the **[TIME]** push-button until the light next to TI A to B illuminates. Press the **[2nd]** push-button and then press the **AVG.** push-button (second function to the **TIME** button). Observe that the **AVG** light illuminates; indicating that the Time Interval Averaged A to B function is now selected.

NOTE

The averaging function, once it is selected, will automatically turn on whenever a **TIME** measuring function is selected. For example, Selecting **PER A** averaged turns the **AVG** light on. Changing the selected function to **FRQ A** will automatically turn the **AVG** light off. Re-selecting one of the **TIME** functions will automatically turn the **AVG** light on.

Selecting a function from the third group requires additional operations and is described in the following:

11. To select Totalize B press the **[RATIO]** push-button once. The light next to **TOT B** illuminates; indicating that Totalize B is now selected.

12. To select Totalize B by A function press the **[RATIO]** push-button until the light next to **TOT B** illuminates. The counter is now set to totalize indefinitely. To select the Totalize B by A function press the **[GT]** (gate) push-button in the **DISPLAY/MODIFY** group and observe that the reading on the display is as follows:

tot InF

This reading indicates that the instrument is set to Totalize infinitely. Now press the **[VERNIER UP]** push-button once and observe that the display reading is changed to the following:

tot bY A

This reading indicates that the instrument is now set to Totalize at B with A serving as the gating signal. Press the **[GT]** push-button again. The instrument is now ready to perform the required function.

13. To select Totalize B by AA function repeat the procedure as described above. Pressing the **[VERNIER ↑]** push-button changes the display reading as follows:

tot bY AA

This reading indicates that the instrument is now set to Totalize, at B input, with a pair of consecutive transitions at A, having the same direction, serving as the gating signal. Press the **[GT]** push-button again. The instrument is now ready to perform the required function.

14. To select Ratio A/B press the **[RATIO]** push-button again. The light next to **FRQ/B** illuminates; indicating that Ratio A/B is now selected.

15. To select the Ratio C/B function press the **[RATIO]** push-button until the light next to **FRQ/B** illuminates. The counter is now set to measure Ratio **FRQ/B**. To select the Ratio C/B function press the **[2nd]** and **[FRQ SEL]** (frequency select) push-buttons in sequence and observe that the reading on the display change to display as follows:

A to B

This reading indicates that the instrument is set to Ratio A/B. Now press the **[VERNIER ↑]** push-button once and observe that the display reading is changed to the following:

C to B

This reading indicates that the instrument is now set to Ratio C/A. Press the **[2nd/EXE]** push-button again. The instrument is now ready to perform the required function.

16. The V Peak A function has two measurement rates: Fast - for frequencies above 100 Hz and Slow - for the range of 40 Hz to 10 MHz. Note that the instrument, after **DCL** defaults to its Fast rate. Selecting the measurement rate is described later in this manual.

3-9. Selecting Gate And Delay Time

The Model 776 may be operated in its preset gate or delay times of one second, or with one of its 500 built-in increments. When selecting the gate time, the instrument will increment up or down, one gate time, each time the [↑] or [↓] push-button is pressed. The present gate time may be noted on the display by pressing the [GT] push-button.

The gate times may only be selected in conjunction with frequency, time averaged, ratio FRQ/B, and Phase A to B functions.

The gate time may be selected as follows:

1. Select a frequency measurement function.
2. Press the [GT] push-button. Observe that the GT light turns on and that the instrument displays the following message:

1.0

This reading indicates the selected gate time in seconds.

3. To change the gate time press the [VERNIER ↑] or [VERNIER ↓] push-buttons. Pressing the [↑] push-button increases the value of the gate time. Conversely, pressing the [DOWN] push-button decreases the value of the gate time. Depressing the [↑] or [↓] push-buttons for more than 1 second, causes the instrument to increment or decrement continuously.
4. Pressing the [↑] push-button and the instrument was at a gate time of 100 seconds forces the instrument into a **USER GATE** mode. This mode requires an external gating signal. Operating the counter with an external gate is explained later in this section.
5. Pressing the [↑] and [↓] simultaneously changes the gate time to a preset value of 1.0 second.
6. To resume normal display operation, press the [GT] push-button. The GT light turns off and the instrument is now ready to perform measurements with the newly selected gate time.

NOTE

To prevent operator error, there is an internal audible alarm that sounds whenever a limit is reached. (e.g. low limit of 100 μ s).

The sequence of selecting the delay time is similar to the procedure for selecting the gate time. Delay times may only be selected and applied to single shot (non-av-

eraged) time measurement. To select a delay time value proceed as follows:

1. Select a single shot time measurement function such as Period, Pulse Width, or Time Interval A to B.
2. Press the [DLY] push-button. The DLY light turns on and the instrument displays the following message:

1.0

This reading indicates the selected delay time in seconds.

3. To change the delay time press the [VERNIER ↑] or [VERNIER ↓] push-buttons. Pressing the [↑] push-button increases the delay time. Conversely, pressing the [↓] push-button decreases the delay time. Depressing the [↑] or [↓] push-buttons for more than 1 second, causes the instrument to increment or decrement continuously.
4. Pressing the [↑] push-button and the instrument was at a delay time of 100 seconds forces the instrument into a **USER DELAY** mode. This mode requires an external delay signal. Operating the counter with an external delay is explained later in this section.
5. Pressing the [↑] and [↓] simultaneously changes the delay time to a preset value of 1.0 seconds.
6. To resume normal display operation, press the [DLY] push-button. The DLY light turns off and the instrument is now ready to perform measurements with the newly selected delay time.

3-10. Setting Trigger Levels

There are two trigger level push-buttons associated with each Channel A (TL A) and Channel B (TL B). The [VERNIER ↑] and [VERNIER ↓] push-buttons, when operated in conjunction with TL A or TL B, set the voltage level that will trigger the instrument. To set the trigger levels proceed as follows:

NOTE

The procedure for setting the trigger level is identical for Channels A and B. Trigger level A (TL A) can only be modified when functions that are related to input A are selected, e.g. FRQ A, TIME A to B etc. Selecting a function which involves Channel B enables access to the TL B parameter.

1. Using the procedure which is described above, set the instrument to Frequency A function. If other front panel

lights illuminate, reset the counter using the software reset procedure which is described in paragraph 3-5.

2. Press the [TL A] push-button. Observe that the TL A and VOLTS indicators turn on and that the display reads as follows:

0.00

This reading indicates the selected trigger level in units of volts.

3. To set a positive trigger level press the [VERNIER \uparrow] push-button. Holding in the [\uparrow] or [\downarrow] push-buttons for more than 1 second, causes the instrument to increment or decrement continuously. To set a negative trigger level press the [VERNIER \downarrow] push-button until the desired level has been reached.

NOTE

Pressing the [VERNIER \uparrow] or [VERNIER \downarrow] push-buttons, when the limits of +5.00 or -5.00 respectively have been reached, causes an audible alarm to sound.

4. Simultaneously press the two [VERNIER] push-buttons and note that the display reading resets to 0.00.

5. Press the [TL A] push-button. The indicator light turns off and the instrument returns to its previous measurement state.

6. To set the trigger level for both Channels A and B, select a function which involves both inputs (e.g ratio A/B, Phase A to B, time interval A to B or totalize B by A). Pressing the [TL] push-button once turns the TL A light on; indicating that the instrument displays the trigger level for Channel A. A second consecutive press turns the TL B light on; indicating that the instrument displays the trigger level for Channel B. A third push turns TL B light off. The instrument then resumes its normal operation.

3-11. Setting Input Conditioning Controls

A proper set-up of the input controls ensures proper operation of the instrument. There are five push-buttons which control the input. These push-buttons are common to both Channels A and B.

Changing one of the input setting controls is simply a matter of pressing the required push-button. There are 5 lights for each input channel which are associated with each of the five controls.

To set input condition controls for Channel A proceed as follows:

1. Set the instrument to operate at one of the following functions: FRQ A, PER A, PLS A, or V Peak A.

2. To select the required coupling mode press the [AC] push-button. Instrument is dc coupled when the AC light is off. When the AC light is on the instrument is ac coupled.

3. To change the slope that the instrument will trigger on, press the [SLOPE] push-button. The counter triggers on a positive going edge if the slope light is off. If the slope light is on the counter triggers on a negative going edge.

4. Attenuation is required when the input signal exceeds the specified dynamic range. To attenuate the signal press the [x10] push-button. The input signal is attenuated by a factor of 10 when the x10 light is on. When the x10 light is off, the input signal is not attenuated.

5. In low frequency applications, where the frequency range is below 100 KHz, it is recommended to use the low pass filter. The low pass filter attenuates the high frequency components which may interfere with the required measurement. To apply a low pass filter press the [LPF] push-button. High frequency signals are filtered when the LPF light is on. The filter is deactivate when the LPF light is off.

6. In high frequency applications above 1 MHz, or high slew rate signals, it is recommended that the input cable be terminated with 50 Ω at the counter end. To change the input impedance from 1 M Ω to 50 Ω press the [50 Ω] push-button. Input is termination with 50 Ω when the 50 Ω light is on. Input impedance is 1 M Ω when the 50 Ω light is off.

To set input condition controls for Channel B proceed as follows:

1. Set the instrument to operate in one of the following functions: FRQ B or TOT B.

2. Use the same procedure as described above for Channel A.

To set input condition controls for both Channels A and B proceed as follows:

1. Set the instrument to operate in one of the following functions: Time Interval A to B, Ratio FRQ/B, Phase A to B, TOT B by A, or TOT B by AA.

2. To select the AC coupling mode for Channel A, press the [AC] push-button once. The AC A light illuminates:

indicating that Channel A is now ac coupled. Pressing the [AC] push-button again turns the AC A light off but AC B light turns on; indicating that Channel A is dc coupled and Channel B is ac coupled. Pressing the button once more, turns both AC A and AC B light on; indicating that both channels are now ac coupled. Pressing the same push-button again turns both lights off. This now indicates that both channels are set to dc coupling mode.

3. Use the same procedure to set the slopes, attenuation, impedance and filtering.

3-12. Selecting The Number Of Displayed Digits

A major advantage of Model 776 over similar products is its capability to display a fixed number of digits regardless of the frequency of the input signal. For example, with one second of gate time, the Model 776 displays a minimum of 10 digits. This however, may turn into a disadvantage when measuring the frequency of a relatively unstable signal; in which just the most significant digits are stable and the least significant digits are "jumping around" with no significant meaning. Model 776 permits truncation of the unstable least significant digits, while still preserving its full performance. To select the number of displayed digits proceed as follows:

1. Press the [2nd] push-button. Observe that the instrument prompts the following message:

2nd ?

2. Press the [DIGITS] push-button (second function to [AC A]). The instrument now displays the following:

xx diGit

Where x is the selected number of digits and could range from 03 to 10 digits.

3. Use the [VERNIER \uparrow] to increase the number of the displayed digits. Conversely, press the [VERNIER \downarrow] to decrease this number.

4. Pressing the [VERNIER \uparrow] and [VERNIER \downarrow] simultaneously, presets xx to 10; indicating that results will be displayed with up to 10 digits of resolution, and that no digit will be truncated.

5. To return to normal operation of the Model 776 simply press and release the [EXE] push-button (second function to [2nd]). The instrument than displays the

processed measurement with the programmed number of digits.

NOTE

Selecting five digits to be displayed, instead of ten, will eliminate the five least significant digits and will move the entire display to the right by five places. An example of a normal display reading, and the same display reading with five digits of resolution is given as follows.

Display reading with 10 digits:

1.234567890

Display reading with selected 5 digits:

1.2345

NOTE

Under certain conditions, Model 776 may display frequency reading with less than ten digits. This may occur when the selected gate time is smaller than 1.0 second. In that case, the instrument overrides the programmed pre-selected number of digits and displays only as many digits as it can. When gate time is increased, Model 776 again limits the number of displayed digits to the selected value.

3-13 Selecting Measurement Rate

Model 776 offers a choice from three measurement rates. Two measurement rates are accessible through front panel programming - normal rate (about 3 readings per second), and single shot (hold). A fast measurement rate (up to 100 reading per second) is also available but is only accessible from the GPIB interface. The fast measurement rate will be discussed in details in Section 4. The HOLD light determines front panel measurement rate. When the indicator is off, the instrument is in its normal measurement rate. When the HOLD light is on, the instrument is set to single shot measurements. To select the measurement rate proceed as follows:

1. Press, in sequence, the [2nd/EXE] and the [HOLD] push-buttons (second function to [RATIO]). The HOLD light turns on; indicating that the instrument is now armed for a single-shot measurement cycle. Arming is explained later in this chapter.

2. To return to normal measurement rate, press, in sequence, the [2nd/EXE] push-button and then the [HOLD] push-button. The HOLD light turns off, indicating that the instrument is now ready to accept and process readings at its normal rate.

NOTE

Measurement rate is gate time dependent. Model 776 can process 3 readings in one second when its gate time is set to below 300 ms.

3-14 Arming

Capturing the required sequence of input signals may, at times, create a major problem for the design engineer. Imagine a single source that repeatedly generates bursts of signals having various repetition rates, pulse widths, and number of pulses. It would be next to impossible to measure such parameters along the time axis unless the counter is prepared for this task. Model 776 has arming capabilities which permits such complex measurements. Do not confuse arming with Trigger. Model 776 may not be triggered. Model 776, unless armed, will not perform the task of signal processing. Model 776 may be armed (prepared) for the next measurement in four ways:

1. Continuously armed by an input signal, when Model 776 is set to its normal mode of operation.
2. With front panel [CLR] push-button, when the instrument is set to HOLD mode.
3. With an arming pulse applied to the rear panel EXT. INPUT connector, when the instrument is in the HOLD mode.
4. With commands given over the IEEE-488 bus as described in Section 4. This section covers front panel and external arming in details.

3-14-1 Continuous Arming With the Input Signal

When no special arming mode was selected, Model 776 is armed by its input signal. This means that with no legal input signal, the counter idles. The Gate indicator is off until the first transition, at the input connector, is sensed. An input signal, within the dynamic range, initiates a measurement cycle. The gate light blinks every time that the internal gate opens. There is no special procedure to set the Model 776 up for continuous arming. This mode is especially useful in analyzing the contents of a burst.

3-14-2 Front Panel Arming

Front panel arming is performed with the [CLR] push-button. To use front panel arming proceed with the following steps:

1. Using the procedure described in paragraph 3-13, select the hold mode. Observe that the HOLD light turns on and that the gate light ceases from flashing, indicating that the instrument is in its one-shot measurement mode. The display zeroes and no reading is processed until an arming stimulus is applied.
2. To arm the instrument for a single reading, press and release the [CLR] push-button. The next transition at the input connector will cause the gate to open. The instrument then checks for the legality of the input signal, processes the reading and displays the result on the display. The display will retain the last processed reading until cleared, re-armed, or until another function is selected.
3. To arm the instrument for a new measurement, press the [CLR] push-button. Observe that the display zeroes and that a new measurement cycle is initiated.
4. To remove the instrument from its one-shot arming mode, turn the hold function off by pressing in sequence the [2nd] and [HOLD] push-buttons.

3-14-3 External Arming

External arming operates much like front panel arming except for the arming stimulus itself. In this case the arming stimulant is applied to the rear panel EXT. INPUT connector. The arming pulse must conform to TTL levels. To use the external arming feature, proceed as follows:

1. Using the procedure described in paragraph 3-13, select the hold mode. Observe that the HOLD light turns on and that the gate light ceases from flashing, indicating that the instrument is in its one-shot measurement mode. The display zeroes and no reading is processed until an arming stimulus is applied.
2. Connect the external arming source to the rear panel EXT INPUT connector. The first positive going transition at the EXT INPUT connector arms the Model 776 for taking and processing the next available signal. Note that after each positive going transition of the arming signal, the numeric display is set to read zero until the next data is processed and displayed. Model 776 ignores any transitions at the EXT INPUT connector when the gate is open.

3. To remove the instrument from its one-shot arming mode, turn the hold function off by pressing in sequence the [2nd] and [HOLD] push-buttons.

3-15. Using Auto Trigger Level

The auto trigger level function is extremely useful when measuring repetitive signals having an unknown dc component. The auto trigger is capable of finding the peaks of the signal and then setting the trigger level exactly at their center. In addition, the auto trigger automatically sets the correct attenuation and adjusts the input signal to fit within the dynamic range. The auto trigger mode does not operate on totalize B and frequency C functions. Auto trigger level function works independently in conjunction with Channels A and B.

To set the Model 776 to operate in auto trigger mode proceed as follow:

1. Press in sequence the [2nd] and the [AUTO TRIG] (second function to [TL A]) push-buttons. Observe that the AUTO TRIG light illuminates, indicating that the auto trigger function is selected. When the indicator is off, the instrument is in its normal manual trigger level mode.
2. Apply the signal to be measured to the appropriate input connector. After a short search sequence, the gate opens and the measurement is processed.
3. TL A or TL B lights blink if an error was detected. Refer to paragraph 3-6-3 for a additional error indications information.
4. To return the Model 776 to normal trigger level mode, press in sequence the [2nd] and the [AUTO TRIG] push-buttons.

3-16. Using V Peak A

The V PEAK A function turns the Model 776 into a versatile RF peak voltage meter where both low and high peaks are detected, processed and displayed. This is especially useful in analyzing both the amplitude and the dc component of an unknown signal. There are two available measurement rates for the V Peak function: Fast for normal measurements above 100 Hz, and slow rate for measurements of signals below 100 Hz. To select the V Peak A function proceed as follows:

1. Press in sequence the [2nd] and the [V PK A] (second function to [FREQ]) push-buttons. Observe that the VOLTS light illuminates. This indicates that the instrument is now set to V Peak A measurements. The normal display reading is transform into a two section display like the following:

0.00 0.00

The three digits on the left indicate the lower peak amplitude. The right three digits indicate the higher peak amplitude. Negative values have a leading minus sign where positive values have no sign. The minus sign and the decimal points are automatically set by the instrument.

2. To select the measurement rate press the [GT] push-button in the DISPLAY/MODIFY group and observe that the reading on the display is as follows:

FASt

This reading indicates that the instrument is set to its fast measuring rate. Now press the [VERNIER $\hat{\uparrow}$] push-button once and observe that the display reading is changed to the following:

SLO

This reading indicates that the instrument is set to measure the V Peak A with its slow measuring rate. Press the [GT] push-button again. The instrument is now ready to perform the required function.

3. Press the [GT] push-button to return the counter to normal V Peak display.
4. Press one of the FUNCTION push-buttons to select another function. Observe that the display returns to normal display reading and that the VOLTS light turns off.

3-17. Using User Gate

The User Gate is useful when a gate time other than the internal pre-determined gate times is required. The limits which must be observed are the minimum limit of 100 μ S and the maximum limit of 1000 s. The User Gate function is accessible in FRQ A, B and C, FRQ/B, PER AVG, PLS AVG, and TI AVG A to B operating modes. To operate the instrument in its User Gate mode proceed as follows:

1. Set the instrument to PRQ A. Press the [GT] push-button once. Observe that the Gate light turns on, and that the instrument displays the gate time.
2. Press and hold the [VERNIER $\hat{\uparrow}$] push-button and observe that the display increments. After the 100 s gate time the instrument enters the User Gate mode and displays the following readout:

USER GAtE

Depressing the [VERNIER \uparrow] push-button after the user gate is displayed causes an audible alarm to sound.

3. Press the [GT] push-button. The Gate light turns off and the instrument is now ready to perform measurements with an external gate time.

4. Apply an external TTL pulse to the rear panel EXT INPUT connector. This signal now serves as the external gate time. The high level duration of the external pulse determines the period of the gate time.

5. To exit the User Gate function press the [VERNIER \downarrow] push-button. Pressing both the [VERNIER \uparrow] and [VERNIER \downarrow] push-buttons presets the displayed gate time to 1.0 s.

3-18. Using Delay

The Model 776 has a delay function which inhibits the closure of the opened gate for a pre-determined period. This function is very useful in burst measurements, relay open/close time measurements where bounce time should be eliminated, and in measurements done on a train of pulses. The delay function is accessible in PER A, PLS A, and Time Interval A to B. The delay time may be selected using the following procedure:

1. Set the instrument to [PER A]. Press the [DLY] push-button in the DISPLAY/MODIFY group. Observe that the DLY light turns on and that the instrument displays the delay time.

2. To change the delay time, press the [VERNIER \uparrow] or [VERNIER \downarrow] push-buttons. When one of the [\uparrow] or [\downarrow] push-buttons are depressed for more than one second, the instrument increments or decrements continuously.

3. Depressing simultaneously the [VERNIER \uparrow] and the [VERNIER \downarrow] push-buttons modifies the delay time to a preset value of 1.0 s.

4. To resume normal display, press the [DLY] push-button. The DLY light turns off. When enabled, the instrument performs measurements with the newly selected delay time.

5. To enable the delay mode, press the [2nd] push-button and then the [DELAY] (second function to [GT/DLY]) push-button. Observe that the DELAY light illuminates. This indicates that the instrument is now set to operate in its delay mode. The delay light turns off automatically when another function, other than from those specified above, is selected. Conversely, returning to one of the above functions restores the delay mode.

6. To return to normal operation depress in sequence the [2nd] and the [GT/DLY] push-buttons. The DELAY light turns off, indicating that the instrument will no longer delay the closure of its gate.

NOTE

To prevent operator's error, there is an internal audible alarm that beeps whenever a limit is reached. (e.g 100 μ s low limit).

3-19. Using User Delay

The User Delay is useful when a delay time other than the pre-determined delay times is required. The limits which must be observed are the minimum limit of 100 μ s and the maximum limit of 10.000 s. The User Delay function is accessible in PER A, PLS A, and Time Interval A to B operating modes. To operate the instrument in its User Delay mode proceed as follows:

1. Set the instrument to PER A. Press the [DLY] push-button once. Observe that the DLY light turns on, and that the instrument displays the delay time.

2. Press and hold the [VERNIER \uparrow] push-button and observe that the display increments. After the 100 s delay time the instrument enters the User Gate mode and displays the following readout:

USER dLAY

Depressing the [VERNIER \uparrow] push-button after the user gate is displayed causes an audible alarm to sound.

3. To resume normal display, press the [DLY] push-button. The DLY light turns off. When enabled, the instrument performs measurements with the user delay time.

4. To enable the user delay mode depress in sequence the [2nd] and the [DELAY] (second function to [GT/DLY]) push-buttons. Observe that the DELAY light illuminates. This indicates that the instrument is now set to operate in its User Delay mode. The delay light turns off automatically when another function, other than from those specified above, is selected. Conversely, returning to one of the above functions restores the delay mode.

5. Apply an external TTL pulse to the rear panel EXT INPUT connector. This signal now serves as the external gate time. Delay is then enabled as long as this input is kept at TTL high level. The first negative transition to TTL low disables the delay. The delay is then disabled as long as this input is kept at TTL low level.

3-20. Using Front Panel Set-Ups

Setting up all parameters in a versatile instrument such as the Model 776 may take some time. The set-up time is even longer when more than one set-up is required. Model 776 incorporates a battery backed-up non-volatile memory that preserves stored information up to three years. It is possible to store complete front panel set-ups in 10 different memory locations which are built into the instrument especially for this purpose.

3-20-1. Store Set-Ups

First modify the front panel parameters as necessary to perform your tasks. When all parameters are set and checked, proceed to store this set-up as follows:

1. Depress the [STO] push button and observe that the display is modified to indicate the following:

StorE ?
(? appears flashing)

This reading indicates that the instrument is ready to receive one memory location where front panel set-up is to be stored. Set-ups may be stored in locations 0 to 9. Depressing [STO] again cancels this function and the instrument resumes normal operation.

2. Select one memory location from 0 to 9 and depress the button which is marked with the selected number. The instrument displays the following for one second:

StorE D
(Where D is the selected memory location)

This display indicates that the function generator acknowledges the entered memory location. The instrument then resumes normal operation.

3-20-2. Recall Set-Ups

Turning AC Mains power off does not affect the stored data in the RAM. Therefore, front panel set-up which were previously recorded by the user remain preserved. To recall a front panel set-up proceed as follows:

1. Depress the [RCL] push button and observe that the display is modified to indicate the following:

rEcALL ?
(? appears flashing)

This reading indicates that the instrument is ready to recall the memory location where front panel set-up was stored. Depressing the [RCL] button cancels this function and the instrument resumes normal operation.

2. Select one memory location from 0 to 9 so as to recall the desired set-up, and depress the button which is marked with the selected number. The instrument displays the following for one second:

rEcALL D
(Where D is the selected memory location)

The instrument then recalls the parameters that were previously stored in the selected memory location and updates front panel indicators with the recalled parameters.

3-22. Using An External Reference

Generally, Model 776 provides two accuracy grades for the internal time base: stabilized clock, or an optional temperature compensated crystal oscillator (TCXO). The best accuracy, over the specified temperature operating range, that may be achieved with the TCXO is 1 PPM, or 0.1 PPM - accuracy which will satisfy the most demanding requirements. With special applications, however, where such inaccuracies may become a limiting factor, an external reference may provide a better solution. An EXT REF connector is available on the rear panel. However, before applying an external reference signal, it is first necessary to open the top cover and change a switch setting. The procedure of changing this switch is given in Section 5 of this manual.

3-23. Changing GPIB Address

GPIB address is modified using front panel programming. The non-volatile memory stores the GPIB address. Conventional address switches are not provided. Detailed instructions how to change the GPIB address are given in Section 4 paragraph 4-7.

4

IEEE-488 Operation

1. Introduction

The IEEE-488 bus is an instrumentation data bus with standards adopted by the IEEE (Institute of Electrical and Electronic Engineering) in 1975 and given the IEEE-488 designation. Model 776 conforms to this standard - in full.

This section contains general bus information as well as detailed programming information and is divided as follows:

1. General introductory information pertaining to the IEEE-488 bus may be found primarily in paragraphs 4-2 through 4-5.
2. Information necessary to connect the Model 776 to the bus and to change the bus address is contained in paragraphs 4-6 and 4-7.
3. Programming of the instrument with general bus command is covered in paragraph 4-8.
4. Device-dependent command programming is described in detail in paragraph 4-9. The commands outlined in this section can be considered to be the most important since they control virtually all instrument functions.
5. Additional information pertaining to front panel error messages and controller programs can be found in paragraphs 4-11-1 and 4-11-2.

4-2. Bus Description

The IEEE-488 bus was designed as a parallel data transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal,

the bus has only eight data lines which are used for both data and most commands. Five bus management lines and three handshake lines round out the complement of signal lines. Since the bus is of parallel design, all devices connected to the bus have the same information available simultaneously. Exactly what is done with the information by each device depends on many factors, including device capabilities.

A typical bus configuration for remote controlled operation is shown in Figure 4-1. The typical system will have one controller and one or more instruments to which commands are given and from which data is received. There are three categories that describe device operation. These include: controller; talker; listener.

The controller controls other devices on the bus. A talker sends data, while a listener receives data, an instrument, may be a talker only, a listener only, or both a talker and listener.

Any given system can have only one controller (control may be passed to an appropriate device through a special command). Any number of talkers or listeners may be present up to the hardware constraints of the bus. The bus is limited to 15 devices, but this number may be reduced if higher than normal data transfer rates are required or if long interconnect cables are used.

Several devices may be commanded to listen at once, but only one device may be a talker at any given time. Otherwise, communications would be scrambled much

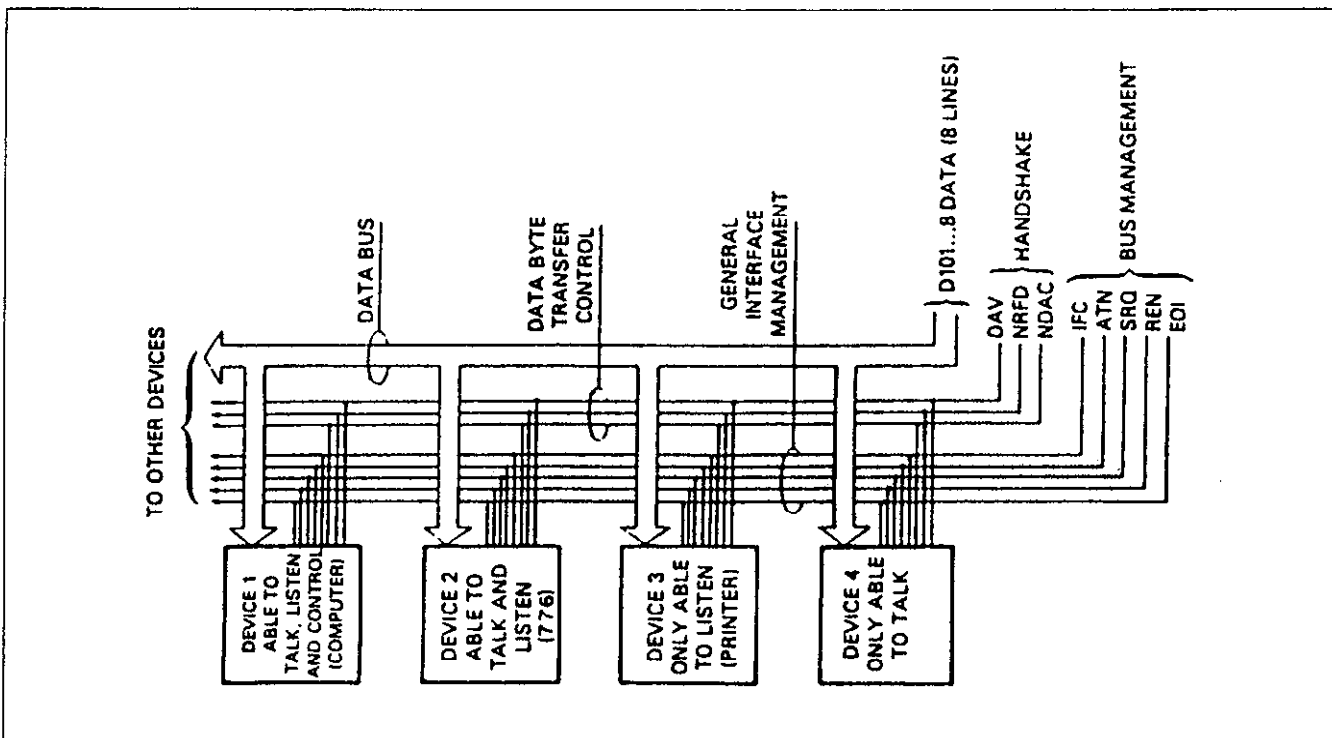


Figure 4-1. IEEE Bus Configuration

like an individual is trying to select a single conversation out of a large crowd.

Before a device can talk or listen, it must be appropriately addressed. Devices are selected on the basis of their primary address. The addressed device is sent a talk or listen command derived from its primary address. Normally, each device on the bus has a unique primary address so that each may be addressed individually. The bus also has another addressing mode called secondary addressing, but not all devices use this addressing mode.

Once the device is addressed to talk or listen, appropriate bus transactions may be initiated. For example, if an instrument is addressed to talk, it will usually place its data on the bus one byte at a time. The listening device will then read this information, and the appropriate software is then be used to channel the information to the desired location.

4-3. IEEE-488 Bus Lines

The signal lines on the IEEE-488 bus are grouped into three general categories. The data lines handle bus information, while the handshake and bus management lines assure that proper data transfer and bus

operation takes place. Each of the bus lines is "active low" so that approximately zero volts is a logic "one". The following paragraphs describe the purpose of these lines, which are shown in Figure 4-1.

4-3-1. Bus Management Lines

The bus management group is made up of five signal lines that provide orderly transfer of data. These lines are used to send the uniline commands described in paragraph 4-8-1.

1. **ATN (Attention)** - the ATN line is one of the more important management lines. The state of the ATN line determines whether controller information on the data bus is to be considered data or a multiline command as described in paragraph 4-8-2.
2. **IFC (Interface Clear)** - Setting the IFC line true (low) causes the bus to go to a known state.
3. **REN (Remote Enable)** - Setting the REN line low sends the REN command. This sets up instruments on the bus for remote operation.
4. **EOI (End Or Identify)** - The EOI line is used to send the EOI command that usually terminates a multi-byte transfer sequence.
5. **SRQ (Service Request)** - the SRQ line is set low by a device when it requires service from the controller.

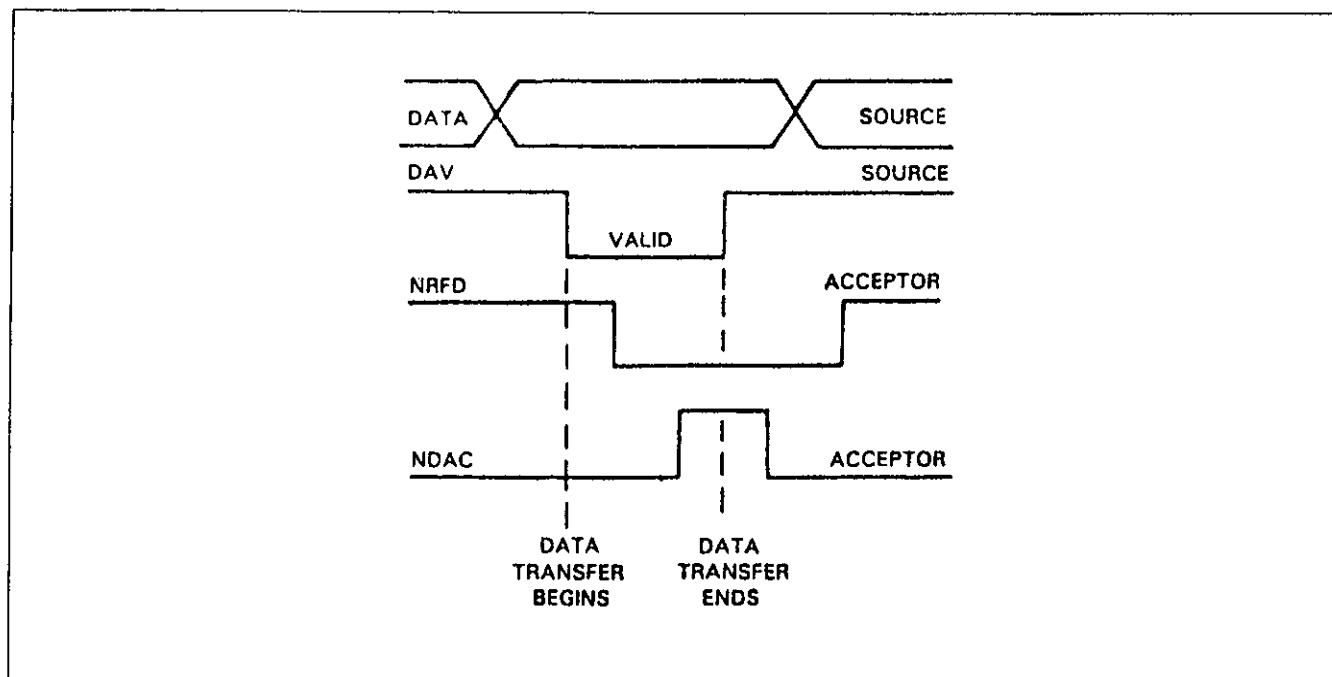


Figure 4-2. IEEE Handshake Sequence

4-3-2. Handshake Lines

The bus uses three handshake lines that operate in an interlocked sequence. This method assures reliable data transfer regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the handshake lines is controlled by the data source, while the remaining two lines are controlled by accepting devices. The three bus handshake lines are:

1. **DAV** (Data Valid) - The source controls the state of the DAV line.
2. **NRFD** (Not Ready For Data) - the acceptor controls the state of the NRFD line.
3. **NDAC** (Not Data Accepted) - the acceptor also controls the NDAC line.

The complete handshake sequence for one data byte is shown in Figure 4-2. Once data is on the bus, the source checks to see that NRFD is high, indicating that all devices on the bus are ready for data. At the same time NDAC should be low from the previous byte transfer. If these conditions are not met, the source must then wait until the NRFD and NDAC lines have the correct status. If the source is controller, NRFD and NDAC must remain stable for at least 100 ns after ATN is set low. Because of the possibility of bus hang up, some control-

lers have time-out routines to display error messages if the handshake sequence stops for any reason.

Once the NRFD and NDAC lines are properly set, the source sets the DAV line low, indicating that data on the bus is now valid. The NRFD line then goes low; the NDAC line goes high once all devices on the bus have accepted the data. Each device will release the NDAC line at its own rate, but the NDAC line will not go high until the slowest device has accepted the data byte.

After the NDAC line goes high, the source then sets the DAV line high to indicate that the data on the bus is no longer valid. At this point, the NDAC line returns to its low state. Finally, the NRFD line is released by each of the devices at their own rates, until the NRFD line finally goes high when the slowest device is ready, and the bus is set to repeat the sequence with the next data byte.

The sequence just described is used to transfer both data and multiline command. The state of the ATN line determines whether the data bus contains data or commands.

4-3-3. Data Lines

The IEEE-488 bus uses the eight data lines that allow data to be transmitted and received in a bit-parallel, byte-serial manner. These eight lines use the convention

DI01 through DI08 instead of the more common D0 through D7 binary terminology. The data lines are bi-directional and, as with the remaining bus signal lines, low is true.

4-4. Interface Function Codes

The interface function codes are part of the IEEE-488-1978 standards. These codes define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual.

Table 4-1 lists the codes for the Model 776. The numeric value following each one or two letter code define Model 776 capability as follows:

SH (Source Handshake Function) - The ability for the Model 776 to initiate the transfer of message/data on the data bus provided by the SH function.

AH (Acceptor Handshake Function) - The ability for the Model 776 to guarantee proper reception of message/data on the data bus provided by the AH function.

T (Talker Function) - The ability of the Model 776 to send device-dependent data over the bus (to another device) is provided by the T function. Model 776 talker capabilities exist only after the instrument has been addressed to talk.

L (Listen Function) - The ability of the Model 776 to receive device-dependent data over the bus (from another device) is provided by the L function. Listener function capability of the Model 776 exist only after it has been addressed to listen.

RS (Service Request Function) - The ability of the Model 776 to request service from the controller is provided by the RS function.

RL (Remote-Local Function) - The ability of the Model 776 to be placed in remote or local modes is provided by the RL function.

PP (parallel Poll Function) - The ability of the Model 776 to respond to a parallel poll request from the controller is provided by the PP function.

DC (Device Clear Function) - The ability for the Model 776 to be cleared (initialized) is provided by the DC function.

DT (Device Trigger Function) - The ability of the Model 776 to have its output triggered is provided by the DT function.

C (controller Function) - The Model 776 does not have a controller function.

TE (Extended Talker Capabilities) - The Model 776 does not have extended talker capabilities.

LE (Extended Listener Function) - The Model 776 does not have extended listener function.

Table 4-1. Model 6030 Interface Function Codes

| CODE | INTERFACE FUNCTION |
|------------|--|
| SH1 | Source Handshake Function |
| AH1 | Acceptor Handshake Capabilities |
| T6 | Talker (basic talker, serial poll, unaddressed to talk on LAG) |
| L4 | Listener (basic listener, unaddressed to listen on TAG) |
| SR1 | Service request capability |
| RL1 | Remote/Local capability |
| PP2 | Parallel Poll capability |
| DC1 | Device Clear capability |
| DT1 | Device Trigger capability |
| C0 | No controller capability |
| E1 | Open collector bus drivers |
| TE0 | No Extended Talker capabilities |
| LE0 | No Extended Listener capabilities |

4-5. Software Considerations

The most sophisticated computer in the world would be useless without the necessary software. This basic requirement is also true of the IEEE-488 bus, which requires the use of handler routines as described in this paragraph.

Before a controller can be used with the IEEE-488 interface, the user must make certain that appropriate handler software is present within the controller. With the IBM PC computer, for example, the GPIB interface card must be used with an additional I/O ROM, which contains the necessary handler software.

Other small computers that can be used as controllers have limited IEEE command capability. The capabilities of other small computers depends on the particular interface being used. Often, little software "tricks" are required to achieve the desired results.

From the preceding discussion, the message is clear: make sure the proper software is being used with the instrument. Often, the user may incorrectly suspect that a hardware problem is causing fault, when it was the software that was causing the problem all along.

4-6. HARDWARE CONSIDERATIONS

Before the instrument can be used with the IEEE-488 bus, it must be connected to the bus with a suitable connector. Also, the primary address must be properly programmed as described in this section.

4-6-1. Typical Controlled Systems

The IEEE-488 bus is a parallel interface system. As a result, adding more device is simply a matter of using more cables to make the desired connections. Because of this flexibility, system complexity can range from simple to extremely complex.

The simplest possible controlled system comprises a controller and one Model 776. The controller is used to send commands to the instrument, which sends data back to the controller.

The system becomes more complex when additional instrumentation is added. Depending on programming, all data may be routed through the controller, or it may be transmitted directly from one instrument to another.

For very complex applications, a much larger computer can be used. Tape drives or disks may then be used to store data.

4-6-2. Connections

The instrument is connected to the bus through an IEEE-488 connector. This connector is designed to be stacked to allow a number of parallel connections on one instrument.

NOTES

1. To avoid possible mechanical damage, it is recommended that no more than three connectors be stacked on any one instrument. Otherwise, the resulting strain may cause internal damage to the connectors.

2. The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. Also, the maximum cable length is 20 meters. Failure to observe these limits will probably result in erratic bus operation.

Custom cables may be constructed using the information in Table 4-2. Table 4-2 also lists the contact assignments for the various bus lines. Contacts 18 through 24 are return lines for the indicated signal lines, and the cable shield is connected to contact 12. Each ground line is connected to digital common in the Model 776.

CAUTION

The voltage between IEEE common and ground must not exceed 0V or damage may result to your instrument.

Table 4-2. IEEE Contact Designation.

| Number | Contact Designation | IEEE-488 Type |
|--------|---------------------|---------------|
| 1 | DIO1 | Data |
| 2 | DIO2 | Data |
| 3 | DIO3 | Data |
| 4 | DIO4 | Data |
| 5 | EOI | Management |
| 6 | DAV | Handshake |
| 7 | NRFD | Handshake |
| 8 | NDAC | Handshake |
| 9 | IFC | Management |
| 10 | SRQ | Management |
| 11 | ATN | Management |
| 12 | SHIELD | Ground |
| 13 | DIO5 | Data |
| 14 | DIO6 | Data |
| 15 | DIO7 | Data |
| 16 | DIO8 | Data |
| 17 | REN | Management |
| 18 | Gnd | Ground |
| 19 | Gnd | Ground |
| 20 | Gnd | Ground |
| 21 | Gnd | Ground |
| 22 | Gnd | Ground |
| 23 | Gnd | Ground |
| 24 | Gnd | LOGIC Ground |

4-7. Changing GPIB Address

The primary address of your instrument may be programmed to any value between 0 and 30 as long as the selected address is different from other devices addresses in the system. This may be accomplished using a front panel programming sequence. Note that the primary address of the instrument must agree with the address specified in the controller's program.

NOTE

The programmed primary address is briefly displayed during the power-up cycle of the Model 776. It is stored in the non-volatile memory of the instrument and is retained even when power is turned off.

To check the present address, or to enter a new one, proceed as follows:

1. Press the 2nd push-button once then press the ADR push-button (second function to SLOPE). The display will be modified to display the following:

IE Adr x

Where x may be any number from 0 to 30.

2. Press the VERNIER \uparrow or \downarrow push-buttons the select a new GPIB primary address.

3. To store the newly selected primary address depress ENT (second function to STO). The instrument will then resume normal operation.

4-8. Bus Commands

While the hardware aspect of the bus is essential, the interface would be essentially worthless without appropriate commands to control the communications between the various instruments on the bus. This paragraph briefly describes the purpose of the bus commands, which are grouped into the following three categories:

1. Uniline commands: Sent by setting the associated bus line low.
2. Multiline commands: General bus commands which are sent over the data lines with the ATN line low (true).
3. Device-dependent commands: Special commands that depend on device configuration; sent over the data lines with ATN high (false).

4-8-1 Uniline Commands

Uniline commands are sent by setting the associated bus line to low. The ATN, IFC, and REN commands are asserted only by the system controller. The SRQ command is sent by an external device. The EOI command may be sent by either the controller or an external device depending on the direction of data transfer. The following is description of each command.

REN (Remote Enable) - The remote enable command is sent to the Model 776 by the controller to set the instrument up for remote operation. Generally, this should be done before attempting to program the instrument over the bus. The Model 776 will indicate that it is in the remote mode by illuminating its front panel REM indicator.

Table 4-3. IEEE-488 Bus Command Summary

| COMMAND TYPE | COMMAND ATN LINE(*) | STATE OF | COMMENTS |
|------------------------------|---------------------|----------|--|
| Uniline | REN | X | Set up for remote operation |
| | EOI | X | Sent by setting EOI low |
| | IFC | X | Clears Interface |
| | ATN | Low | Defines data bus contents |
| | SRQ | X | Controlled by external device |
| Multiline Universal | LLO | Low | Locks out front panel controls |
| | DCL | Low | Returns device to default conditions |
| | SPE | Low | Enable serial polling |
| | SPD | Low | Disables serial polling Addressed |
| | SDC | Low | Returns unit to default condition |
| | GTL | Low | Returns to local control |
| | GET | Low | Triggers device for reading |
| Unaddress | UNL | Low | Removes all listeners from bus |
| | UNT | Low | Removes all talkers from bus |
| Device- Dependent(**) | | High | Programs Model 6030 for various modes. |

(*) X = Don't Care. (**) See paragraph 4-9 for complete description

To place the Model 776 in the remote mode, the controller must perform the following steps:

1. Set the REN line true.
2. Address the Model 776 to listen.

NOTE

Setting REN true without addressing will not cause the REM indicator to turn on; however, once REN is true, the REM light will turn on the next time an address command is received.

EOI (End Or Identify) - The EOI command is used to positively identify the last byte in a multi-byte transfer sequence. This allows variable length data words to be transmitted easily.

IFC (Interface Clear) - The IFC command is sent to clear the bus and set the Model 776 to a known state. Table 4-4 summarizes the instrument's state after IFC or DCL. Although device configurations differ, the IFC command usually places instruments in the talk and listen idle states.

ATN (Attention) - The controller sends ATN while transmitting addresses or multiline commands. Device-dependent commands are sent with the ATN line high (false).

SRQ (Service Request) - The SRQ command is asserted by an external device when it requires service from the controller. If more than one device is present, a serial polling sequence, as described in paragraph 4-8-2, must be used to determine which has requested service.

4-8-2. Universal multiline Commands

Universal commands are multiline commands that require no addressing. All instrumentation equipped to implement the command will do so simultaneously when the command is transmitted over the bus. As with all multiline commands, the universal commands are sent over the data lines with ATN set low:

LLO (Local Lockout) - The LLO command is sent by the controller to remove the Model 776 from the local operating mode. Once the unit receives the LLO command, all its front panel controls (except Power) will be inoperative.

NOTE

The REN bus line must be true before the instrument will respond to an LLO command.

To lock out the front panel controls of the Model 776, the controller must perform the following steps:

1. Set ATN true.
2. Send the LLO command to the instrument.

DCL (Device Clear) - The DCL command may be used to clear the Model 776, setting it to a known state. Note that all devices on the bus equipped to respond to a DCL will do so simultaneously. When the Model 776 receives a DCL command, it will return to the default conditions listed in Table 4-4.

To send a DCL command the controller must perform the following steps:

1. Set ATN true.
2. Place the DCL command on the bus.

SPE (Serial Poll Enable) - The serial polling sequence is used to obtain the Model 776 status byte. Usually, the serial polling sequence is used to determine which of several devices has requested service over the SRQ line. However, the serial polling sequence may be used at any time to obtain the status byte from the Model 776. For more information on status byte format, refer to paragraph 4-9-20. The serial polling sequence is conducted as follows:

1. The controller sets the ATN line true.
2. The SPE (Serial Poll Enable) command is placed on the bus by the controller.
3. The Model 776 is addressed to talk.
4. The controller sets ATN false.
5. The Model 776 then places its status byte on the bus to be read by the controller.
6. The controller then sets the ATN line low and places SPD (Serial Poll Disable) on the bus to end the serial polling sequence.

Steps 3 through 5 may be repeated for other instruments on the bus by using the correct talk address for each instrument. ATN must be true when the talk address is transmitted and false when the status byte is read.

SPD (Serial Poll Disable) - The SPD command is sent by the controller to remove all instrumentation on the bus from the serial poll mode.

4-8-3. Addressed Commands

Addressed commands are multiline commands that must be preceded by a listen command derived from the device's primary address before the instrument will respond. Only the addressed device will respond to each of these commands:

SDC (Selective Device Clear) - The SDC command performs essentially the same function as the DCL command except that only the addressed device will respond. This command is useful for clearing only a selected instrument instead of all devices simultaneously. The Model 776 will return to the default conditions listed in Table 4-4 when responding to an SDC command.

To transmit the SDC command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 776 to listen.
3. Place the SDC command on the data bus.

GTL (Go To Local) - The GTL command is used to remove the instrument from the remote mode of operation. Also, front panel control operation will usually be

restored if the LLO command was previously sent. To send the GTL command, the controller must perform the following sequence:

1. Set ATN true.
2. Address the Model 776 to listen.
3. Place the GTL command on the bus.

NOTE

The GTL command does not remove the local lockout state. With the local lockout condition previously set, the GTL command will enable front panel control operation until the next time a listener address command is received. This places the Model 776 in the local lockout state again.

Table 4-4. Default Conditions. (Status After SDC or DCL)

| MODE | VALUE | STATUS |
|------------------|-------|-------------------------------------|
| Function | F0 | Frequency A |
| Coupling | AC0 | DC coupled on channel A. |
| Attenuator | AA0 | x1 attenuator on channel A. |
| Filter | AF0 | Filter off on channel A. |
| Slope | AS0 | Positive slope on channel A. |
| Impedance | AI0 | 1 M Ω on channel A. |
| Coupling | BC0 | DC coupled on channel B. |
| Attenuator | BA0 | x1 attenuator on channel B. |
| Filter | BF0 | Filter off on channel B. |
| Slope | BS0 | Positive slope on channel B. |
| Impedance | BI0 | 1 M Ω on channel B. |
| Auto Trigger | L0 | Manual trigger disabled. |
| Delay | I0 | Delay disabled. |
| V Peak Rate | V0 | Fast measurement rate. |
| Totalize Mode | M0 | Totalize infinitely. |
| Ratio Mode | C0 | Ratio A/B. |
| Displayed Digits | N10 | Set maximum displayed digits to 10. |
| Rate | S1 | Normal 3 readings per second. |
| SRQ mask | Q0 | SRQ disabled. |
| Terminator | Z0 | CR LF with EOI. |
| Display mode | D0 | Display the measurement. |
| Data format | X0 | prefix on, no leading zeros. |
| Trigger level | AL0 | 0V on channel A. |
| Trigger level | BL0 | 0V on channel B. |
| Gate time | G1 | 1 second gate time. |
| Delay time | W1 | 1 second delay time. |

GET (Group Execute Trigger) - The GET command is used to trigger or arm devices to perform a specific measurement that depends on device configuration. Although GET is considered to be an addressed command, many devices respond to GET without being addressed. Using the GET command is only one of several methods that can be used to initiate a measurement cycle. More detailed information on triggering can be found in Section 3 of this manual.

To send GET command over the bus, the controller must perform the following sequence:

1. Set ATN true.
2. Address the Model 776 to listen.
3. Place the GET command on the data bus.

GET can also be sent without addressing by omitting step 2.

4-8-4. Unaddress Command

The two unaddress commands are used by the controller to simultaneously remove all talkers and listeners from the bus. ATN is low when these multiline commands are asserted.

UNL (Unlisten) - All listeners are removed from the bus at once when the UNL commands is placed on the bus.

UNT (Untalk) - The controller sends the UNT command to clear the bus of any talkers.

4-8-5. Device-Dependent Commands

The meaning of the device-dependent commands is determined by instrument configuration. Generally, these commands are sent as one or more ASCII characters that tell the device to perform a specific function. For example, F0 is sent to the Model 776 to place the instrument in the **FREQ A** mode. The IEEE-488 bus treats device-dependent commands as data in that ATN is high (false) when the commands are transmitted.

IEEE-488 device-dependent commands are sent to the Model 776 to control various operating conditions such as display modify, operating mode, output and parameter insertion. Each command is made up of an ASCII alpha character followed by one or more numbers designating specific parameters. For example the output waveform is programmed by sending an ASCII "U" followed by a number representing the output. The IEEE bus treats device-dependent commands as data in that ATN is high when the commands are transmitted.

A number of commands may be grouped together in one string. The Model 776 will ignore all non-printable

ASCII characters (00 HEX through 20 HEX) except the "CR" (carriage return). A command string is terminated by an ASCII "CR" (carriage return) character (0D HEX) which tells the instrument to execute the command string, recognized as end of command string.

If an illegal command or command parameter is present within a command string, the instrument will:

1. Ignore the entire string.
2. Display appropriate front panel error message.
3. Set certain bits in its status byte.
4. Generate an SRQ if programmed to do so.

These programming aspects are covered in the following.

NOTE

Before performing a programming example, it is recommended that the instrument be set to its default values by sending an SDC over the bus.

In order to send a device-dependent command, the controller must perform the following sequence:

1. Set ATN true.
2. Address the Model 776 to listen.
3. Set ATN false.
4. Send the command string over the data bus one byte at a time.

NOTE

REN must be true when attempting to program the Model 776.

Commands that effect the Model 776 are listed in Table 4-5.

4-9. Device Dependent Commands Programming

4-9-1. Function (F)

The function command select the type of measurement made by the Model 776. The 13 parameters, which are associated with the function command, set the instrument to measure one of these functions. The function may be programmed by sending one of the following commands:

- F0 = FRQ A
- F1 = FRQ B
- F2 = FRQ C
- F3 = PER A
- F4 = PLS A
- F5 = TI A to B

Table 4-5. Device-Dependent Command Summary

| Mode | Command | Description |
|----------------------|------------------------------------|--|
| Function | F0 | Frequency on Channel A |
| | F1 | Frequency on Channel B |
| | F2 | Frequency on Channel C |
| | F3 | Period on Channel A |
| | F4 | Pulse on Channel A |
| | F5 | Time interval from A to B |
| | F6 | Totalize on B |
| | F7 | Ratio FRQ/B (see also Ratio Mode) |
| | F8 | Phase A to B |
| | F9 | V peak A |
| | F10 | Period average on Channel A |
| | F11 | Pulse average on Channel A |
| F12 | Time interval from A to B averaged | |
| Coupling | AC0 | DC coupled on Channel A |
| | AC1 | AC coupled on Channel A |
| | BC0 | DC coupled on Channel B |
| | BC1 | AC coupled on Channel B |
| Attenuator | AA0 | X1 attenuator on Channel A |
| | AA1 | X10 attenuator on Channel A |
| | BA0 | X1 attenuator on Channel B |
| | BA1 | X10 attenuator on Channel B |
| Filter | AF0 | Filter Off on Channel A |
| | AF1 | Filter On on Channel A |
| | BF0 | Filter Off on Channel B |
| | BF1 | Filter On on Channel B |
| Slope | AS0 | Positive Slope on Channel A |
| | AS1 | Negative Slope on Channel A |
| | BS0 | Positive Slope on Channel B |
| | BS1 | Negative Slope on Channel B |
| Impedance | AI0 | 1 M Ω impedance on Channel A |
| | AI1 | 50 Ω impedance on Channel A |
| | BI0 | 1 M Ω impedance on Channel B |
| | BI1 | 50 Ω impedance on Channel B |
| Trigger level | ALn | Set Trigger level for Channel A |
| | BLn | Set Trigger level for Channel B n = \pm d.ddE \pm d (d = digit) |
| Auto level | L0 | Auto trigger level disabled |
| | L1 | Auto trigger level enabled (mode overrides manual mode) |

Table 4-5. Device-Dependent Command Summary (continued)

| Mode | Command | Description |
|----------------------------|---------|---|
| Gate Time | Gn | Set the Gate time in seconds n = d.dE±d (d = digit, decimal point optional) |
| | GU | Set gate time to user gate |
| Delay Time | Wn | Set the Delay time in seconds n = d.dE±d (d = digit, decimal point optional) |
| | WU | Set delay time to user delay |
| Delay | I0 | Delay disabled |
| | I1 | Delay enabled |
| Vpk measurement rate | V0 | Fast rate |
| | V1 | Slow rate |
| Totalize Gating Modes | M0 | Totalize infinitely on B |
| | M1 | Totalize on B by A |
| | M2 | Totalize on B by AA |
| Ratio Mode | C0 | Ratio measurements Frequency A/B |
| | C1 | Ratio measurements Frequency C/B |
| Displayed Digits | Nn | Set the maximum of the displayed digits (n=3 to 10) |
| Set-ups Store Recall | STn | Store front panel set-up in n memory location |
| | REn | Recall front panel set-up from n memory location |
| Trigger | T | One-shot in S0 mode, display clear in S1 mode |
| Rate | S0 | One-shot on T or GET |
| | S1 | Normal, up to 3 readings per second |
| | S2 | Fast, up to 100 readings per second, 100 Hz to 120 MHz |
| | S3 | Fast, up to 100 readings per second, 10 MHz to 225 MHz |
| SRQ Mask | Q0 | SRQ disabled |
| | Q1 | SRQ on ready |
| | Q2 | SRQ on reading done |
| | Q4 | SRQ on error |

F6 = TOT B
F7 = RATIO FRQ/B
F8 = Phase A to B
F9 = V peak A
F10 = PER AVG A
F11 = PLS AVG A
F12 = TI A to B AVG

4-9-2. Channels A, B Coupling (AC, BC)

The coupling commands give the user control over the input coupling of Channels A and B inputs. Coupling may be programmed by sending one of the following commands:

AC0 = DC coupling channel A.

AC1 = AC coupling channel A.
BC0 = DC coupling channel B.
BC1 = AC coupling channel B.

4-9-3. Channels A, B Attenuator (AA, BA)

The attenuator commands give the user control over the input attenuator mode of channels A and B. The attenuator may be programmed by sending one of the following commands:

AA0 = x1 attenuator channel A.
AA1 = x10 attenuator channel A.
BA0 = x1 attenuator channel B.
BA1 = x10 attenuator channel B.

4-9-4. Channels A, B Filter (AF, BF)

The filter commands give the user control over the filter at Channels A and B input. The filter may be programmed by sending one of the following commands:

AF0 = filter on channel A.
AF1 = filter off channel A.
BF0 = filter on channel B.
BF1 = filter off channel B.

4-9-5. Channels A, B Slope (AS, BS)

The slope selection commands give the user control over triggering edge at channels A and B inputs. The slope may be programmed by sending one of the following commands:

AS0 = Positive slope channel A.
AS1 = Negative slope channel A.
BS0 = Positive slope channel B.
BS1 = Negative slope channel B.

4-9-6. Channels A, B Impedance (AI, BI)

The impedance selection commands give the user control over the input impedance at channels A and B inputs. The impedance may be programmed by sending one of the following commands:

AI0 = 1 M Ω impedance channel A.
AI1 = 50 Ω impedance channel A.
BI0 = 1 M Ω impedance channel B.
BI1 = 50 Ω impedance channel B.

4-9-7. Channels A, B Trigger Level (AL, BL)

The trigger level commands give the user control over the trigger threshold point at channels A and B inputs.

The trigger level may be programmed by sending one of the following commands:

ALn = Trigger level channel A.
BLn = Trigger level channel B.

n is the trigger level in units of volts and in engineering format; e.g. (\pm D.DD \pm D). The sign and the exponent are optional. The trigger level value may range from -5.00 to +5.00 V in 10 mV increments or from -50.0 to +50.0 V in 100mV increments. Selecting trigger level within the range of \pm 5.00 V, automatically sets the attenuator to x1. Selecting a trigger level within the range of \pm 50.0 V, automatically modifies attenuator setting to x10.

Following DCL or SDC commands, the instrument defaults to AL0 and BL0 (trigger levels set to 0.00 V).

4-9-8. Channels A, B Auto trigger level (L)

The auto trigger level commands give the user control over the auto trigger level mode. Auto-trigger mode is automatically selected for both Channels A and B. The auto-trigger level mode may be programmed by sending one of the following commands:

L0 = Auto-trigger level disabled.
L1 = Auto-trigger level enabled.

4-9-9. Gate Time (G, GU)

The gate time commands control the time that the gate remains open. The gate time may be programmed by sending command strings using the following formats:

Gnn = Internal gate time
GU = External user gate time

nn is the gate time in units of seconds and in engineering format. e.g. (D.DE \pm D). Sign, decimal point, and exponent are optional.

The operator has the option of selecting an external gate time having periods other than those programmed into the instrument. The counter may be programmed to accept external gate times by sending the GU command over the bus.

Following DCL or SDC, the instrument defaults to gate time of one second (G1.0).

4-9-10. Delay Time (W, WU)

The delay time commands control the delay in closing the gate after the gate was open. The delay time may be

programmed by sending commands using the following formats:

Wnn = Internal delay time.

WU = External user delay time.

nn is the delay time in units of and seconds in engineering notations: e.g. (D.DE±D). Sign, decimal points, and exponent are optional.

The operator has the option of selecting an external delay time having periods other than those programmed into the instrument. Model 776 may be programmed to accept external delay times by sending the GU command over the bus.

Following DCL or SDC, the instrument defaults to delay time of one second (W1.0).

4-9-11. V Peak Measurement Rate (V)

The V peak measurement rate commands control the rate of which the instrument performs its v peak measurements. Model 776 offers a choice of two measurement rates: Fast, and slow. The fast rate is normally used when measuring amplitudes of a signal having frequencies from 100 Hz. The slow rate is used when performing measurements below 100 Hz. The v peak measurement rate may be programmed by sending a command using the following formats:

V0 = Fast measurement rate.

V1 = Slow measurement rate.

4-9-12. Totalize Modes (M)

Model 776 offers three gating options for its Totalize mode. They are: Gate is open infinitely, Gated by A, and Gated by AA. The totalize mode commands give the user control over the selection of one of these gating options. The totalize mode may be programmed by sending command strings using the following format:

M0 = Totalize on B, gate open infinitely.

M1 = Totalize on B, gated by A.

M2 = Totalize on B, gated by AA.

4-9-13. Ratio Mode (C)

The Ratio Mode commands operate in conjunction with the F7 command (FRQ/B). These commands control the input to be divided by the B Channel input. The ratio mode may be programmed by sending command strings using the following format:

C0 = Ratio measurement, frequency A/B.

C1 = Ratio measurement, frequency C/B.

4-9-14. Displayed Digits (N)

The displayed digits function sets the maximum number of digits that the Model 776 will display. To program the number of digits send the following command:

Nn

Where n may have any value from 3 to 10. Upon DCL or SDC, the instrument will be set to N10.

4-9-15. Set-ups (ST, RE)

The setups commands select the memory location where the actual set-up is to be stored at (ST), or recalled from (RE). To store or recall a front panel set-up use one of the following commands:

STn

REn

n designates a specific memory address, and may range from 0 to 9. DCL or SDC has no effect on the stored set-ups.

4-9-16. Triggering (T)

The "T" and GET commands are used to trigger the Model 776 over the IEEE bus. Triggering command arms the counter for a fresh measurement cycle. In its continuous mode, Model 776 is always armed, while in its hold mode (S0), a separate trigger stimulant is required to arm for a new measurement cycle. To arm the Model 776 for a new measurement cycle use the following commands:

T = Addressable trigger.

GET = Group Execute Trigger.

4-9-17. Rate (S)

The rate commands give the user control over the speed that Model 776 outputs its processed measurements on the bus. Model 776 may output up to 100 formatted readings in one second. Such speed, however, requires that either S2 or S3 rates are selected, that the programmed gate time is less than 10 ms, and that unnecessary information such as prefixes, and leading spaces are removed from the output string. Also when selecting one of the fast rates, note that there are frequency limits which are associated with each rate mode. S0 and S1 may be selected from the front panel. S2 and S3 can only be programmed from the GPIB. The various speed rates may be programmed using one of the following commands:

S0 = Hold, One shot on T. or on GET, or on an external arming input.

S1 = Normal, Approximately 3 reading per second.

S2 = Fast, up to 100 reading per second, 100 Hz to 120 MHz.

S3 = Fast, up to 100 reading per second, 10 MHz to 225 MHz.

4-9-18. Display Modes (D)

The display command controls what parameter the Model 776 will place on the display. The eight parameters associated with the display commands set the instrument to display the normal measurement, gate time, delay time, trigger level A, trigger level B, number of selected digits, analog output resolution, analog output offset, and ratio mode. The counter may be programmed to place one of the above parameters on the display using the following commands:

D0 = Display the normal measurement.

D1 = Display the gate time.

D2 = Display the delay time.

D3 = Display the A trigger level.

D4 = Display the B trigger level.

D5 = Display the number of digits.

D6 = Display the analog output resolution.

D7 = Display the analog output offset.

D8 = Display the programmed ratio mode.

4-9-19. SRQ Mode (Q) and Serial Poll Status Byte Format

The SRQ command controls which of a number of conditions within the Model 776 will cause the instrument to request service from the controller with the SRQ line command. Once the SRQ is generated, the Model 776 status byte can be checked, via serial polling, to determine if it was the Model 776 that requested service. Other bits in the status byte could also be set depending on certain data or error conditions. The Model 776 can be programmed to generate SRQ under one of the following conditions.

1. If the Model 776 is ready to receive device-dependent commands.
2. If a reading has been completed.
3. If an error condition has occurred.

SRQ Mask: In order to facilitate SRQ programming, the Model 776 uses an internal mask to generate the SRQ. When a particular mask bit is set, Model 776 sends an SRQ when those conditions occur. Bits within the mask can be controlled by sending the ASCII letter "Q" followed by a decimal number to set the appropriate

bits. Table 4-6 lists the commands to set the various mask bits, while Table 4-7 lists all legal SRQ Mask commands.

NOTE

There are 8 legal SRQ mask commands that are possible with the Model 776. Table 4-7 lists all combinations, e.g selecting Q6. Model 776 will request service when one of reading done or error occurs.

Status Byte Format: The status byte contains information relating to data and error conditions within the instrument. Table 4-8 lists the meaning of the various bits. The status byte is obtained by using the SPE, SPD polling sequence.

The various bits in the status byte are described below:

1. **Ready:** Set after power-up. This bit is cleared when the Model 776 receives a command and set again when the instrument have completed to decode the command (Model 776 is ready for the next command string).
2. **Reading done:** Set after completion of a measurement cycle. The reading done bit is cleared after Model 776 was addressed to talk in R0 mode.
3. **Error:** Set if an illegal command has been received or one of gate error, gate time error, or trigger level error has occurred in the last measurement cycle. This bit is cleared by reading the error status string (R7).
4. **Rqs (request service):** Model 776 sets this bit if one or more conditions for service request occur, and the SRQ mask, for at least one of these service request conditions is enabled. This bit is cleared by reading the Status Byte using the SPE, SPD polling sequence.

NOTES

1. Once the Model 776 has generated an SRQ, its status byte should be read to clear the SRQ line. Otherwise the instrument will continuously assert the SRQ line.
2. The Model 776 may be programmed to generate an SRQ for more than one condition simultaneously. For example, to set SRQ mask bits for an SRQ if an error occurs and when the instrument is ready for the next string, the following command would be sent: Q5. All possible mask combinations are listed in Table 4-7.
3. If the instrument is programmed to generate an SRQ when reading is done, it will generate the SRQ only once when the reading is complete; the SRQ may be cleared by reading the status byte. The reading done bit in the status byte may then be cleared by requesting a normal reading from the instrument (R0).

4-10. Reading From Model 776

The Reading sequence is used to obtain from Model 776, various information strings such as measurement, gate time, delay time or trigger level. Each information string is made up of ASCII alpha and alphanumeric characters. For more details on the information strings format refer to paragraph 4-10-1.

The reading sequence is conducted as follows:

1. The controller sets the ATN line true.
2. The Model 776 is addressed to talk.
3. The controller sets ATN false.
4. The instrument sends the information string over the bus one byte at a time.
5. The controller recognizes that the string is terminated.
6. The controller sets the ATN line true.
7. The UNT (untalk) command is placed on the bus by the controller.

NOTE

Most controllers use the CR (Carriage Return) or LF (Line Feed) character to terminate their input sequences, but other techniques may be used as well to recognize the end of input sequence (for example the EOI line is low on the bus during the transfer of the last byte).

4-10-1 Data Control commands (R)

The Data Control commands allows access to information concerning present operating conditions of the instrument. When a data control command other than R0 is given, the Model 776 transmits the associated data string instead of its normal data string. **The next time it is addressed to talk, Model 776 will transmit its normal measurement data string (R0).** Note that Model 776 defaults to R0 state. It is therefore not necessary to include the R0 command in every reading request.

The Model 776 Data Control commands include:

- R0** = Send normal measuring data string
- R1** = Send Gate Time data status string
- R2** = Send Delay Time data status string
- R3** = Send Trigger Level A data status string
- R4** = Send Trigger Level B data status string
- R5** = Send Input conditioning status string
- R6** = Send Operating Mode Status string
- R7** = Send Error Status string

Table 4-9 shows the general data string format for each of the seven commands (decimal point floats).

Table 4-10 shows the interpretation for the input conditioning status, operating mode status and error status strings (R5, R6 and R7).

NOTES

1. Data strings have fixed length of 15 ASCII characters for the R0, R5 and R6 commands without the prefix and terminator. For all other data strings (R1 through R4 and R7), the length of the data string is 5 ASCII characters without the prefix and terminator. If the data string is sent with a prefix, four additional ASCII characters are included (refer to paragraph 4-2-3). If the data string is sent with one or two terminators, the length of the data string increases by one or two characters respectively.

2. All normal measurement data string information (R0), besides the status strings (R1 through R7), will be sent only once each time a measurement has been successfully completed. This may halt the controller for the duration of the gate or delay time. It is therefore recommended that the status byte will be continuously monitored and normal reading taken only after the READING DONE bit is set true.

WARNING

Model 776 updates its GPIB buffers only once at the end of a successful measurement cycle. If a normal reading is requested before the gate is closed, the bus could be held for, at least, the duration of the gate time. With some controllers, this delay may cause controller time-out, or even a complete bus lockup. It is therefore recommended that the Model 776 is programmed to assert an RQS on Reading Done (Q2), and that a normal reading is requested only if the Reading Done bit (B1) in the status byte is set. The procedure of reading the Status Byte, as well as its interpretation, is given in paragraph 4-9-21.

3. All status string information, besides the normal data strings, will be sent only once each time the command is sent. Once the data string is read, the instrument will send its normal data string (R0) the next time it is addressed to talk. CR LF is normal terminator. The

Table 4-6. SRQ Mask Commands

| Command | Sets Bit Number | Condition to Generate SRQ |
|---------|-----------------|---------------------------|
| Q1 | B0 (LSB) | Ready |
| Q2 | B1 | Reading done |
| Q4 | B2 | Error |

Table 4-7. SRQ Mask Legal Commands

| Bit Number | B2 | B1 | B0 (LSB) |
|------------|-------|--------------|----------|
| Command | Error | Reading Done | Ready |
| Q0 | NO | NO | NO |
| Q1 | NO | NO | YES |
| Q2 | NO | YES | NO |
| Q3 | NO | YES | YES |
| Q4 | YES | NO | NO |
| Q5 | YES | NO | YES |
| Q6 | YES | YES | NO |
| Q7 | YES | YES | YES |

terminator may be changed (see paragraph 4-10-2). The prefixes are listed in Table 4-9.

NOTES

1. The Error Status string will be returned only once each time the command is sent. Once status is read, the instrument will send its normal string the next time the instrument is addressed to talk and reading done bit is set true.
2. To ensure that the correct status is received, the status string should be read immediately after sending the command, to avoid having an incorrect status transmitted.
3. The status string should not be confused with the status byte. The status string contains a string of bytes pertaining to the various operating modes of the instrument. The status byte is a single byte that is read with

the SPE, SPD command sequence and contains information on SRQ status.

4. The error status string is cleared by reading R7. Reading this status also clears the reading done and the error bits in the status byte.

4-10-2. Terminator (Z)

To allow a wide variety of controllers to be used, the terminator can be changed by sending an appropriate command over the bus. The default value is the commonly used carriage return, line feed (CR LF) sequence (mode Z0). The terminator sequence will assume this default value after receiving a DCL or SDC.

The EOI line on the bus is usually set low by the device during the last byte of its data transfer sequence. In this way, the last byte is properly identified, allowing variable length data words to be transmitted. The Model 776 will normally send EOI during the last byte of its data string or status word. The terminator and the EOI response from the Model 776 may be sent with one of the following commands:

- Z0 = CR,LF with EOI
- Z1 = CR,LF without EOI
- Z2 = LF,CR with EOI
- Z3 = LF,CR without EOI
- Z4 = CR with EOI
- Z5 = CR without EOI
- Z6 = LF with EOI
- Z7 = LF without EOI
- Z8 = No terminator with EOI
- Z9 = No terminator without EOI

Table 4-8. Status Byte Interpretation

| Bit Number | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 (LSB) |
|----------------|----|-----|----|----|----|-------|--------------|----------|
| Interpretation | 0 | rqs | 0 | 0 | 0 | Error | Reading Done | Ready |

Table 4-9. Data String Formats

| Command | Data String Format | Description |
|---------|--|--|
| R0 | (FRQA)+1.234567890E+0(TERM) (FRQB)+1.234567890E+0(TERM) (FRQC)+1.234567890E+0(TERM) (PERS)+1.234567890E+0(TERM) (PLSS)+1.234567890E+0(TERM) (TABS)+1.234567890E+0(TERM) (TOTB)+1.234567890E+0(TERM) (ATOB)+1.234567890E+0(TERM) (CTOB)+1.234567890E+0(TERM) (PHAS)+1.234567890E+0(TERM) (VPKA)-0.00 -0.00 (TERM) (PERV)+1.234567890E+0(TERM) (PLS V)+1.234567890E+0(TERM) (TABV)+1.234567890E+0(TERM) | for FRQ A measurements for FRQ B measurements for FRQ C measurements for PER A measurements for PLS A measurements for T.I A to B measurements for TOT B measurements for Ratio A/B measurements for Ratio C/B measurements for Phase A to B measurements for V PeaK A measurements for PER AVG A measurements for PLS AVG measurements for T.I A to B AVG measurements |
| R1 | (GATE)10E-0(TERM) | for Gate Time |
| R2 | (DLAY)10E-0(TERM) | for Delay Time |
| R3 | (TRGA)+0.00(TERM) | for Trig Level A |
| R4 | (TRGB)+0.00(TERM) | for Trig Level B |
| R5 | (STAT)0000000000000000(TERM) | Input conditioning status |
| R6 | (776)000001000100000(TERM) | Machine status |
| R7 | (EROR)00000(TERM) | Error status |

NOTES

1. Most controllers use the CR or LF character to terminate their input sequence. Using the NO TERMINATOR mode (Z8 or Z9) may cause the controller to hang up unless special programming is used.
2. Some controllers may require that EOI be present at the end of transmitting.

4-10-3. Prefix (X)

The prefix from the data string may be suppressed using this command. When the prefix is suppressed the output

data string is four byte shorter. The X command is also used to replace leading space character (ASCII 20 HEX) in the data string with character 0 (ASCII 30 HEX). For some controllers, an attempt to read a number instead of a string, will result a reading error because of its inability to read spaces before the first significant digit. To eliminate this problem the Model 776 should be programmed to send the data string with leading zeros. X4 mode is an absolute necessity to reach the reading speed of up to 100 readings per second (in conjunction with S2 and S3). X command parameters include:

Table 4-10. Status Word Interpretation

| Command | Status Word Format |
|-----------------|--|
| R5 After SDC | (STAT) F AC AA AF AS AI BC BA BF BS BI L I 0(term) (STAT) 00 0 0 0 0 0 0 0 0 0 0 0 0 0 0(CR LF) |
| R6 After SDC | (776) OPT1 OPT2 OPT3 V M C N O P S Q Z D X(term) (776) n n n 0 0 0 10 0 0 1 0 0 0 0(CR LF) |
| R7 After SDC | (EROR) ILI ILP GATEERR TLERR 0 (CR LF) (EROR) 0 0 0 0 0 0 (CR LF) |

X0 = Send data string with prefix, without leading zeroes.

X1 = Send data string without prefix, without leading zeroes.

X2 = Send data string with prefix, with leading zeroes.

X3 = Send data string without prefix, with leading zeroes.

X4 = Send data string without prefix, without leading zeroes, without leading spaces.

4-11. Front Panel Error Messages

The process of programming the Model 776 involves the proper use of syntax. Syntax is defined as the orderly or systematic arrangement of programming commands or languages. The Model 776 must receive valid commands with proper syntax or it will:

1. Ignore the entire commands string in which the invalid command appears.

2. Set appropriate bits in the status byte and error word.

3. Generate an SRQ if programmed to do so.

4. Display an appropriate front panel message.

4-11-1. ILL INS (Illegal Instruction) Error

An ILL INS error results when the Model 776 receives an invalid command such as A0. This command is invalid because no such letter exist in the instruments programming language.

4-11-2. ILL PAR (Illegal Parameter) Error

An ILL PAR error occurs when the numeric parameter associated with a legal command letter is invalid. For example, the command D10 has an invalid option because the Model 776 has no display mode associated with that number.

5

Maintenance and Performance Tests

5-1. Introduction

This section provides maintenance, service information, and performance tests for the Model 776, the clock multiplier and the 2.4 GHz input channel. Fuse replacement procedure and line voltage selection are also included.

WARNING

The procedures described in this section are for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Many of the steps covered in this section may expose the individual to potentially lethal voltages that could result in personal injury or death if normal safety precautions are not observed.

5-2. Line Voltage Selection

The Model 776 may be operated from either 115 V or 230 V nominal 50-60 Hz power sources. The instrument was shipped from the factory set for an operating voltage as advised on your purchase order. To change the line voltage, proceed as follows:

WARNING

Disconnect the Model 776 from the power cord and all other sources before changing line voltage setting.

1. Using a flat-blade screwdriver, place the line voltage selection switch in the desired position. The voltages are marked on the selection switch.
2. Install a power line fuse consistent with the operating voltage. See paragraph 5-3.

CAUTION

The correct fuse type must be used to maintain proper instrument protection.

5-3. Fuse Replacement

The Model 776 has a line fuse to protect the instrument from excessive current. This fuse may be replaced by using the procedure described in the following:

WARNING

Disconnect the instrument from the power line and from other equipment before replacing the fuse.

1. Place the end of a flat-blade screwdriver into the slot in the LINE FUSE holder on the rear panel. Push in and rotate the fuse carrier one quarter turn counterclock-

Table 5-1. Line Fuse Selection

| POWER LINE VOLTAGE | FUSE TYPE | KI p/n |
|--------------------|--------------------|---------|
| 90 - 125V | 0.4A, 250V Slo-Blo | FU-80 |
| 195 - 250V | 0.2A, 250V Slo-Blo | FU-96-3 |

wise. Release the pressure on the holder and let its internal spring to push the fuse and the carrier out of the holder.

2. Remove the fuse and replace it with the proper type using Table 5-1 as a guide.

CAUTION

Do not use a fuse with a rating higher than specified or instrument damage may occur. If the instrument persistently blows fuses, a problem may exist within the instrument. If so, the problem must be rectified before continuing operation.

5-4. Selecting an External Frequency Reference

The Model 776 has a 5 PPM oscillator for an internal time base clock. The Model 776/2.4G and 776/2.4G/R have TCXO (temperature compensated crystal oscillator) included with Channel C option.

These time bases are enough to satisfy most accuracy requirements; however, in applications where such an inaccuracy is a limiting factor, an external standard can be applied to the counters. The basic accuracy of the counters is then converted to the accuracy of the applied frequency source.

The Model 776 accepts a 10 MHz source; the Model 776/2.4G and 776/2.4G/R accepts a 5 MHz or 10 MHz source.

The counters feature a rear panel input/output BNC connector designated as 10 MHz CLOCK OUT/EXT CLOCK IN. This connector serves two functions:

- When an internal clock is selected, a 10 MHz signal from the internal time base circuit is available at this output.
- While using the instrument with an external reference, a signal is applied to the same connector.

The counters are shipped set to operate with an internal time base, and with a 10 MHz signal available at the rear panel CLOCK output. To change these settings, refer to the following procedure:

WARNING

Disconnect the line cord and test leads from the instrument before removing the top cover.

1. Remove the top cover as described in the disassembly instructions in paragraph 5-5.

2. Position the shorting links as required:

A. For Models 776/2.4G and 776/2.4G/R, refer to Figure 5-1 for the shorting link locations on the TCXO board. LK1 and LK2 select the internal or external reference. LK3 configures the instrument for a 5 MHz or 10 MHz external reference.

B. For a Model 776, refer to Figure 5-2 for shorting link locations on the main board. LK1 (a and b), which is located at the rear of the instrument near the power transformer, selects the internal or external reference.

3. Replace the top cover.

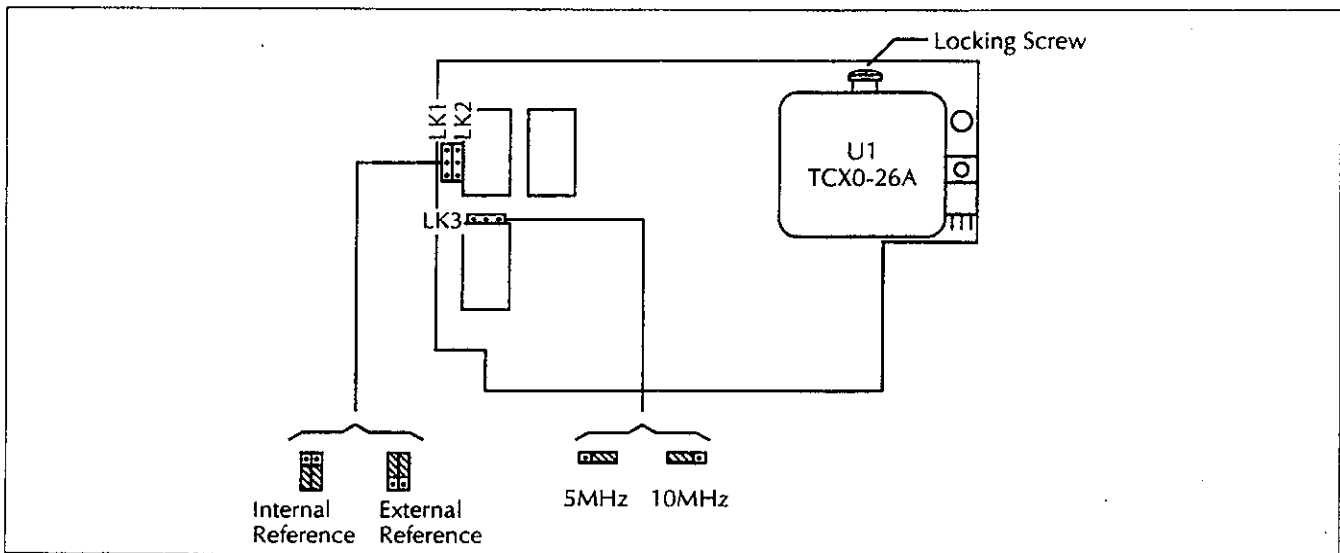


Figure 5-1. Reference Frequency and INT/EXT Clock Selection.

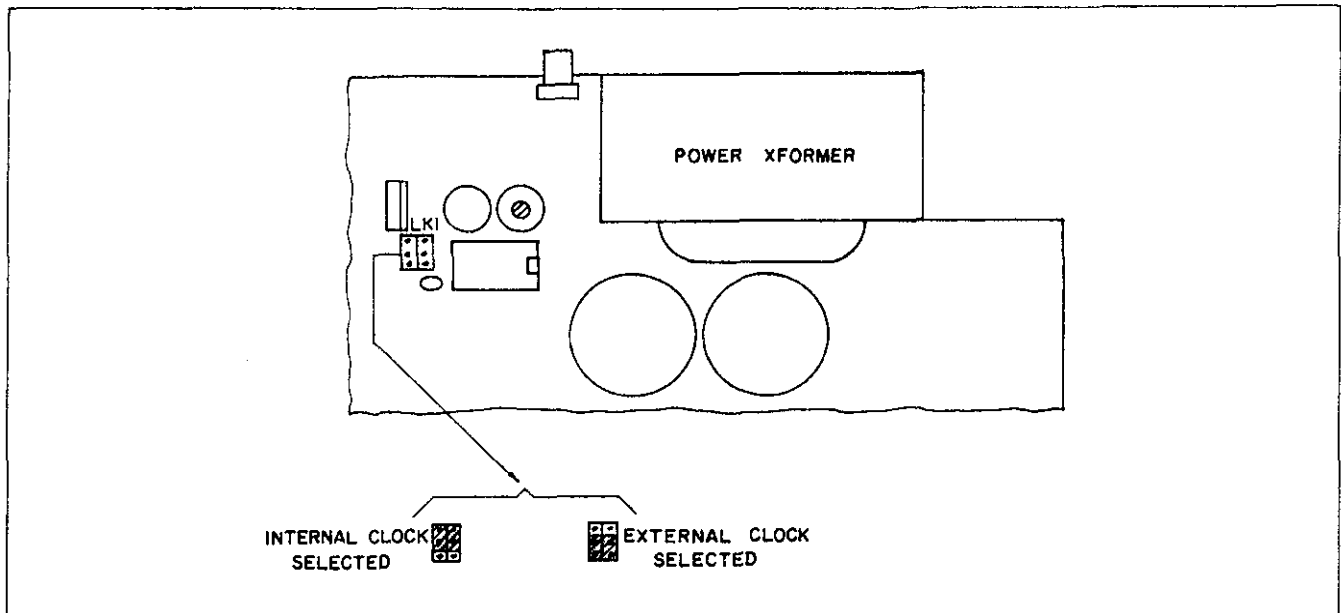


Figure 5-2. External/Internal Time Base Clock Selection.

5-5. Disassembly Instructions

If it is necessary to troubleshoot the instrument or replace a component, use the following disassembly procedure to remove the top and bottom covers:

1. Remove the four screws that secure each of the top and the bottom covers.
2. Grasp the top cover at the side and carefully lift it off the instrument. Similarly remove the bottom cover.
3. When replacing the covers, reverse the above procedure.

5-6. Special Handling of Static Sensitive Devices

CMOS devices are designed to operate at a very high impedance levels for low power consumption. As a result, any normal static charge that builds up on your person or clothing may be sufficient to destroy these devices if they are not handled properly. When handling such devices, use precautions which are described in the following to avoid damaging them.

1. The CMOS ICs should be transported and handled only in containers specially designed to prevent static build-up. Typically, these parts will be received in static-protected containers of plastic or foam. Keep these devices in their original containers until ready for installation.

2. Remove the devices from the protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Remove the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the device is to be inserted must also be grounded to the bench or table.
5. Use only anti-static type solder sucker.
6. Use only grounded soldering irons.
7. Once the device is installed on the PC board, the device is normally adequately protected, and normal handling resume.

5-7. Cleaning

Model 776 should be cleaned as often as operating condition require. Thoroughly clean the inside and the outside of the instrument. Remove dust from inaccessible areas with low pressure compressed air or vacuum cleaner. Use alcohol applied with a cleaning brush to remove accumulation of dirt or grease from connector contacts and component terminals.

Clean the exterior of the instrument and the front panel with a mild detergent mixed with water, applying the solution with a soft, lint-free cloth.

5-8. Repair and Replacement

Repair and replacement of electrical and mechanical parts must be accomplished with great care and caution.

Printed circuit boards can become warped, cracked or burnt from excessive heat or mechanical stress. The following repair techniques are suggested to avoid inadvertent destruction or degradation of parts and assemblies.

Use ordinary 60/40 solder and 35 to 40 watt pencil type soldering iron on the circuit board. The tip of the iron should be clean and properly tinned for best heat transfer to the solder joint. A higher wattage soldering iron may separate the circuit from the base material. Keep the soldering iron in contact with the PC board for a minimum time to avoid damage to the components or printed conductors.

To desolder components use a commercial " solder sipper ", or better, solder removing SOLDER - WICK, size 3. Always replace a component with its exact duplicate as specified in the parts list.

5-9. Performance Checks

The following performance checks verify proper operation of the instrument, and should normally be used :

- a. As part of incoming inspection of instrument specifications;
- b. As part of troubleshooting procedure;
- c. After any repair or adjustment, before returning instrument to regular service.

5-9-1. Environmental Conditions

Tests should be performed under laboratory conditions having an ambient temperature of 25 ± 5 °C and a relative humidity of less than 80%. If the instrument has

been subjected to conditions outside these ranges, allow at least one additional hour for the instrument to stabilize before beginning the adjustment procedure.

5-9-2. Warm-Up Period

Most equipment is subject to at least a small amount of drift when it is first turned on. To ensure accuracy, turn on the power to the Model 776 and allow it to warm-up for at least 30 minutes before beginning the performance tests procedure.

5-9-3. Recommended Test Equipment

Recommended test equipment for troubleshooting, calibration and performance checking is listed in table 5-2. Test instruments other than those listed may be used only if their specifications equal or exceed the required minimal characteristics.

5-10. Performance Checks Procedure

NOTE

The Models 776 and 776/2.4G have a default gate time of 1 second. The Model 776/2.4G/R has a default gate time of 100ms. The resolution of counter readings in the following procedures are for a 1 second gate time. Readings on the Model 776/2.4G/R will have one less digit.

5-10-1. Channels A and B Sensitivity Check

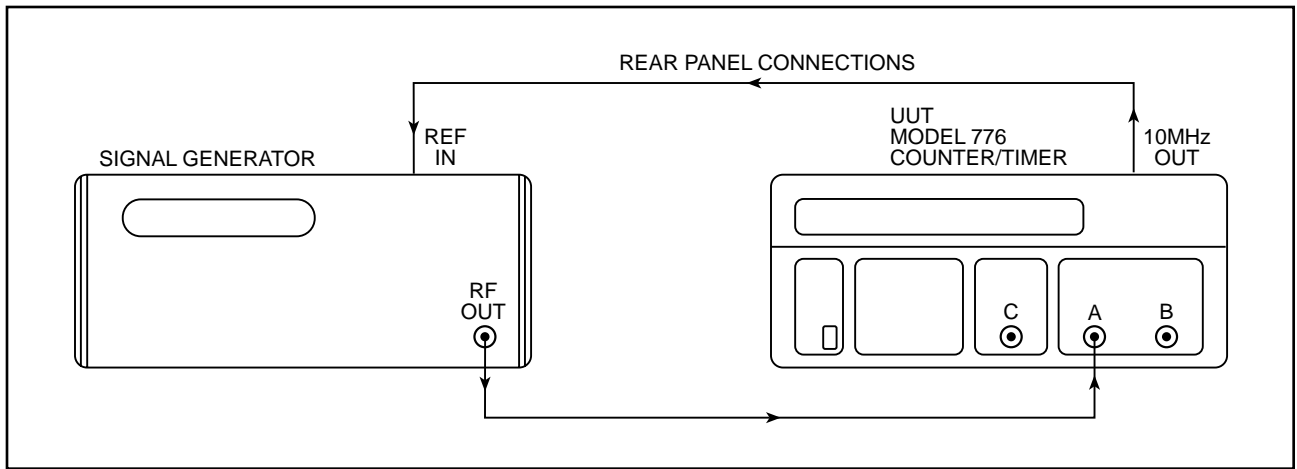
Equipment: Synthesized signal generator
 Procedure:

| Instrument | Recommended Model | Minimum Specifications | Use (*) |
|-------------------------------------|-------------------|-------------------------------|---------|
| DMM | Keithley 175A | .1 V - 100 VDC, AC rms, 0.05% | P,A,T |
| Pulse/Function Generator | HP 8116A | 4 s - 20 ns | P |
| Synthesized Signal Generator | HP 8663A | 100 KHz - 2560 MHz | P,A |
| Oscilloscope | Tektronix 2465 | 300 MHz band width | T |
| DCV Calibrator | Fluke | 1 V - 100 V, 0.01% | A |
| 10 MHz Standard | Oscillatec | 10 MHz ± 10 E-12 | P,A |
| 50 Ω feedthrough Termination | Tek 011-0049-01 | 50 Ω , 2 W, 1% | P,A |

(*) P= Performance Test, A= Adjustments, T= Troubleshooting

Table 5-2. Required Test Equipment.

Figure 5-3. Channels A and B Sensitivity Test Set-up.



1. Connect the test equipment as described in Figure 5-3.
2. Press Model 776 push-buttons in the following sequence [2nd], [DCL] and then [50Ω].
3. Set Synthesizer frequency and amplitude as given in the following table and verify a stable counter readings as follows:

| SYNTH FREQ | SIGNAL LEVEL | REQUIRED READING | ALLOWED ERROR |
|---------------|-----------------|---------------------|------------------|
| 1 MHz | 50 mV | 1.00000000 E+6 | ±2 MHz |
| 80 MHz | 50 mV | 80.0000000 E+6 | ±0.2 Hz |
| 100 MHz | 50 mV | 100.0000000 E+6 | ±0.2 Hz |
| 150 MHz | 50 mV | 150.0000000 E+6 | ±2 Hz |
| 225 MHz | 50 mV | 225.0000000 E+6 | ±2 Hz |

4. Change synthesizer frequency setting to 10 MHz and signal level setting to 50 mV rms.
5. Press [LPF] push-button and observe that the counter does not process any more readings.
6. Again press [LPF] and then [x10] push-button and observe that the Model 776 still does not process readings.
7. Change synthesizer amplitude level setting to 250 mV rms.
8. Verify that counter reading is 10 MHz ±20 MHz.
9. Modify the connections in Figure 5-5 above so that the synthesizer will now be connected to Channel B. Select [FREQ B].
10. Repeat the procedure above to verify Channel B sensitivity.

5-10-2. Channel C Sensitivity Check

Equipment: Synthesized signal generator
Procedure:

1. Connect the test equipment as described in Figure 5-4.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL] and then [FREQ C].
3. Set Synthesizer frequency and amplitude as given in the following table and verify a stable counter readings as follows:

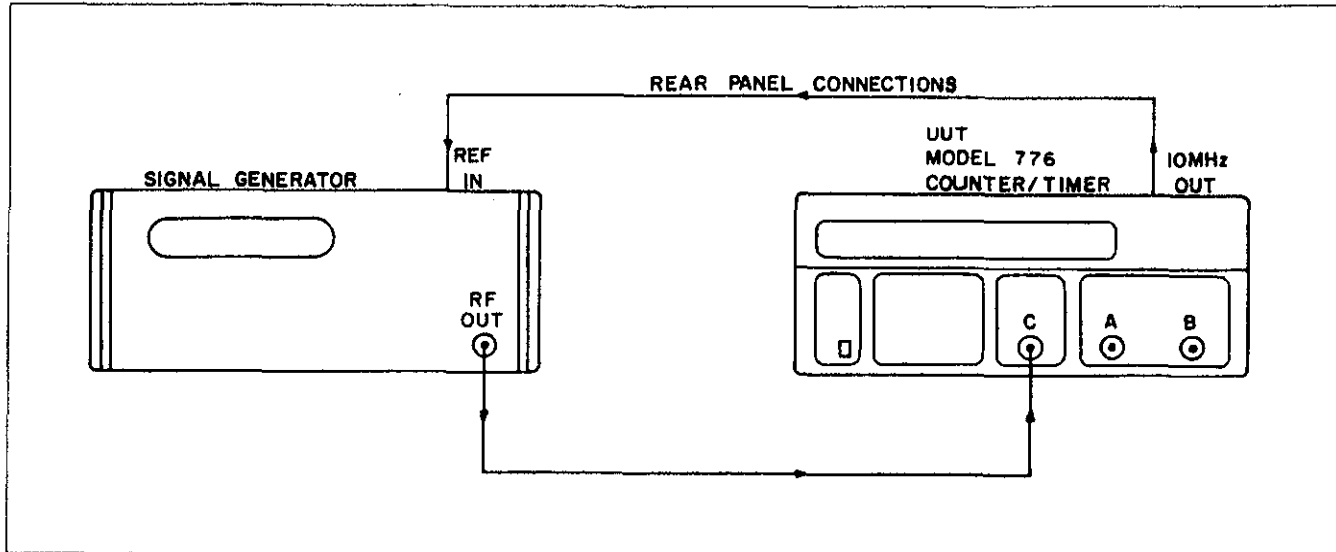
| SYNTH FREQ | SIGNAL LEVEL | COUNTER READING | ALLOWED ERROR |
|---------------|-----------------|--------------------|------------------|
| 50 MHz | 15 mV | 50.0000000 E+6 | ±1 LSD |
| 100 MHz | 15 mV | 100.0000000 E+6 | ±2 LSD |
| 500 MHz | 15 mV | 500.0000000 E+6 | ±1 LSD |
| 1000 MHz | 15 mV | 1.000000000 E+9 | ±2 LSD |
| 2000 MHz | 15 mV | 2.000000000 E+9 | ±1 LSD |
| 2400 MHz | 15 mV | 2.400000000 E+9 | ±1 LSD |

5-10-3. Period A, Period A Averaged Operation Check

Equipment: Synthesized signal generator
Procedure:

1. Connect the test equipment as described in Figure 5-5.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [PER A] and then [50Ω].

Figure 5-4. Channel C Sensitivity Test Set-up.



3. Set Synthesizer frequency to 1 MHz and amplitude level to 50 mV rms.

4. Verify a stable counter readings as follows:

1.000 E-6 \pm 1 LSD

5. Press [2nd] and then [AVG] push-buttons.

6. Set Synthesizer frequency to 125 MHz and amplitude level to 50 mV rms.

7. Verify a stable counter readings as follows:

8.00000000 E-9 \pm 2 LSD

5-10-4. Ratio A/B Operation Check

Equipment: Synthesized signal generator

Procedure:

1. Connect the test equipment as described in Figure 5-6.

2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [FRQ/B], [AC B], and then [50 Ω A&B].

3. Set Synthesizer frequency to 225 MHz and amplitude level to 50 mV rms.

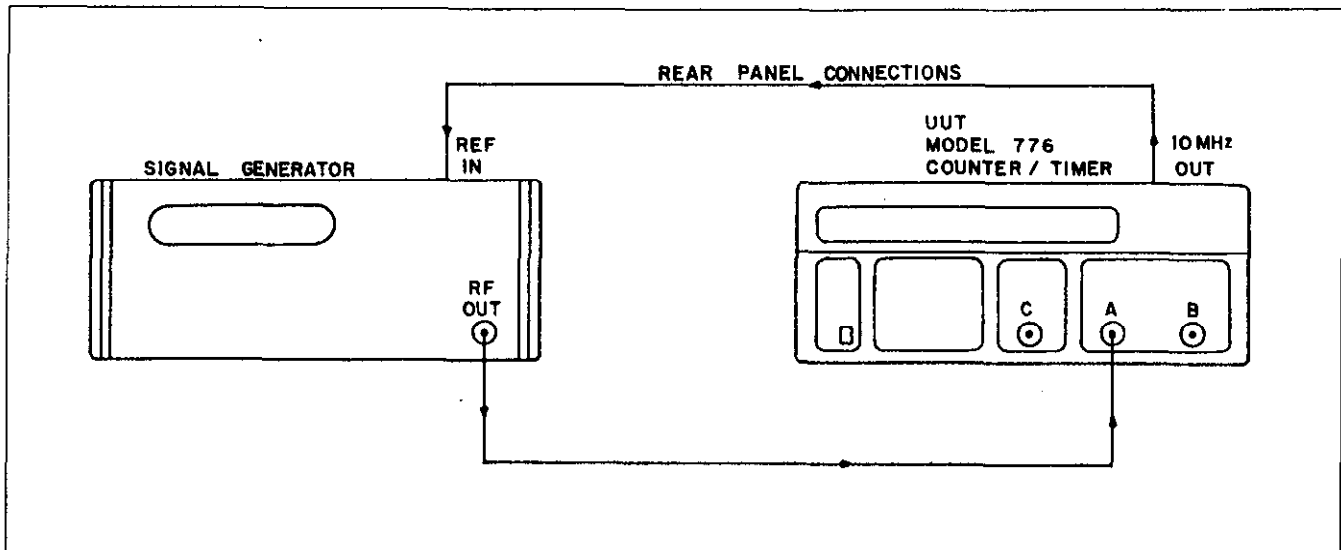
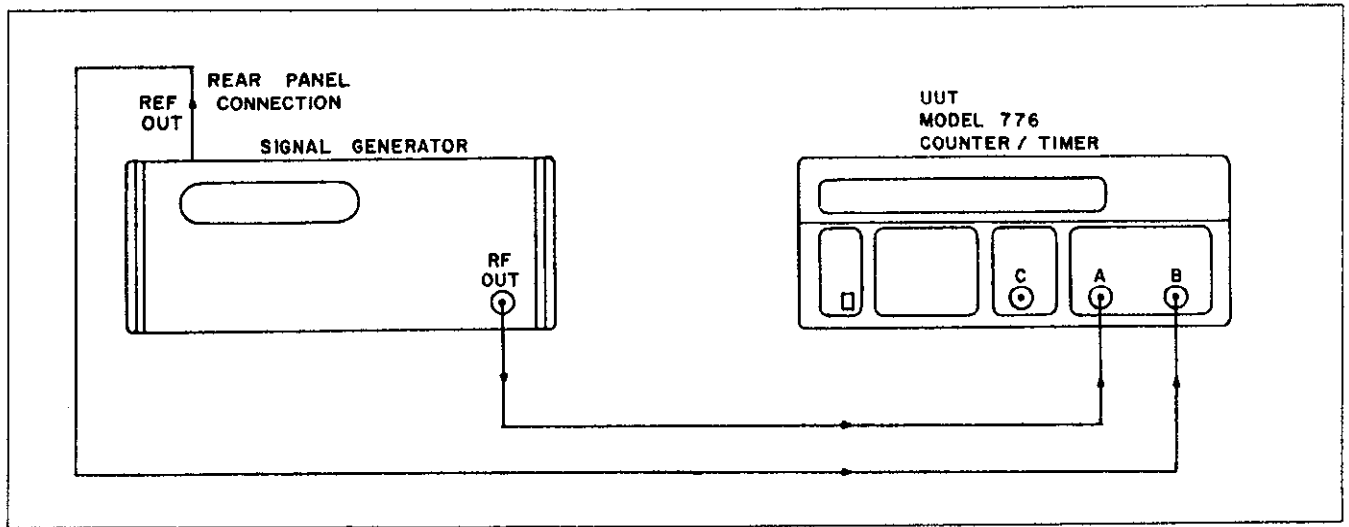


Figure 5-5. Period A and Period A Averaged Test Set-up.

Figure 5-6. Ratio A/B Test Set-up.



4. Verify a stable counter readings as follows:

22.5000000 ±1 LSD

5-10-5. Ratio C/B Operation Check

Equipment: Synthesized signal generator

Procedure:

1. Connect the test equipment as described in Figure 5-7.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [2nd] [FRQ SEL], and select FrEQ C, [FRQ/B], [AC B], and then [50Ω B].

3. Set Synthesizer frequency to 2000 MHz and amplitude level to 50 mV rms.

4. Verify a stable counter readings as follows:

200.0000 ±1 LSD

5-10-6. Pulse A, T.I A to B, Pulse A AVG and T.I. AVG Operation Check

Equipment: Pulse/Function generator

Procedure:

1. Connect the test equipment as described in Figure 5-8. It is essential that both cables to channels A and B are exactly equal in length.

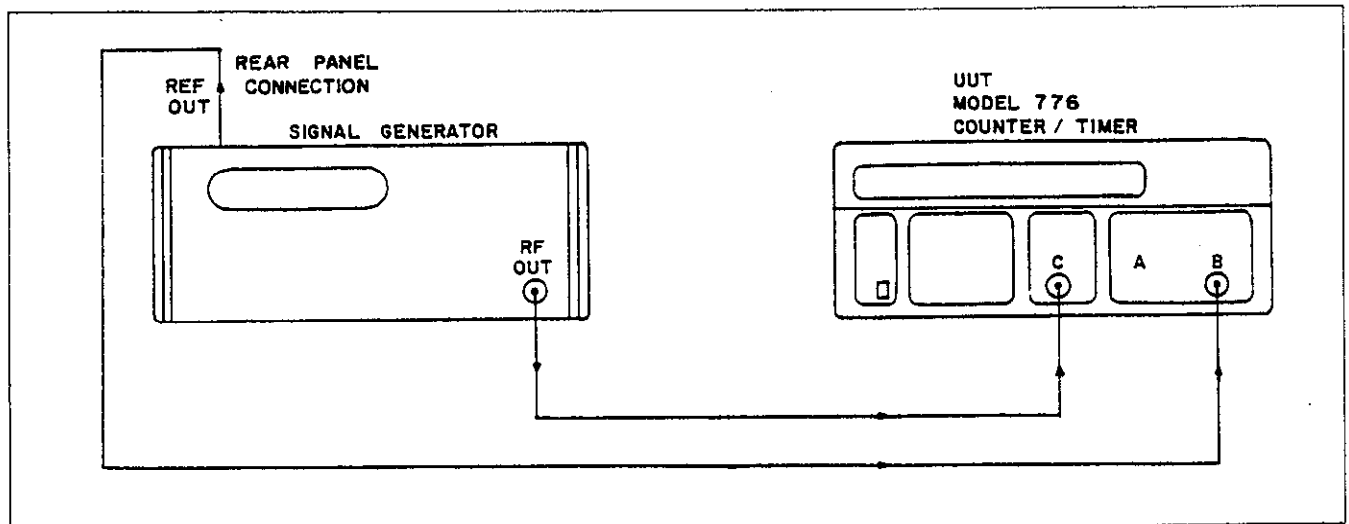
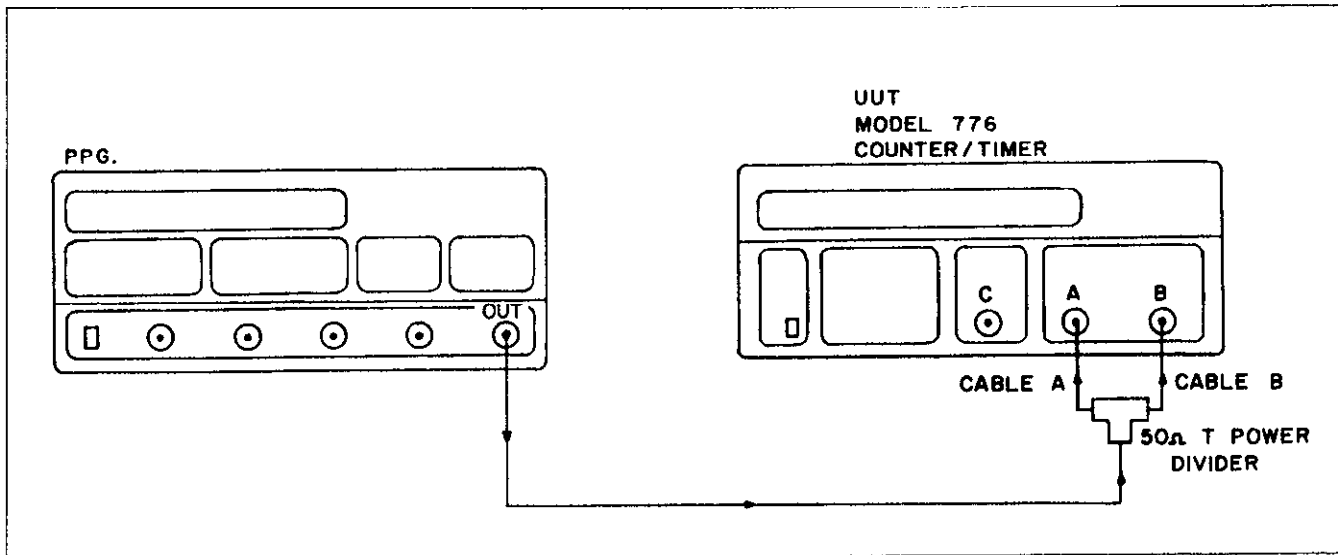


Figure 5-7. Ratio C/B Test Set-up.

Figure 5-8. Pulse A, T.I A to B and Averaged Test Set-up.



2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [PLS A] and then [50Ω A&B].
3. Set Pulse/function generator parameters as follows:

Output Wave form - Normal Pulse
 Pulse Frequency - 18.2 KHz
 Pulse Width - 20 μs
 Pulse Amplitude - ±2 Vp-p

4. Verify a stable counter readings as follows:

20.000 E-6 ±2 E-6

5. Press [2nd] and then [AVG] to select PULSE A AVG.

6. Verify a stable counter readings as follows:

20.00000 E-6 ±2 E-6

7. Press [2nd] and then [AVG] to delete AVG function.
8. Select [T.I A to B] and [∖.B] functions by pressing the appropriate push-buttons.

9. Verify a stable counter readings as follows:

20.000 E-6 ±2 E-6

10. Press [2nd] and then [AVG] to select T.I. A to B AVG.

11. Verify a stable counter readings as follows:

20.00000 E-6 ±2 E-6

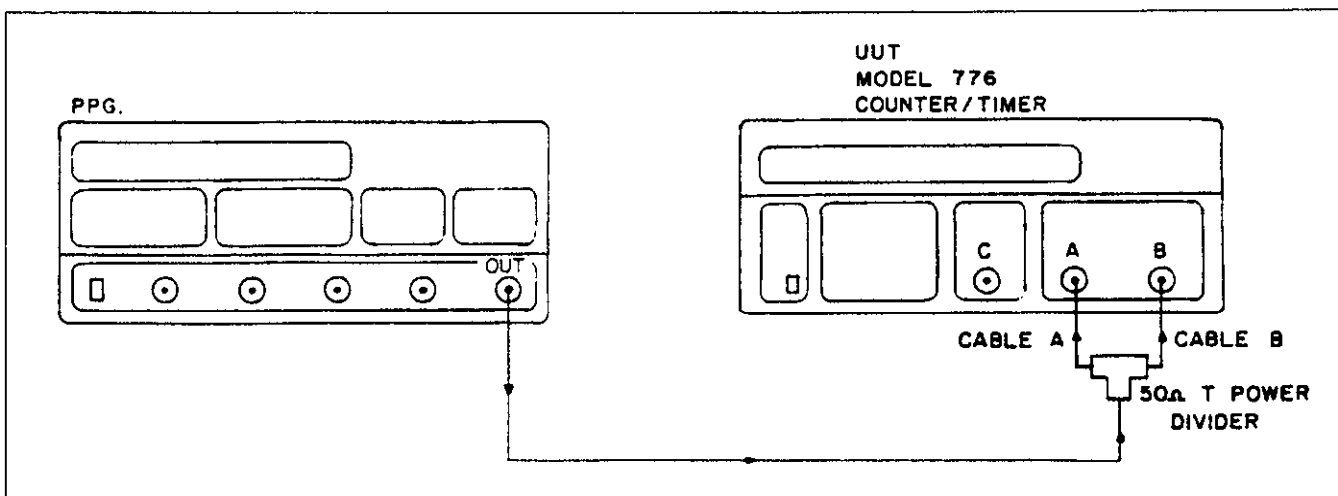


Figure 5-9. Phase A to B Test Set-up.

5-10-7. Phase A to B Operation Check

Equipment: Pulse/Function generator

Procedure:

1. Connect the test equipment as described in Figure 5-9. It is essential that both cables to channels A and B are exactly equal in length.

2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [Phase A-B], [\sim A] and then [50 Ω A&B].

3. Set Pulse/function generator parameters as follows:

- Output Wave form - Normal Pulse
- Pulse Frequency - 18.2 kHz
- Pulse Width - 27.5 μ s
- Pulse Amplitude - ± 2 Vp-p

4. Verify a stable counter readings as follows:

180.00 ± 2.00

5-10-8. Totalize B Operation Check

Equipment: Pulse/Function generator

Procedure:

1. Connect the test equipment as described in Figure 5-10.

2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [TOT B], [50 Ω] and then [CLR].

3. Set Pulse/function generator parameters as follows:

- Output Wave form - Pulse
- Pulse Frequency - 40 MHz
- Pulse Width - 10 ns

Pulse Amplitude - ± 2 Vp-p

Trigger Mode - External Burst

Burst - 1999

Trigger Slope - Positive

4. Press the pulse/function generator MANUAL trigger push-button. Verify a counter readings as follows:

1999

5. Again press the pulse generator MANUAL trigger push-button. Verify a counter readings as follows:

3998

5-10-9. Auto Trigger Level A and B Operation Check

Equipment: Pulse/Function generator

Procedure:

1. Connect the test equipment as described in Figure 5-11.

2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [50 Ω A], [2nd], [AUTO TRIG] and then [TL A].

3. Set Pulse/function generator parameters as follows:

- Output Wave form - Normal Sinewave
- Frequency - 50 kHz
- Duty Cycle - 50%
- Amplitude - 1 Vp-p
- Offset - 4V

4. Verify that trigger level A reading is as follows:

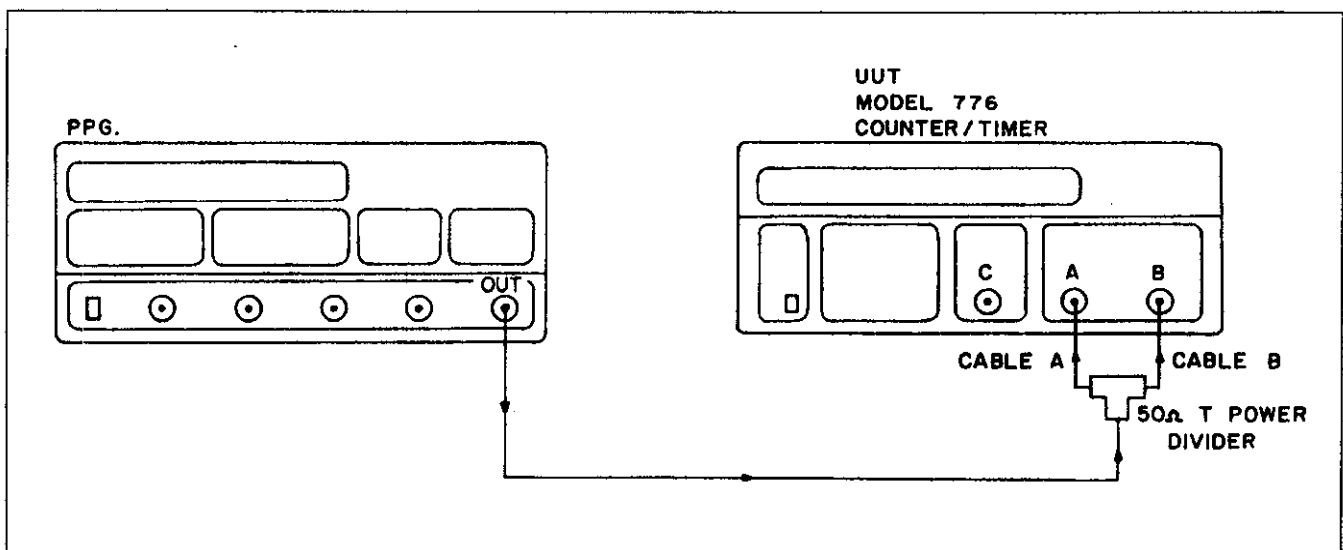
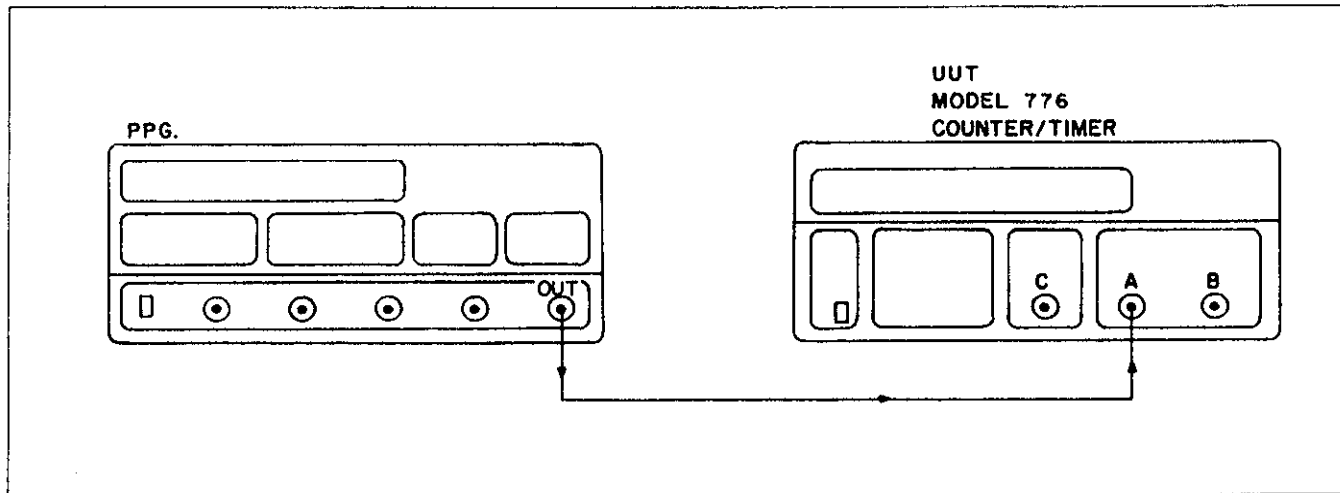


Figure 5-10. Totalize B Test Set-up.

Figure 5-11. Auto Trigger A and B Test Set-up.



4.00 V \pm 0.20 V

5. Modify the connections in Figure 5-11 above so that the pulse generator will now be connected to Channel B.
6. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [FREQ B], [50Ω B], [2nd], [AUTO TRIG] and then [TL B].
7. Repeat the procedure above to verify Channel B auto trigger level operation.

5-10-10. Delay Operation Check

Equipment: Pulse/Function generator

Procedure:

1. Connect the test equipment as described in Figure 5-12.

2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [PER A], [50Ω A], [2nd], [DELAY], [2nd], and then [AUTO TRIG].

3. Set Pulse generator parameters as follows:

Output Wave form - Normal Pulse
 Pulse Frequency - 50 KHz
 High Level - +2.0 V
 Low Level - -2.0 V

4. Verify a counter reading as follows:

approximately 1 s

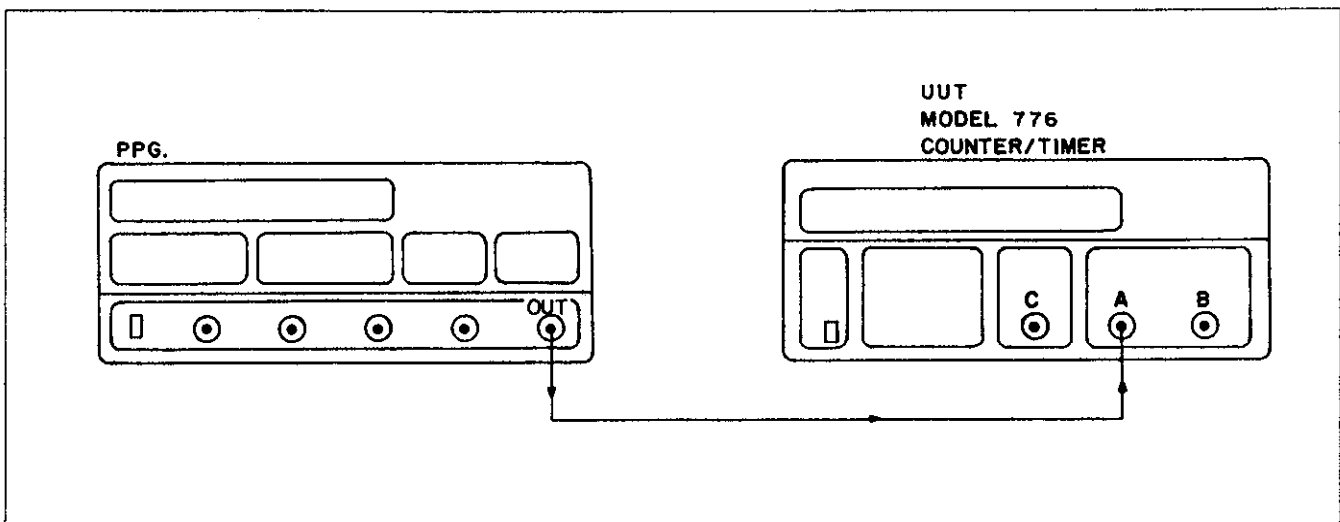
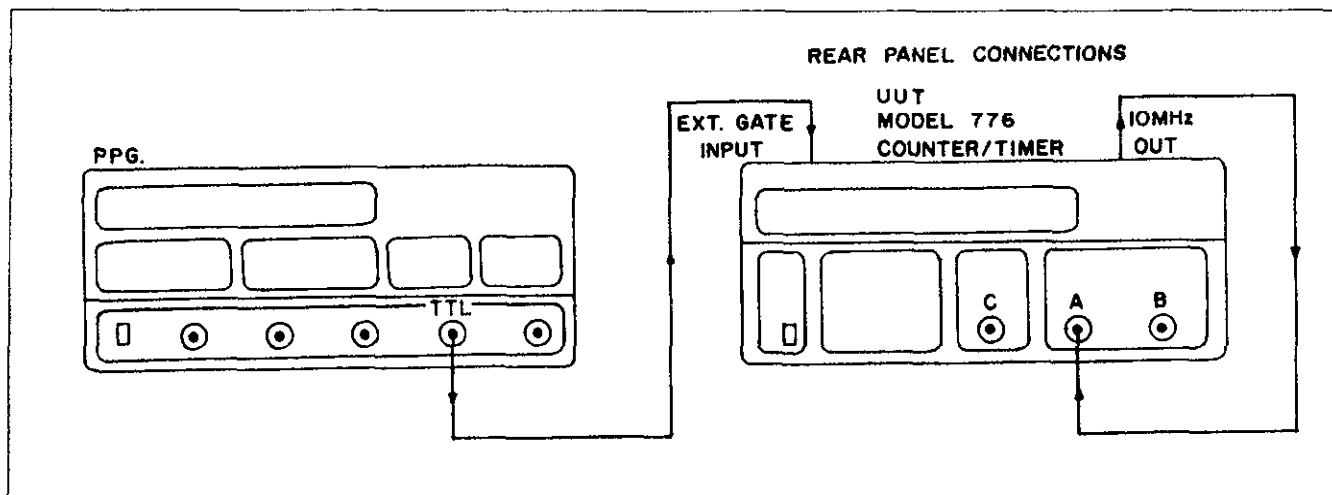


Figure 5-12. Delay Test Set-up.

Figure 5-13. User Gate Test Set-up.



5-10-11. User Gate Operation Check

Equipment: Pulse/Function generator

Procedure:

1. Connect the test equipment as described in Figure 5-13.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [50Ω A] and then [AC A].
3. Select the USER GATE function on the counter. (Refer to section 3 paragraph 3-17).
4. Set Pulse/function generator frequency to 667 MHz, and pulse width to 1 s.
5. Verify a stable counter reading as follows:

10.00000000 E+6 ±2

5-10-12. Time Base Accuracy Check

Equipment: 10 MHz standard

Procedure:

1. Connect the test equipment as described in Figure 5-14.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [50Ω], [2nd] and then [AUTO TRIG].
3. Verify a stable counter reading as follows:

10.00000000 E+6 ±5000 LSDs; or

10.00000000 E+6 ±1000 LSDs with option 2.4G installed;

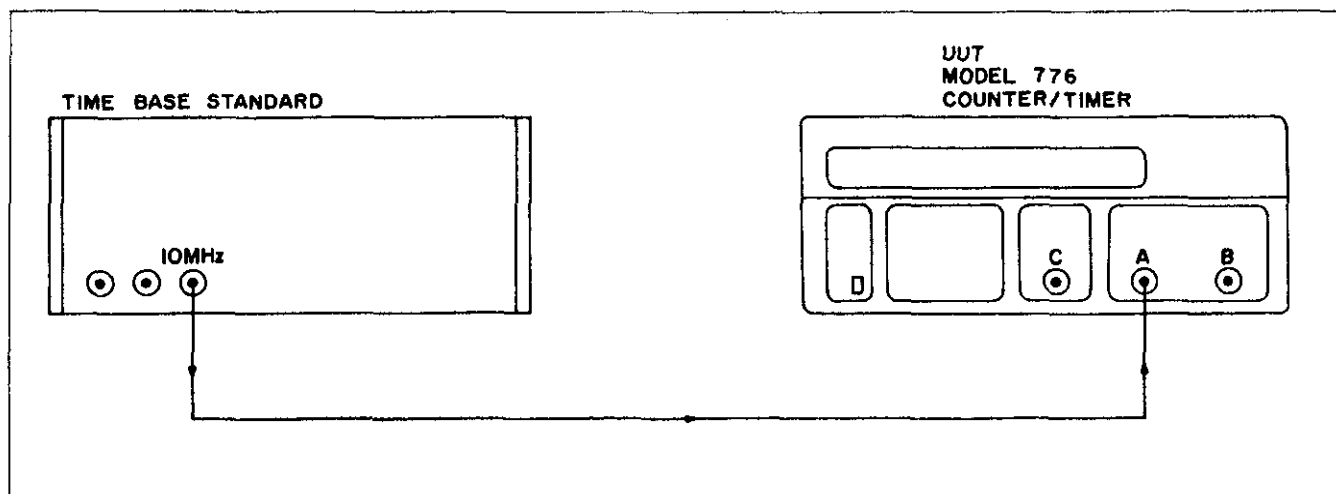


Figure 5-14. Time Base Accuracy Test Set-up.

NOTES

6

Theory of Operation

6-1. Introduction

This section contains an overall functional description of the Model 776 as well as detailed circuit analysis of the various sections of the instrument. Information pertaining to the standard IEEE interface and the various options are also included.

Information is arranged to provide a description of individual functional circuit blocks. As an aid to understanding, the descriptions are keyed to accompanying block diagrams, and simplified schematics. Detailed schematics and component layout drawings are located at the end of this instruction manual.

6-2. Overall Functional Description

Model 776 is a 10 digit counter with 16 different measurement functions as standard, and 1 additional measurement function as an option. The counter utilizes a modern technique, which combines both reciprocal, and conventional measurement techniques, hence, increasing resolution in low frequency measurements, as well as, high frequency measurements; compared to other available counters which utilize the more conventional-fixed-gate-time technique. As an example, a conventional counter measuring 1 KHz with a gate time of 1 second will display a resolution of 1 Hz, where Model 776 with the same gate time will always display a minimum of nine digits of resolution.

The heart of the instrument contains two counting registers: N1 and N2, two synchronizers, selectors, and gates. Figures 5-1 and 5-2 demonstrate the inter-connec-

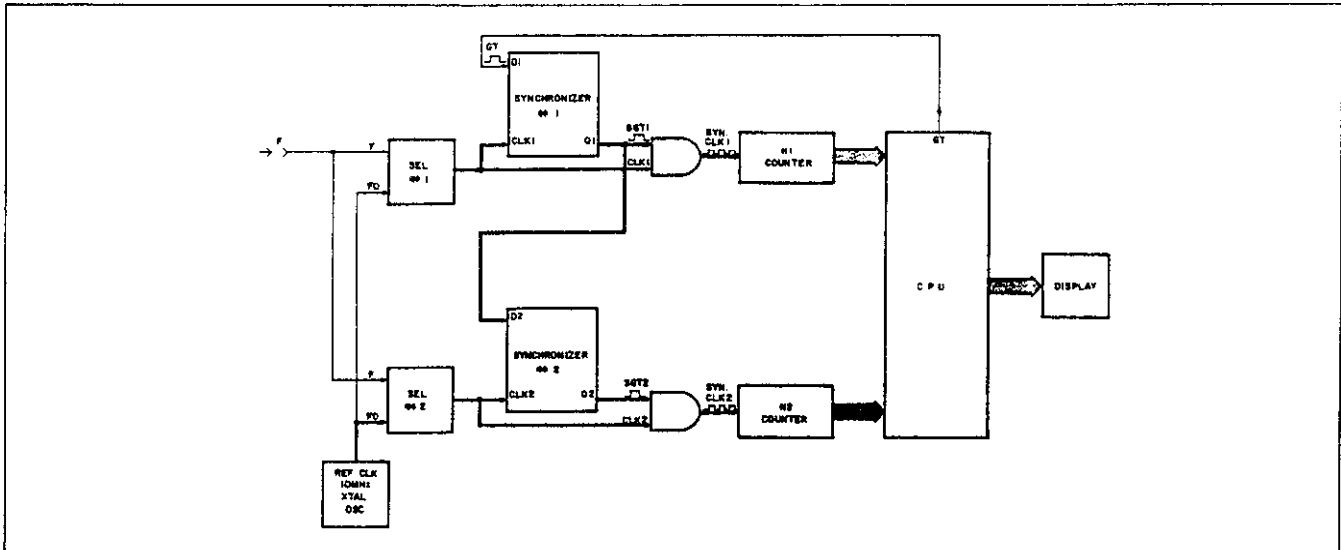
tion of these four elements. The Model 776, while performing frequency measurements, will automatically determine which one of these configurations are to be used. The criteria for this decision is built into the software. However, under certain conditions the counter can only operate using the reciprocal technique (e.g. Frequency C. hold, and single shot frequency measurements).

During frequency measurement, using the reciprocal measurement technique (Figure 5-1), Selector 1 routes the input signal (F) to clock 1 (CLK 1). Selector 2 routes the reference clock signal to clock 2 (CLK 2). The gate time (GT) is generated by the CPU, and is synchronized to the unknown input signal (CLK 1) in such a way that the synchronized gate time 1 (SGT 1) now has a period with an exact integer multiple of pulses from the unknown input signal. Counter N1 then totalizes the number of input pulses during the SGT 1. Synchronizer #2 generates the synchronized gate time 2 (SGT 2) from SGT 1. SGT 2 now has a period with an exact integer multiple of pulses from the reference clock signal. Counter N2 totalizes the number of reference clock pulses (CLK 2). The CPU then computes the result to be displayed, using the following formula:

$$F = \frac{N1}{N2 \times T} \quad \text{where: } T = \text{the period of the reference clock}$$

While performing frequency measurements above 100 MHz, the inter-connection configuration is automatically changed to use the conventional mode of operation, as shown in Figure 5-2.

Figure 6-1. Reciprocal Frequency Measurement.



In this case, selector 2 routes the input signal (F) to clock 2 (CLK 2). Selector 1 routes the reference clock signal to clock 1 (CLK 1). The gate time (GT) which is generated by the CPU is synchronized to clock 1 (CLK 1) in such a way that the synchronized gate time #1 (SGT 1) now has a period with an exact integer multiple of the reference clock pulses. Counter N1 then totalizes the number of the reference clock pulses during SGT 1. Synchronizer #2 generates the synchronized gate time 2

(SGT 2) from SGT 1. SGT 2 now has a period with an exact integer multiple of pulses from the input signal (F). Counter N2 totalizes the number of input signal pulses (CLK 2). The CPU then computes the result to be displayed, using the following formula:

$$F = \frac{N2}{N1 \times T} \quad \text{where; } T = \text{the period of the reference clock (CLK)}$$

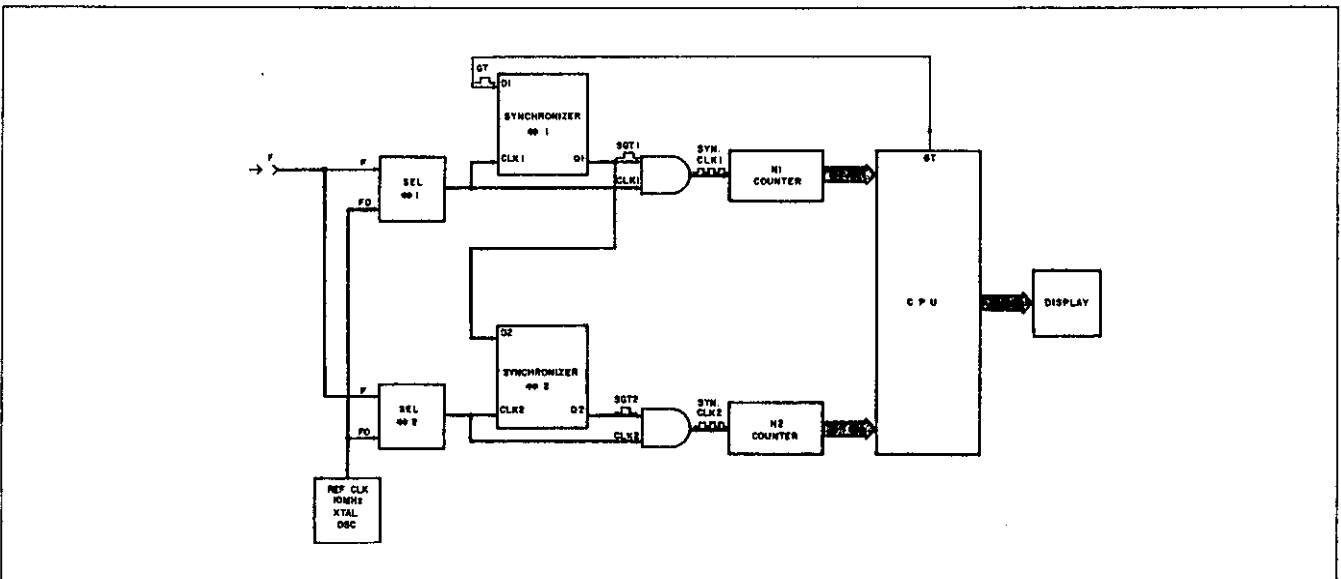


Figure 6-2. Conventional Frequency Measurement.

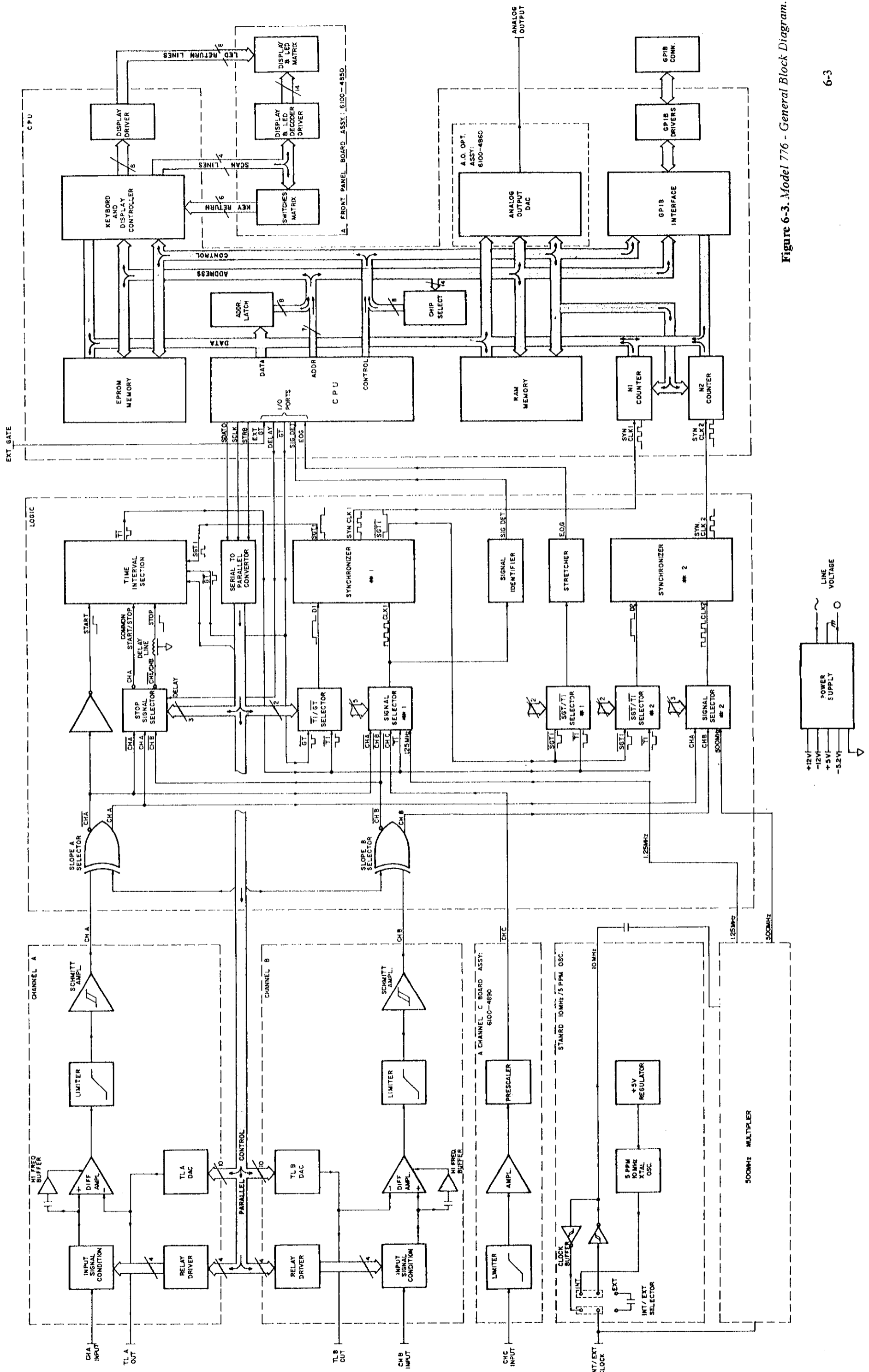


Figure 6-3. Model 776 - General Block Diagram.

A simplified block diagram of the complete Model 776 is given in Figure 6-3. The input signal is applied through the input amplifiers to switching circuits which in turn routes the signals to the correct counting circuits. If channel C is installed, a signal from the Channel C input terminal will pass through the channel C input amplifier to the internal selectors. The CPU, working under software control, then converts the signals into a form suitable for displaying on the front panel or for the IEEE bus.

6-3. Analog Circuitry

The following paragraphs contain a description of the input circuits, measurement logic circuits, frequency multiplier and of the power supply. These circuits may be found on schematic diagrams located at the end of this manual.

6-3-1. Input Circuits A and B

NOTE

Channels A and B are identical in terms of components and operation. Therefore, the following description, which reviews only Channel A circuits applies to channel B as well. Note that letter designations for components in Channel A are different for similar components in Channel B.

The signal which is applied to the Channel A input terminal is preconditioned in front of the amplifier circuit by means of relays and electronic components as follows:

Coupling: Coupling is controlled by a relay K1, and capacitor C1. When instrument is DC coupled, K1 contacts are closed. When instrument is AC coupled, K1 contacts are open and C1 blocks the DC components of the input signal.

Attenuation: Attenuation is controlled by relay K3, resistor network R3 and R39, and capacitor network C3 and C6. When K2 shorts between contacts 1 and 7, R3 and C6 are shorted and there is no attenuation. Actuating K2 shorts between contacts 7 and 14 thereby introduces a x10 voltage attenuation.

Filtering: The low pass filter is controlled by relay K4. Contacts on K4 are normally closed; shorting R6. When the relay contacts open, the impedance of R16, and the capacitance of Q2 act as a low pass filter.

Termination: Termination is controlled by relay K2. Relay is normally open, leaving a 1 M Ω impedance (R4+R5) in front of the input amplifier. When the relay contacts are closed, the input impedance is shunted by R1 and R2 (50 Ω).

Input Protection: Front panel input conditioning are capable of handling signals within the specified dynamic range of the Model 776. Protection of the input circuit from over-voltage signals (up to the specified limits) are done by R4, clipping diodes within U10, C8, R7, CR 2 and Q2.

Amplifier: The amplifier comprises a band split/differential amplifier. This section consists of a high frequency amplifier - Q2, and low frequency differential amplifier - U10 and Q5. The two bands are summed at the junction of R12 and R10, and then buffered by Q3. The diode network - CR5 to CR8 limit the amplitude of the signal which is then applied to the comparator U12a. U12a operates as a schmidt trigger amplifier which translates, for the following stages, the various input wave forms to an appropriate ECL logic levels.

Trigger Level Control: The trigger level control circuit generates a DC voltage which is directly proportional to the required input threshold point. This voltage is then applied through R22 to the negative input of the differential amplifier which was previously discussed. U7 and U6 are a serial to parallel converters which control the D to A converter - U8, U9a, U9b, and their associated components. The output of U9b generates a dc voltage in the range of -5 V to +5 V. This voltage is then applied, in parallel, to the rear panel TRIGGER LEVEL A, and through the voltage divider R21 and R35 to the negative input of the differential amplifier.

6-3-2. Input Circuit C

The signal which is applied to the Channel C input terminal is AC coupled through C1 to a 6 dB attenuator R18 through R22, and through a limiting diode network CR1 through CR6, to the input of the first stage amplifier U1. The amplifier section comprises three stage amplifiers U1 through U3 and their associated components. Limiting diodes, CR8 through CR13, prevent saturation of the following stages. The signal from the U3 is routed to a divide by 128 circuit - U4. The output from this divider is ac coupled and dc leveled by R16 and R17, and then routed through J1 to the main board assembly.

U4 is a self oscillating circuit, that is, if no proper signal is available at its input, the output will oscillate at an uncontrollable frequency. To prevent this oscilla-

tion from reaching the counting circuit, a special comparator circuit is provided. This comparator detects the magnitude of the signal at the input to the divider. Only when the signal is within the specified limits, the output of the divider will be gated to the rest of the circuit.

The signal at the input to U4 is detected by CR14, C16, and C19. The ac signal is rectified and applied to a comparator circuit - U5 and its associated components. The comparator then behaves just like a gate. With an adequate signal this gate will release the output of U4 to the subsequent circuits.

6-3-3. 10 MHz Standard Reference Oscillator

The reference oscillator circuit contains an hybrid oscillator U57, buffers U56, and voltage regulator U55. C124, C125, and C126 adjust the oscillator frequency to a known reference. C124 is a coarse adjust, and C126 is a fine adjustment. LK1a/b is used for selecting between an internal reference, which is generated by U57, and external reference frequency, which may be applied to a rear panel BNC connector. CR35, CR36, C120, and R192 protects the rear panel input against accidental overloads. U56d is configured as a schmidt trigger circuit which converts the external amplitude level to TTL level.

6-3-4. Reference Oscillator circuit, and TCXO (option 2.4G).

The reference oscillator circuit generates a 500 MHz signal for the Measurement Logic Section. The accuracy of this signal is very high and is fed from a standard 10 MHz reference oscillator as described in paragraph 6-3-3. The repetition rate of 500 cycles in one second is generated by a voltage controlled oscillator (VCO) circuit. The VCO is placed in a phase locked loop, and is lock to the accuracy of the internal reference oscillator. The accuracy of the overall circuit may be improved by adding the TCXO. The TCXO Improves temperature stability, as well as, long term stability of the entire instrument. Figure 6-4 is a simplified block diagram of the reference oscillator circuit.

The 500 MHz oscillator include Q3, C23 through C25, L2, varicap diode CR25, and their associated components. The 500 MHz output is buffered by U9, and then simultaneously applied to J2 and to a divide by four circuit - U3. 125 MHz from U3 is further divided by 100 by U4; the output of 1.25 MHz is then applied to the phase comparator - U2. The output of the phase comparator is filtered, and buffered by U6, and its associated components; its dc equivalent drives the varicap diode which in turn controls the accuracy of the VCO oscillations. The internal 10 MHz frequency reference is divided by 5 by U5. The output from U5 is applied as the phase reference to the phase comparator.

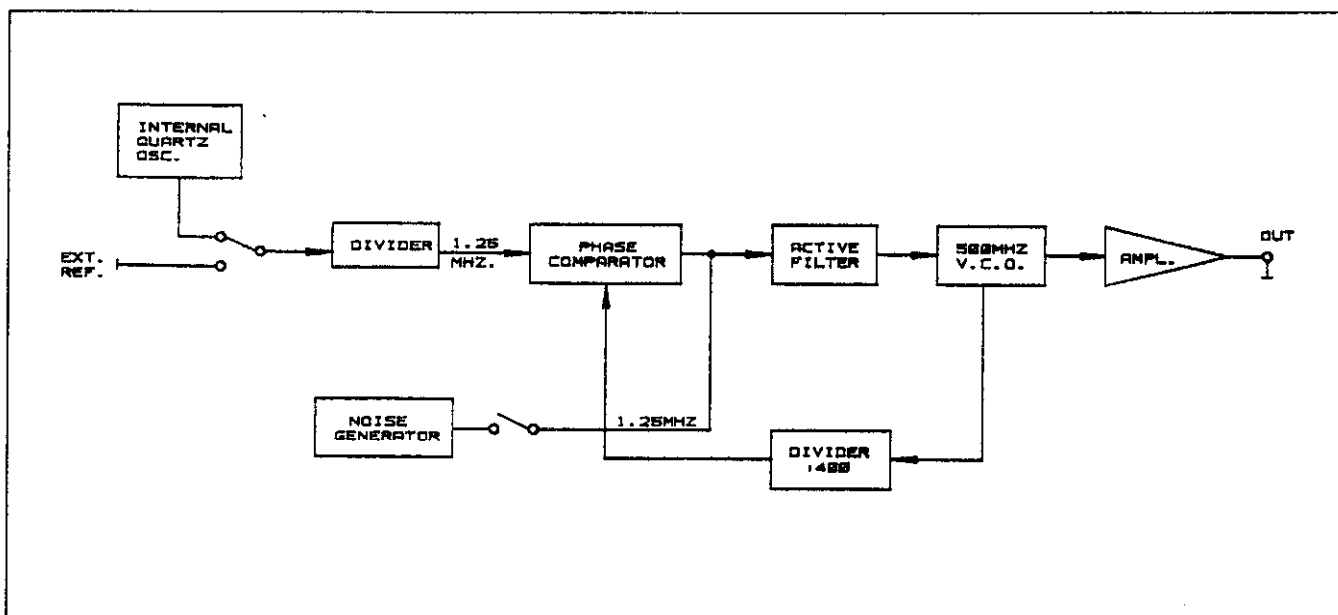


Figure 6-4. Reference Oscillator Circuit Block Diagram.

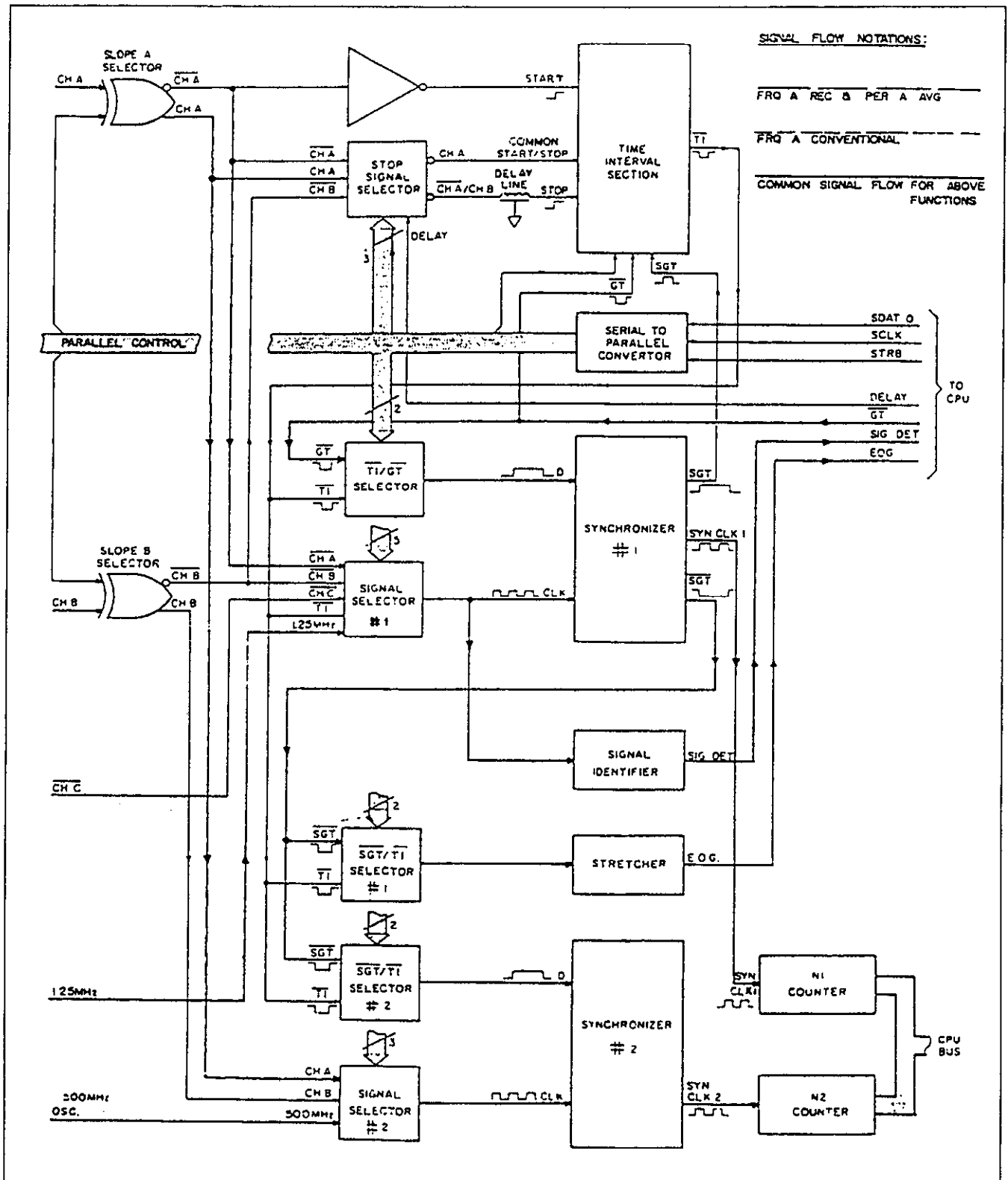


Figure 6-5. Frequency A - Reciprocal, Period A Averaged, and Frequency A Conventional Signal Flow Diagram.

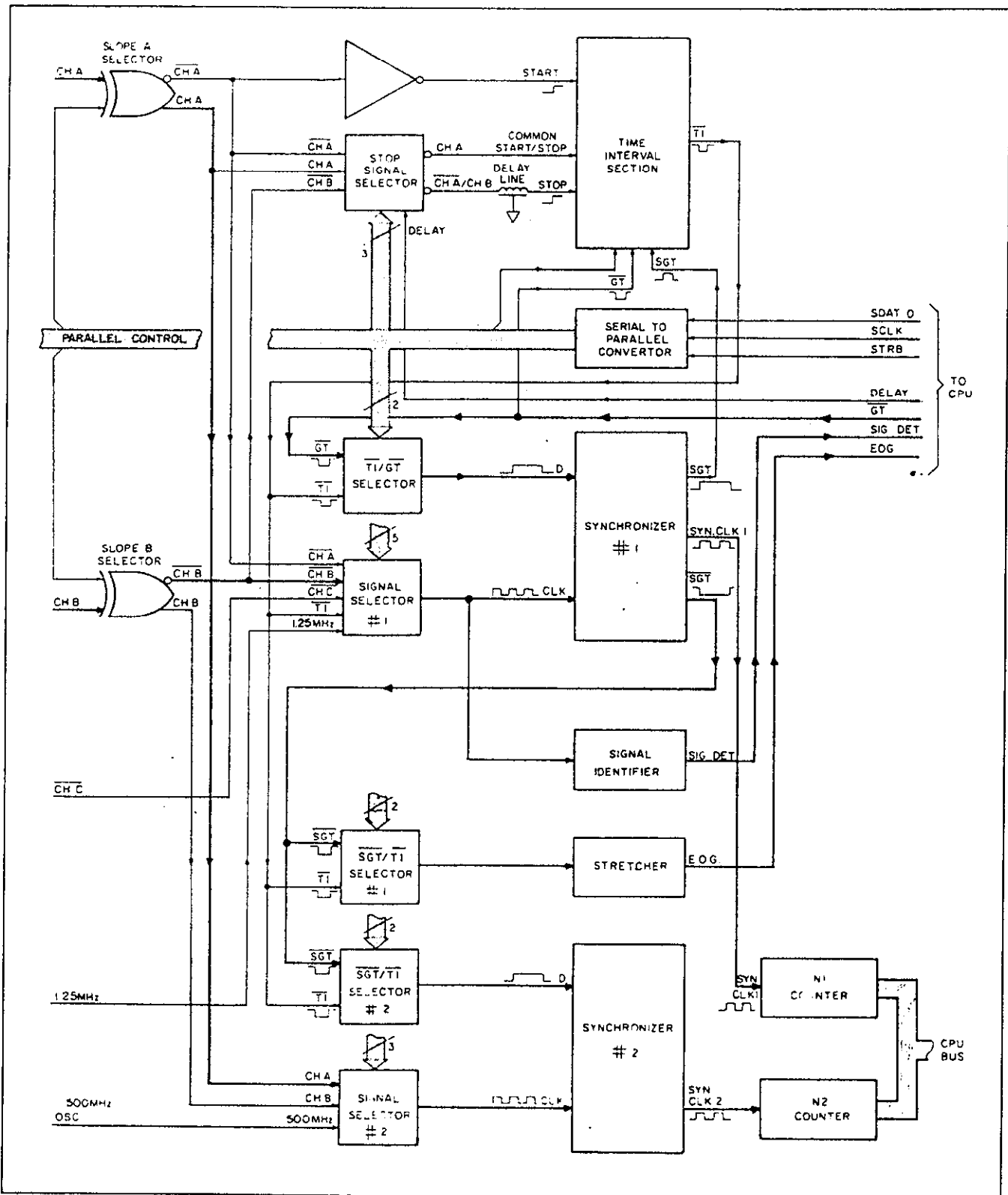


Figure 6-6. Frequency Ratio A/B Signal Flow Diagram.

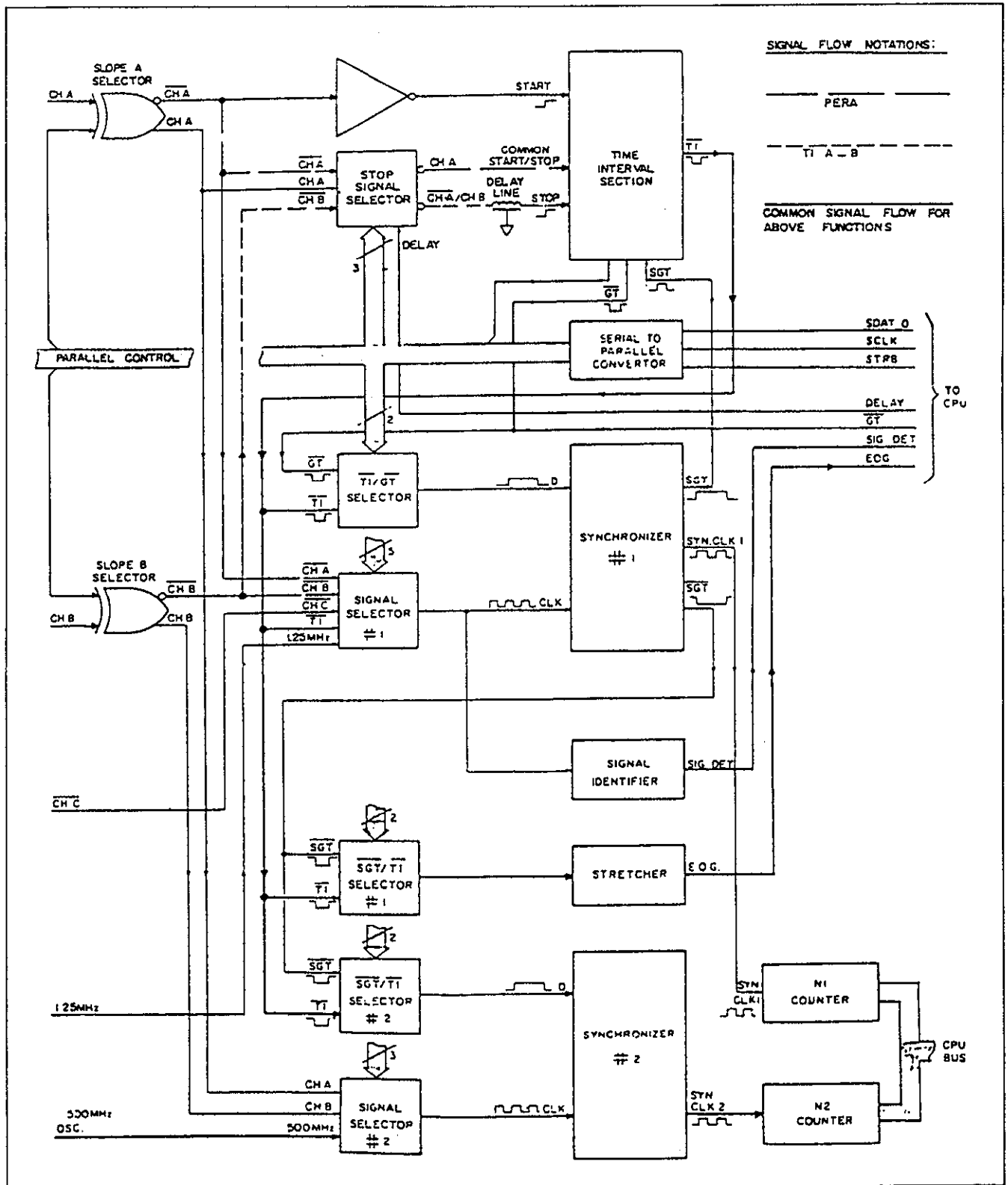


Figure 6-7. Period A, and Time Interval A to B Signal Flow Diagram.

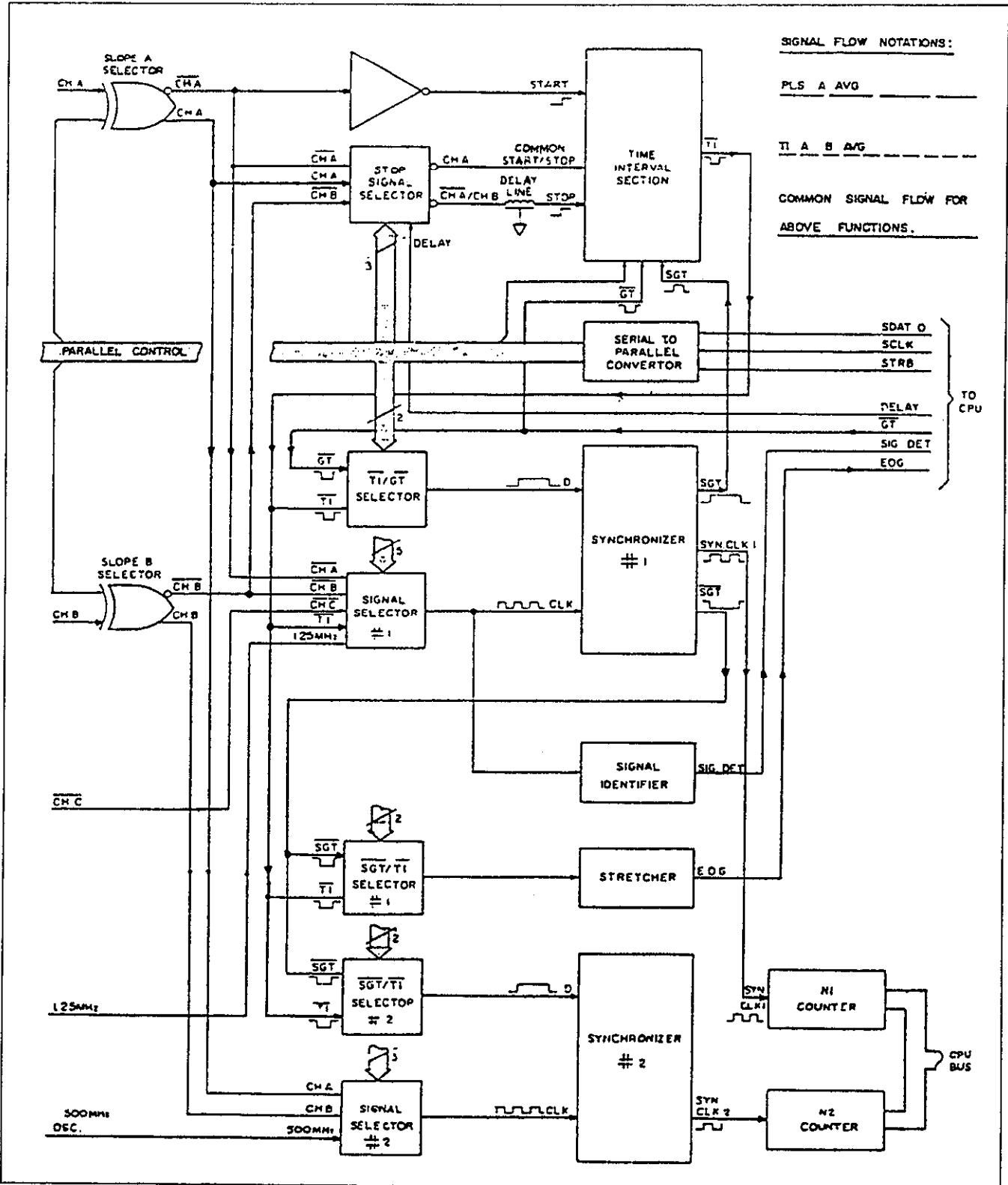


Figure 6-8. Pulse A Averaged and Time Interval A to B Averaged Signal Flow Diagram.

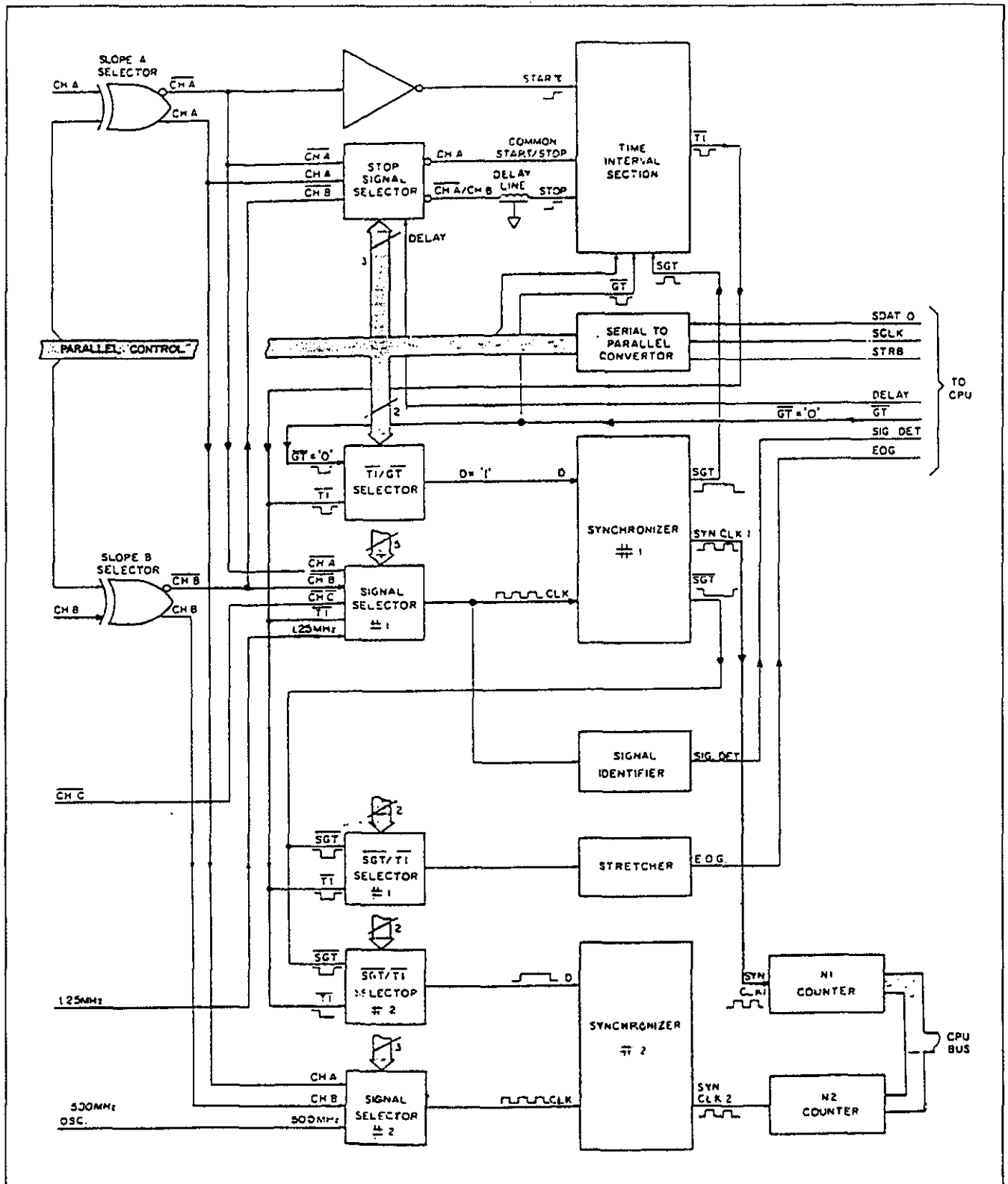


Figure 6-9. Totalize B Infinite Signal Flow Diagram.

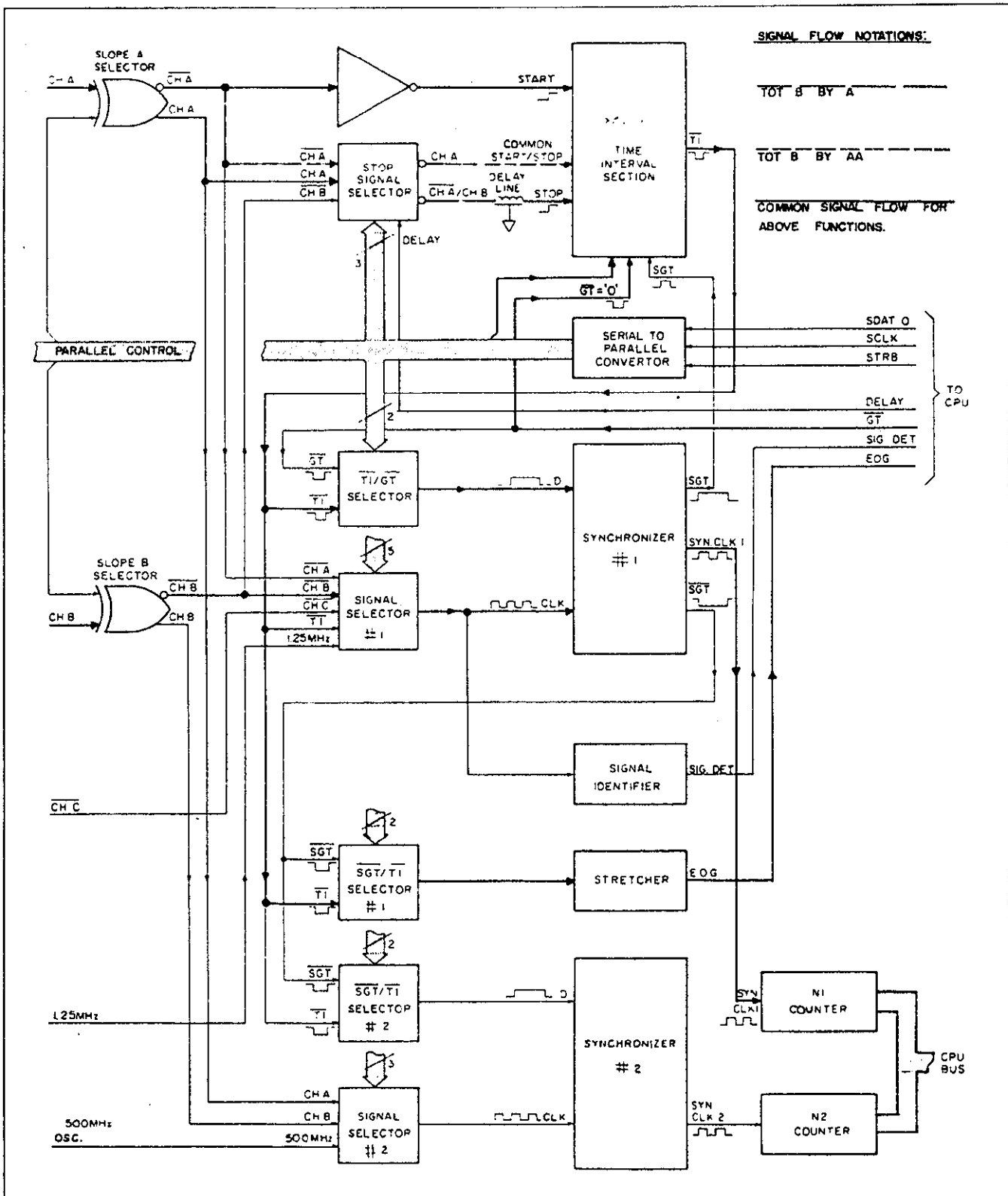


Figure 6-10. Totalize B By A, and Totalize B By AA Signal Flow Diagram.

The reference oscillator also contains a phase noise generator. During certain measurement functions, this generator injects phase noise to the reference oscillator. The noise generator is comprised of CR3, bias resistor R9, and operational amplifier - U7. The noise generator is switched in and out by an analog switch - U8 and is controlled by Q2 and its associated components.

6-3-5. Measurement Logic Section

The measurement logic section is a block which controls various switching, routes the internal signals to the correct ports. It also controls the sequence of the gate and resets and synchronizes the main registers N1 and N2 for the CPU. Figures 5-4 to 5-9 show the routes for the input signal and the reference signal in every measurement function. The following is a brief explanation of the various segments in the measurement logic section.

Control: The control circuit consists of U15, U14, and U13. Information from the CPU is sent in a serial form to the control ICs which in turn convert the serial information to a parallel format. The parallel outputs of these ICs are being used to control the signal selectors, and the signal routing to the various sections within the measuring logic section. Q11 through Q13 convert the TTL logic levels from the CPU to an appropriate voltage levels for U15 (0 V to -5.2 V).

Signal Selector: The signal selector circuit comprises U19, U20, U21, U25, and U28. The function of the signal selector is to route one of Channel A input, Channel B input, Channel C input, or the reference clock to the appropriate processing sections.

Time Interval Section: The time interval section circuit consists of a dual D flip-flop U17a/b, and gates U18a, b and c, and U19b. U17a receives the start signal, and U17b receives a stop signal. Following a reset signal at the reset input of U17a/b, U18c simultaneously produces a single positive pulse (TI), and its complement with a duration which is equal to the time interval between the start, and the stop signals, regardless if the start and stop signals are repetitive. While performing time averaged measurements, these pulses will repeat as long as the gate stays open.

Synchronizer #1: The synchronizer #1 consists of a D flip flop U22b, gate U26b/d, and their associated components. During reciprocal frequency measurement, a gate signal is applied from the CPU to the D input of U22d, and the measured signal is coupled to the CLK input on the same IC. After a reset cycle, and assuming that a signal is present at the appropriate input terminal, the output of U22b generates a pulse with an

approximate width of the original gate signal from the CPU, but with a new adjusted width which is equal to an integer number of periods of the signal being measured. This pulse is used as the #1 synchronized (SGT 1) gating signal throughout the instrument. In conventional frequency measurements, (refer to the above description), the gate time is synchronized to the reference clock 1 (1.25 MHz). SGT 1 opens the gate U26d for the appropriate signal to be later divided, and counted by N1 dividing chain.

Synchronizer #2: The synchronizer #2 consists of a D flip flop U29b, gate U28d, and their associated components. During reciprocal frequency measurement, SGT 1 signal is applied to the D input of U29b. At the same time, the reference clock 2 (500 MHz) is applied to the CLK input on the same IC. The output of U29b generates a pulse SGT 2 with an approximate width of SGT 1, but with a new adjusted width which is equal to an integer number of periods of the reference clock 2. In conventional frequency measurements, the gate time is synchronized to the input signal. SGT 2 opens the gate U28d for the appropriate signal to be later divided and counted by N2 dividing chain.

Signal Identifier: The signal identifier comprises U22a, U31a, and their associated components. A signal when present at the appropriate input terminal, is applied to the CLK input of U22a, converted to a TTL level signal with U31a, and then fed to a CPU port 1.1. This port is used to flag the presence of a signal at the input terminals. This signal is also used as the arming signal of the counter.

Gate Identifier: The gate identifier informs the CPU on the state of the synchronized gate time #1. The gate identifier circuit also serves as a time stretcher of gate signals having very small periods. The gate identifier consists of U26a, U26c, U31d, R158, and C86.

N1 Counter Chain: The N1 counter chain comprises U30b, U31a, U27a, U23a, U46a, U44, and their associated components. U30b, U27a, U23a, and U46a are configured as 7 bit binary up counter with its output connected to U44. U44 is a 32 bit counter with its outputs connected to the data bus. U31c converts the ECL logic level from U30b to TTL.

N2 Counter Chain: The N2 counter chain comprises U29a, U30a, U31b, U27b, U23b, U46b, U45, and their associated components. U29a, U30a, U27b, U23b, and U46b are configured as 8 bit binary up counter with its output connected to U45. U45 is a 32 bit counter with its outputs connected to the data bus. Q15 and U31b convert the ECL logic level from U29a, and U30a respectively to TTL.

6-3-6. Power Supply

For the following discussions, refer to the power supply schematic at the end of the manual. The power supply is made up of a line fuse, power on-off switch, line voltage selection switch, power transformer, two bridge rectifiers, two monolithic regulators, and two discrete regulators which is formed by U52, Q30, Q31, Q32, Q39, and their associated components.

Fuse F1 is the LINE FUSE which is accessible on the rear panel. S2 is the LINE VOLTAGE SELECT switch, which is accessible on the rear panel, to select 115 V or 230 V operation, and S1 is the power on-off switch. CR25 is used as a full-wave rectifier to provide a sufficient DC voltage for the +12 V, and -12 V regulators U50, and U51 respectively.

U52b receives a reference voltage of +5 V from the +12 V supply. This reference is then compared to the regulated +5 V. U52b then controls through Q30 the current through the series pass transistor - Q31. The +5 V supply then acts as the reference for the -5.2 V regulated supply. The operation of U52a is similar to the operation of U52b, except, U52a operates as an inverting amplifier. CR 29, and CR30 protect the +5 V and the -5.2 V respectively against accidental over-voltage.

6-4. Digital Circuitry

Model 776 operation is supervised by the internal CPU. Through the CPU, the counter measurement process, the front panel switching, display, and IEEE operation are all performed under software control. This section briefly describes the operation of the various sections of the CPU, and its associated digital circuitry. A simplified block diagram is included for user reference; for more complete circuit details refer to digital schematics at the end of this manual.

6-4-1. CPU Block Diagram

A block diagram of the Model 776 CPU is shown in Figure 6-3. Circuit operation centers around the CPU unit - U39. The 8031 is an 8-bit CPU capable of directly addressing up to 64K bytes of program memory (ROM), and up to another 64K bytes of data memory (RAM). The CPU works with a 16 MHz clock which is divided internally to provide a bus operation of about 1.6 MHz.

Software for the CPU is contained in an EPROM (Erasable Programmable Read-Only Memory). U42 is a 27128 EPROM containing 16K bytes of software. Temporary storage is provided by U43, RAMs (Random Access Memory) which can store up to 2048 bytes of information.

Interfacing between the CPU, and the IEEE bus is performed by dedicated IEEE-488 bus interface IC - U36. This IC performs many bus functions automatically to minimize CPU overhead. Buffering between the 8291 IC and the IEEE bus lines is done with bus drivers U21 and U22.

Interfacing between the CPU to the keyboard and the display is performed by the Keyboard/Display interface IC - U36.

6-4-2. Memory Mapping

The 8031 CPU is capable of directly addressing two banks of 64k (65,536) bytes memory. One bank of memory is the program memory, and the second memory bank is the data memory. The selection of the banks is done internally by the CPU. Although the CPU has this large addressing capability, only a portion of the possible memory space is actually needed.

The Model 776 uses a total of 32K of program memory stored in the 27256 EPROM U43, and a total of 1K of data memory is stored in U10 and. The 8031 CPU uses a memory-mapped I/O scheme, additional memory location must be allocated for the various I/O function. All the memory-mapped I/O functions are in the data memory space.

6-4-3. Address Decoding

The CPU has a total of 16 address lines which are used to locate a specific memory slot. The LOW address line (A0 to A7) are multiplexed on the address/data bus, and the ALE (address latch enable) signal is used to separate the LOW address from the address/data bus witch is done by U40 address latch. Since no memory or interface element can fully decode address locations, additional address decoding must be used. U38 is 1-of-8 decoder. The decoder is enabled when address lines A15 is HIGH. Once the decoder is selected the decoding is done by addressing lines A11, A12 and A13.

6-4-4. Keyboard/Display Interface

The Keyboard/Display Interface IC U5 is used to control the front panel display, and to find out which one of the buttons was pushed.

6-4-5. IEEE Interface

The Model 776 has a built in IEEE-488 interface that allows the instrument to be controlled through the system controller. Commands may be given over the bus, and data may be requested from the instrument as well.

The IEEE interface is made up of U47, a 8291 GPIA (General Purpose Interface Adapter), U48, and U49, which are interface bus drivers. On the CPU side of the GPIA, data transmission is handled much like any other bus transaction. The CPU accesses the GPIA through the usual D0 through D7 data lines. Address decoding for the internal 14 registers (7 read and 7 write) is provided by the CS, WR, RD, and A0, A1, A2 terminals.

The output of the 8291 IC is a standard IEEE format; the eight data lines (DIO1 through DIO8), the three handshake lines (DAV, NDAC, NRFD), and the five management lines (ATN, REN, IFC, SRQ, EOI), are all

active low with approximately zero volts representing a logic one. The two IEEE bus drivers, U48 and U49 are necessary to bring the drive capability of the interface up to the normal IEEE maximum 15 devices.

The GPIA simplifies CPU interfacing to the IEEE bus because many control sequences take place automatically. For example, when a write is done to the data output register, the handshake sequence is automatically performed at the proper time. Without the GPIA chip, complicated CPU routines would be required to accomplish control sequence that are performed automatically.

NOTES

7

Adjustments and Troubleshooting

7-1. Introduction

This section contains information necessary to adjust and troubleshoot the Model 776 and the 2.4G option.

WARNING

The procedures described in this section are for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Many of the steps covered in this section may expose the individual to potentially lethal voltages that could result in personal injury or death if normal safety precautions are not observed.

7-2. Adjustments

7-2-1. Environmental Conditions

Adjustments should be performed under laboratory conditions having an ambient temperature of $25^{\circ} \pm 5^{\circ} \text{C}$, and a relative humidity of less than 70%. If the instrument has been subjected to conditions outside these ranges, allow at least one additional hour for the instrument to stabilize before beginning the adjustment procedure.

7-2-2. Warm-Up Period

Most equipment is subject to at least a small amount of drift when it is first turned on. To ensure long-term calibration accuracy, turn on the power to the Model

776, and allow it to warm-up for at least 30 minutes before beginning the adjustment procedure.

7-2-3. Recommended Test Equipment

Recommended test equipment for calibration is listed in Table 5-2. Test instruments other than those listed may be used only if their specifications equal or exceed the required characteristics.

7-2-4. Adjustment Procedures

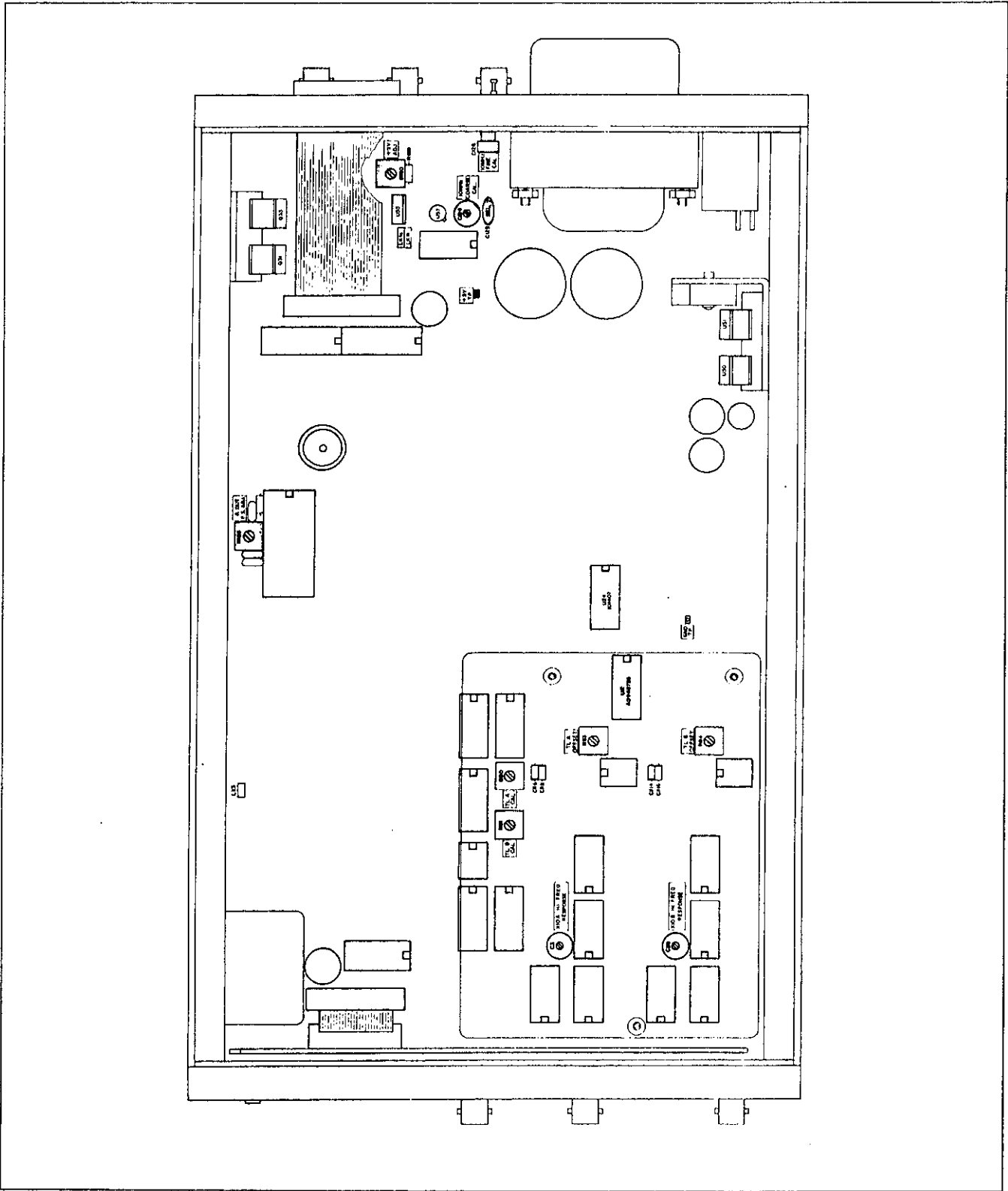
All adjustments are performed with the POWER switch ON. The top cover should be removed to allow access to test points, and adjustments. Between adjustments, always leave top cover on the unit to keep internal temperature.

WARNING

Take special care to prevent contact with live circuits, or power line area which could cause electrical shock resulting in serious injury, or death. Use an isolated tool when making adjustments. Use plastic or nylon screwdriver when adjusting the time base trimmer; other materials could cause confusion in this adjustment.

Refer to Figure 7-1, throughout the following adjustment procedures, for determining adjustment points. Follow the procedure in the sequence indicated because some of the adjustments are interrelated, and dependent on the preceding steps.

Figure 7-1. Model 776 Adjustment Points Location.



Verify that Model 776 is functioning according to the performance checks. Make sure that all results are within, or close to, the range of the required specifications. Otherwise refer to the troubleshooting procedures given later in this section. Center all trimmers and if necessary, remove selected components and clear the holes to allow a selection of new components.

Perform the following adjustment procedure. If an adjustment can not be made to obtain a specific result, refer to the troubleshooting procedures.

7-3. Adjustment Procedure

7-3-1. Power Supply Adjustment

Equipment: DMM

Procedure:

1. Set DMM to DCV measurements. Connect the DMM between ground, and the +5 V test point.
2. Adjust R190 for a DMM reading of $+5.000\text{ V} \pm 10\text{ mV dc}$.

7-3-2. Trigger Level A Adjustment

Equipment: DMM, dc voltage calibrator

Procedure:

1. Set DMM to DCV measurements.
2. Set [TL A] to 0.00 V.
3. Measure and record the voltage at U12 pin 8. Record this voltage with a resolution of $\pm 0.001\text{ V}$.
4. Set [TL A] to 5.00 V.
5. Set dc calibrator output setting to +5.000 V.
6. Using a banana to BNC adapter, connect the calibrator output to the Channel A input connector.
7. Re-connect the DMM probes to U12 pin 8 and adjust R80 to obtain the same voltage level as recorded in step 3.

7-3-3. Trigger Level B Adjustment

Equipment: DMM, dc voltage calibrator

Procedure:

1. Set DMM to DCV measurements.
2. Set [TL B] to 0.00 V.
3. Measure, and record the voltage at U12 pin 9. Record this voltage with a resolution of $\pm 0.001\text{ V}$.
4. Set [TL B] to 5.00 V.
5. Set dc calibrator output setting to +5.000 V.
6. Using a banana to BNC adapter, connect the calibrator output to the Channel B input connector.
7. Re-connect the DMM probes to U12 pin 9, and adjust R81 to obtain the same voltage level as recorded in step 3.

7-3-4. Trigger Level A Offset Adjustment

Equipment: Function generator, oscilloscope

Procedure:

1. Set function generator controls as follows:

Wave form - Sinc
 Frequency - 1 KHz
 Amplitude - 25 mVp-p
 Offset - 0 V
 Symmetry - 50%

2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL] and then [AC A].
3. Connect the function generator output to the Channel A input connector.
4. Set oscilloscope time base to 0.1 ms/div.
5. Connect the oscilloscope probe to U24 pin 9. Connect the ground lead from the probe to ground.
6. Adjust R83 to obtain a square wave having a 50% $\pm 1\%$ duty cycle on the oscilloscope.

7-3-5. Trigger Level B Offset Adjustment

Equipment: Function generator, oscilloscope

Procedure:

1. Set function generator controls as in paragraph 7-3-4.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [FRQ B] and then [AC B].
3. connect the function generator output to the Channel B input connector.
4. Set oscilloscope time base to 0.1 ms/div.
5. Connect the oscilloscope probe to U24 pin 14. Connect the ground lead from the probe to ground.
6. Adjust R84 to obtain a square wave having a 50% $\pm 1\%$ duty cycle on the oscilloscope.

7-3-6. Input A x10 High Frequency Adjustment

Equipment: Function generator, oscilloscope

Procedure:

1. Set function generator controls as follows:

Wave form - Square wave
 Frequency - 10 KHz
 Amplitude - 5 Vp-p
 Offset - 0 V
 Symmetry - 50%

2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [50Ω A], and then [x10 A].
3. connect the function generator output to the Channel A input connector.

4. Connect the oscilloscope probe to the cathode of CR6. Connect the ground lead from the probe to ground.
5. Set oscilloscope and adjust C3 to obtain the best square wave response having minimum overshoot, and undershoot.

7-3-7. Input B x10 High Frequency Adjustment

Equipment: Function generator, oscilloscope
Procedure:

1. Set function generator controls as in paragraph 7-3-5.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], [FRQ B], [50Ω B], and then [x10 B].
3. Connect the function generator output to the Channel B input connector.
4. Connect the oscilloscope probe to the cathode of CR14. Connect the ground lead from the probe to ground.
5. Set oscilloscope and adjust C28 to obtain the best square wave response having minimum overshoot, and undershoot.

NOTE

The Models 776 and 776/2.4G have a default gate time of 1 second. The Model 776/2.4G/R has a default gate time of 100ms. The resolution of counter readings in the following procedures are for a 1 second gate time. Readings on the Model 776/2.4G/R will have one less digit.

7-3-8. Standard - 5 PPM Time Base Adjustment

Equipment: 10 MHz Standard
Procedure:

1. The following adjustment must be performed in a stable temperature environment of 25 °C ±2 °C Remove the top cover, and set C126 to about mid-range. Replace the top cover. Power-up Model 776, and allow it to operate, for at least an hour, with its covers closed.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], and then [50Ω A].
3. Connect the 10 MHz standard to the Model 776 Channel A.
4. Remove the top cover, and adjust C124 to give a reading of:

10.00000000 E+6 ±5000 LSD

If range can not be reached, select C125 (in the range of 8 - 10pF) to bring C124 within range.

5. Replace the top cover, and allow the Model 776 to operate with the covers on for an additional period of 15 minutes.
6. Using a plastic material screwdriver, adjust C126 from the rear panel to give a display reading of:

10.00000000 E+6 ±1000 LSD

If range can not be reached, repeat steps 4 through 6.

7-3-9. TCXO Time Base Adjustment (option 2.4G)

Equipment: 10 MHz Standard
Procedure:

1. The following adjustment must be performed in a stable temperature environment of 25 °C ±2 °C Remove the top cover, refer to Figure 5-1, and remove the adjustment plug at the top of the oscillator bulk. Replace the top cover. Power-up Model 776, and allow it to operate, for at least half an hour, with its covers closed.
2. Press Model 776 push-buttons in the following sequence: [2nd], [DCL], and then [50Ω A].
3. Connect the 10 MHz standard to the Model 776 Channel A.
4. Remove the top cover, and using a plastic-tip screwdriver, adjust the trimming resistor on top of the TCXO board to give a reading of:

10.00000000 E+6 ±100 LSD

5. Replace the adjustment plug and the top cover, and allow the Model 776 to operate with the covers on for an additional period of 15 minutes.
6. Check if frequency is still in the range, as in step 4. If reading shifted, repeat steps 4 through 6.

7-4. Troubleshooting

The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog, and digital circuitry. The individual should also be experienced at using typical test equipment as well as ordinary troubleshooting procedures. The information presented here has been written to assist in isolating a defective circuit, or circuit section; isolation of the specified component is left to the technician.

7-4-1. Recommended Test Equipment

The success or failure in troubleshooting a complex piece of equipment, like the Model 776, depends not

Table 7-1. Recommended Minimum Test Equipment For Troubleshooting

| Instrument | Recommended Model | Minimum Specifications |
|---------------------------------|-------------------|--|
| DMM | Keithley 175A | .1 V- 100 VDC, AC rms, .05% basic accuracy |
| Pulse/Function Generator | HP 8116A | 4 s - 20 ns, 15 Vp-p into 50 Ω |
| Signal Generator | HP 8663A | 100 KHz - 2560 MHz |
| Oscilloscope | Tektronix 2465 | 300 MHz band width |
| 50 ohm feed through Termination | Tek 011-0049-01 | 50 Ω , 2W, 1% |

only on the skills of the technician, but also relies heavily on accurate, reliable test equipment. Table 6-2 lists the recommended test equipment for a complete troubleshooting and adjustment of the Model 776. However, it is also possible to troubleshoot Model 776 with the minimum equipment which is listed in Table 7-1. Other equipment such as logic analyzer, and in-circuit emulator etc, could also be helpful in difficult situation.

7-4-2. Power-Up Self Diagnostics

An advanced feature of the Model 776 is its self diagnosing capabilities. Upon power-up the Model 776 performs a set of tests which is described in paragraph 3-4. If the Model 776 locks up due to ROM or RAM fail, there is a little point in attempting to troubleshoot elsewhere unless the micro controller circuit is operating properly.

7-5. Troubleshooting Procedure

7-5-1. Power Supply Checks

It is highly suggested that the first step in troubleshooting the Model 776, as well as any similar equipment, would be to check the power supply. If the various supply voltages within the instrument are not within the required limits, troubleshooting the remaining circuits can be very difficult. Table 7-2 shows several checks that can be made to the power supplies within the Model 776. In addition to the normal voltage checks, it is also a good idea to check the various supplies with an oscilloscope to make sure no noise or ringing is present.

In case of a "dead short" between one of the supplies to the common ground, it would be best to disconnect

| Step | Item/Component | Required Condition | Remarks |
|------|----------------------|--|--------------------------------|
| 1 | S2 Line Switch | Set to 115 V or 230 V | See paragraph 5-2 |
| 2 | F1 Line Fuse | Continuity | Remove fuse to check |
| 3 | J1 Line Power | Plugged into live receptacle; power on | |
| 4 | +12 V Supply | +12 V \pm 5% | |
| 5 | U50 Input | +15 V minimum | Positive output of CR25 |
| 6 | -12 V Supply | -12 V \pm 5% | |
| 7 | U51 Input | -15 V minimum | Negative output of CR25 |
| 8 | +5 V Supply | +5 V \pm 2% | Cathode of CR29 |
| 9 | Input to +5 V Supply | Approx. +7 V | Positive output of CR28 |
| 10 | Reference to +5 V | +5 V \pm 5% | U52b pin 5 Supply |
| 11 | -5.2 V Supply | -5.2 V \pm 2% | Anode of CR30 |
| 12 | Input to -5.2 V | Approx. -7 V | Negative output of CR28 Supply |
| 13 | +5 V Supply to osc. | + 5 V \pm 5% | U57 pin 8 |
| 14 | Input to +5 V U55 | +12 V | U55 input/+12 V supply |

Table 7-2. Power Supply Checks

In case of a "dead short" between one of the supplies to the common ground, it would be best to disconnect the entire supply section from the remaining of the circuitry, and then determine whether the problem is in the power supply or in the remaining circuits. Model 776 is equipped with such quick-disconnect points, which are located on the bottom side of the main PC board. To access these points, it is necessary to remove the bottom cover, and then to remove the solder layer from these points.

While troubleshooting the power supply section, bear in mind that the +12 V supply also provides the reference voltage to the +5 V. Therefore, it would be impossible to troubleshoot the +5 V supply if the +12 V supply is defective. Similarly, the +5 V supply is used as a reference voltage to the -5.2 V supply.

7-5-2. Digital Circuitry and Display Checks

The most important section, to be verified after the power supply checks, is the digital section with its various clocks. Problems with the digital circuitry could cause erratic operation or false display readings. Problems in the clock generator for the CPU and the digital circuit may cause a complete malfunction of the entire section. The CPU would not even start to generate the control lines which makes it impossible to troubleshoot the remaining of the circuitry. Check the various components, associated with the digital circuitry, clocks, and the IEEE-488 interface, using the information in Table 7-3.

7-5-3. Standard 5 PPM Reference Oscillator Checks

The reference oscillator supplies a precise signal to the 500 MHz oscillator. This oscillator is integrated within a phase locked loop. Therefore, the accuracy of this oscillator determines the final accuracy of the 500 MHz oscillator. Without this clock the instrument will operate erratically. Verify that a 10 MHz TTL level signal is present at U57 pin 5, U56 pin 6, 3, and 8, and at the CLOCK output rear panel connector. Check LK1a/b position.

7-5-4. 500 MHz reference oscillator and TCXO Checks

The 500 MHz oscillator circuit generates an ECL signal for the counting circuit. This generator is a free running voltage controlled oscillator. Its final accuracy is phase locked to the 10 MHz clock reference. Problems with the 500 MHz oscillator will definitely cause false results on the Model 776; in some cases, the counter may display no result at all. Problems in the 500 MHz oscillator may be identified using Table 7-4. When option 51 is installed, a TCXO reference replaces the standard reference oscillator. The TCXO enhances the overall accuracy of the instrument. A malfunctioned TCXO displays similar symptoms to an inoperative 500 MHz oscillator. If a problem appears to be with the 500 MHz oscillator, it is recommended that the TCXO output be checked first.

7-5-5. Trigger Level Checks

The trigger level circuits control the threshold point where the input circuit triggers. If a legal signal is applied to the input connector, and the counter fails to trigger, it is most likely that the fault is in one of the trigger circuits. Problems within the trigger circuit may be located using the checks given in Table 7-5.

7-5-6. Signal Conditioning And Input Circuits Checks

Problems in these circuits could generate false results on the Model 776. Tables 7-6 and Table 7-7 list the checks to be made on the signal conditioning and the input circuits respectively.

7-5-7. Measurement Logic Section Checks

The measurement logic section circuitry is mainly used as a digital traffic control to the analog signals within the instrument. The function control circuit checks is given in Table 7-8. Table 7-9 describes the remaining of the measurement logic circuit. While performing checks from Table 7-9, it is recommended to use a special high frequency probe with very short grounding clip.

Table 7-3. Digital Circuitry and Display Checks

| Step | Tested Circuit | Required Condition | Remarks |
|---|---|--|--|
| 1 | | Turn on power | Some tests here could fail due to digital problems. |
| 2 | Microprocessor clock | 0 to +4 V 16 MHz square wave | Pin 18 on U39. |
| 3 | Microprocessor timer | 0 to +4 V 7.8 KHz square wave | Pin 14 on U39. |
| 4 | Keyboard/Display clock | 0 to +4 V 2.0 MHz square wave | Pin 3 on U36. |
| 5 | IEEE Interface clock | 0 to +4 V 8.0 MHz square wave | Pin 3 on U47. |
| 6 | Beeper clock | 0 to +4 V 3.9 KHz square wave | Pin 1 on U41. |
| 7 | Reset Input | Turn off instrument then back on | Pin 9 on U39 stays low for about .1 s and then goes high. |
| 8 | ALE Line | 0 to +4 V 125 ns pulses | Pin 30 on U39. |
| 9 | PSEN Line | 0 to +4 V 190 ns negative going pulses | Pin 29 on U39. |
| 10 | RD WR Lines | 0 to +4 V 500 ns negative going pulses | Pins 16 and 17 on U39. |
| 11 | Address/Data Bus | 0 to +4 V variable pulse train | Pins 21 thru 28; Pins 32 thru 39; Pins 3 thru 10 on U39 on U42. |
| Depress and hold the $\hat{\uparrow}$ Level A during the next six tests. This will generate serial data on the RXD lines. | | | |
| 12 | TTL Serial Data Input | 0 to +5 V variable pulse train | Pin 2 of U1; Pin 2 of U3; Pin 2 of U6; and, Pin 2 of U7. |
| 13 | ECL Serial Data Input | -5.2 to 0 V variable pulse train | Pin 2 of U15; Pin 2 of U14; and, Pin 2 of U13. |
| 14 | TTL Serial to Parallel Converters Clocks | 0 to +5 V bursts of pulse train | Pin 4 of U37; Pin 3 of U1; Pin 3 of U3; Pin 3 of U6; and, Pin 3 of U7 |
| 15 | ECL Serial to Parallel Converters Clocks | -5.2 to 0 V bursts of pulse train | Pin 3 of U15; Pin 3 of U14; and, Pin 3 of U13 |
| 16 | TTL Serial to Parallel Converters Strokes | 0 to +5 V bursts of pulse train | Pin 15 of U37; Pin 1 of U1; Pin 1 of U3; Pin 1 of U6; and, Pin 1 of U7 |
| 17 | ECL Serial to Parallel Converters Strokes | -5.2 to 0 V bursts of pulse train | Pin 1 of U15; Pin 1 of U14; and, Pin 1 of U13 |
| Depress, in turn, each one of the buttons on the front panel throughout the next test. This test will check all buttons on the front panel as well as the interrupt line. | | | |
| 18 | Keyboard Interrupt Line | 0 to +4 V variable negative going pulses | Pin 4 of U36 |
| 19 | LEDs Sink Lines | 0 to +4 V variable pulses | Pins 10 to 16 on U35; and, Collector of Q20 |

Table 7-4. 500 MHz Oscillator and TCXO Circuit Checks

| Step | Tested Circuit | Required Condition | Remarks |
|---|------------------------------|-------------------------------------|-----------------------------------|
| 1 | | Turn on power | |
| 2 | TCXO 10 MHz | 0 to +4 V pulses | U10 pin 1, U1 pins 9, 10, and 11. |
| 3 | Phase Detector Signal Input | 0 to +4 V 1.25 MHz pulses | U2 pin 3. |
| 4 | Phase Detector Compare Input | 0 to +4 V 1.25 MHz pulses | U2 pin 1, and U4 pin 2. |
| 5 | Low Pass Filter Out | ± 1 V around -0.5 V | U6 pin 6. |
| Perform the following check with a 1:10 probe, and a sampling oscilloscope. | | | |
| 6 | VCO Out | 500 MHz pulses 1 Vp-p around -1.3 V | J2 |
| 7 | Noise Generator | Approximately 200 mVp-p white noise | U7 pin 6. |

Table 7-5. Trigger Level Circuit Checks

| Step | Tested Circuit | Required Condition | Remarks |
|--|-------------------------|----------------------|--------------------------------|
| 1 | | Turn on power | |
| 2 | D to A Reference | +6.2 V ± 300 mV | Pin 15 of U4, and Pin 15 of U8 |
| Change front panel trigger level setting for Channels A and B to +0.00 V | | | |
| 3 | Channel A Trigger Level | +0.00 V ± 35 mV | Pin 7 of U9 |
| 4 | Channel B Trigger Level | +0.00 V ± 35 mV | Pin 7 of U5 |
| Change front panel trigger level setting for Channels A and B to +5.00 V | | | |
| 5 | Channel A Trigger Level | +5.00 V ± 100 mV | Pin 7 of U9 |
| 6 | Channel B Trigger Level | +5.00 V ± 100 mV | Pin 7 of U5 |

Table 7-6. Signal Conditioning Checks

| Step | Tested Circuit | Required Condition | Remarks | |
|------|-----------------------------|--------------------|---|------------------|
| 1 | | Turn power on | The following tests are performed on U2 | |
| | Input conditioning signals: | | <u>Channel A</u> | <u>Channel B</u> |
| 2 | DC | +0.5 V dc | Pin 14 | Pin 11 |
| 3 | AC | +5 V dc | Pin 14 | Pin 11 |
| 4 | Filter On | +5 V dc | Pin 15 | Pin 13 |
| 5 | Filter off | +0.5 V dc | Pin 15 | Pin 13 |
| 6 | 50 Ω | +0.5 V dc | Pin 12 | Pin 10 |
| 7 | 1 M Ω | +5 V dc | Pin 12 | Pin 10 |
| 8 | Negative Slope | +0 V dc | U13 Pin 11 | U13 Pin 14 |
| 7 | Positive Slope | -5.2 V dc | U13 Pin 11 | U13 Pin 14 |
| 9 | x1 | +5 V dc | K3 Pin 6 | K7 Pin 6 |
| 10 | x10 | +0.5 V dc | K3 Pin 6 | K7 Pin 6 |

Table 7-7. Input Circuits Checks

| Step | Tested Circuit | Required Condition | Remarks |
|------|---------------------------|--------------------------------------|---|
| 1 | | Turn on power Press [2nd], [DCL] | Apply 1 MHz .2 Vp-p sine to Channel A input BNC |
| 2 | Channel A Input Amplifier | 1 MHz .150 Vp-p sine | CR6 Cathode |
| 3 | Schmidt Trigger Operation | A -1.7 V to -0.8 V 1 MHz square wave | Pin 1 on U12 |
| | | Select FREQ B function | Apply 1 MHz .2 Vp-p sine to Channel B input BNC |
| 4 | Channel B Input Amplifier | 1 MHz .150 Vp-p sine | CR14 Cathode |
| 5 | Schmidt Trigger Operation | B -1.7 V to -0.8 V 1 MHz square wave | Pin 16 on U12 |

Table 7-8. Function Control Circuit Checks

| FUNCTION | CONTROL LINE (1) | U19 | U26 | U26 | U18, U19 | U25 | U25 | U25 | U25 | U21 | U21 | U21 | U21 | U20 | U28 | U28 | U28 | U20 | U20 |
|----------|------------------|-------|------|-------|-------------|------|-------|------|-------|-------|-------|------|------|------|------|------|-------|-------|-------|
| | | PIN12 | PIN5 | PIN11 | PIN9 | PIN5 | PIN12 | PIN6 | PIN11 | PIN10 | PIN12 | PIN5 | PIN7 | PIN7 | PIN5 | PIN7 | PIN10 | PIN12 | PIN10 |
| FREQ A | (2) REC | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| | CONV | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| FREQ B | (2) REC | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| | CONV | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| FREQ C | REC | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| V PEAK | A | ∅ | ∅ | 1 | 1 | 1 | ∅ | ∅ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ∅ | 1 | 1 |
| PER A | SINGLE | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| | AVG | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| PLS A | SINGLE | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| | AVG | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| TI A→B | SINGLE | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| | AVG | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| TOT B | INF | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| | BY A | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| | BY A→A | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| FA/FB | | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| ∅ A→B* | (3) FA REC | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| | TI A→B | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| FC/FB | | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |

NOTES: (1) 0 DENOTES -5.2V, 1 DENOTES 0V, ∅ DENOTES DONT CARE.
 (2) FOR FREQ A AND B MEASUREMENTS THE LOGIC LEVELS OF THE CONTROL LINES CHANGE BETWEEN REC AND CONV DURING MEASUREMENT CYCLE AUTOMATICALLY.
 (3) FOR ∅ A→B* THE FIRST MEASUREMENT IS FA REC AND THE SECOND MEASUREMENT IS TI A→B AVG.

Table 7-9. Measurement Logic Section Circuits Checks

| Step | Tested Circuit | Required Condition | Remarks |
|--|-----------------------|---|--|
| 1 | | Turn on power Press [2nd], [DCL]. | Apply 1MHz 1V p-p sine to Channel A input BNC. |
| 2 | Signal Selector #1 | -1.7 V to -0.7 V 1 MHz square wave | Pin 3 of U25 |
| 3 | Synchronized Clock #1 | -1.7 V to -0.7 V 1 MHz bursts. Duration of burst is approx 1s | Pin 15 of U26 |
| The following are variable TTL/ECL level signals with about 1 s burst duration - square waves. | | | |
| <u>Square wave period</u> | | | |
| 4 | N1 Divider Chain | 2 μ s | U30b Pin 14 (ECL) |
| | | 4 μ s | U31 Pin 12 (TTL) |
| | | 8 μ s | U23 Pin 5 (TTL) |
| | | 16 μ s | U46 Pin 11 (TTL) |
| | | 32 μ s | U46 Pin 10 (TTL) |
| | | 64 μ s | U46 Pin 9 (TTL) |
| | | 128 μ s | U46 Pin 8 (TTL) |
| 5 | Signal Identifier | TTL low level during measurement cycle. | U31 Pin 4 |
| 6 | Gate Identifier | TTL low level when gate is open. | U31 Pin 13 |
| For the following check use a sampling oscilloscope with a 1:10 probe | | | |
| 7 | Synchronized Clock #2 | -1.7 to -0.7 V 500 MHz bursts. Duration of burst is approx 1 s. | Pin 15 of U28 |
| The following are variable signals with about 1 s burst duration - square waves. | | | |
| <u>Square wave period</u> | | | |
| 8 | N2 Divider Chain | ECL 4 ns | U29 Pin 3 |
| | | ECL 8 ns | U30 Pin 3 |
| | | ECL 16 ns | U27 Pin 14 |
| | | TTL 32 ns | U23 Pin 9 |
| | | TTL 64 ns | U46 Pin 3 |
| | | TTL 128 ns | U46 Pin 4 |
| | | TTL 256 ns | U46 Pin 5 |
| | | TTL 512 ns | U46 Pin 6 |
| Change panel setting to PER A. | | | Apply 1 KHz 1 Vp-p square wave to Channel A input BNC. |
| 9 | Start/Stop Signal | -1.7 V to -0.7 V 1 KHz square wave | U17 Pin 9 |
| 10 | Time Interval | -1.7 V to -0.7 V 1 ms negative going pulse for each cycle | U18 Pin 15 |
| 11 | Gate Identifier | TTL low level for 1 ms, TTL high for about 300 ms after gate closure | U31 Pin 13 |

8

Parts List

8-1. General

This section contains information for ordering replacement parts. The replacement parts are available from the vendors listed or from Keithley Instruments. Mechanical parts are shown separately on Figure 8-1.

8-2. Ordering Information

When ordering replacement parts, always include the following information:

- a) Instrument Model number.
- b) Instrument Serial number.
- c) Keithley part number.
- d) Part description.
- e) Circuit designation (where applicable).

Keithley will do its best to improve the instrument and make changes in style of components and replacement parts. Replacement parts may differ in appearance from those found in your instrument but are always equal or superior in performance.

8-3. Parts Description

In the following Parts List Tables, unless otherwise noted, resistors power rating is 1/4W, resistance is given in Ω , and capacitance is given in μF .

Some parts in the following parts lists are marked with an asterisk (*). These parts belong to the standard time base circuit. These parts will not be assembled when option 2.4G is installed.

Matched or selected components may only be bought from the factory. Selection guides for such components are not given anywhere in this manual.

Table 8-1. Model 776 PARTS LIST - MAIN BOARD ASSEMBLY

| DWG PART | | | DWG PART | | |
|----------|------------|--------------------------------------|----------|------------|----------------------------------|
| REF | NUMBER | DESCRIPTION | REF | NUMBER | DESCRIPTION |
| C1 | 1521-04730 | CAP POL.047 μ F 20% 250V MKT1818 | C60 | 1540-01060 | CAP TANT 10 μ F 25V |
| C2 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C61 | NOT USED | |
| C3 | 1550-01800 | CAP VAR 5-18PF DV11PS18A | C65 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C5 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C66 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C6 | 1510-03R00 | CAP MICA 3 pF 10% 500V | C67 | 1560-01040 | CAP CHIP .1 μ F 50V |
| C7 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C68 | 1560-01040 | CAP CHIP .1 μ F 50V |
| C8 | 1510-06200 | CAP MICA 62 pF 10% 500V | C69* | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C9 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C70 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C10 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C71 | 1500-04R70 | CAP CER 4.7 pF 20% 50V |
| C11 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C72 | 1500-01010 | CAP CER 100 pF 20% 50V |
| C14 | 1500-01030 | CAP CER 10 nF 20% 50V | C73 | 1560-01040 | CAP CHIP .1 μ F 50V |
| C15 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C74 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C16 | 1510-06200 | CAP MICA 62 pF 10% 500V | C75 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C17 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C76 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C18 | 1500-01010 | CAP CER 100 pF 20% 50V | C77 | 1560-01040 | CAP CHIP .1 μ F 50V |
| C19 | 1500-01010 | CAP CER 100 pF 20% 50V | C78 | 1560-01040 | CAP CHIP .1 μ F 50V |
| C20 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C79 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C21 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C80 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C22 | 1560-01040 | CAP CHIP .1 μ F 50V | C81 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C23 | 1540-01060 | CAP TANT 10 μ F 25V | C82 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C24 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C83 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C25 | 1500-01010 | CAP CER 100 pF 20% 50V | C84 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C26 | 1521-04730 | CAP POL.047 μ F 20% 250V MKT1818 | C85 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C27 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C86 | 1500-01030 | CAP CER 10 nF 20% 50V |
| C28 | 1550-01800 | CAP VAR 5-18 pF DV11PS18A | C87 | 1532-01070 | CAP ELEC 100 μ F 16V |
| C29 | NOT USED | | C88 | 1510-02200 | CAP MICA 22 pF 20% 50V |
| C30 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C89 | 1533-01080 | CAP ELECTR 1000 μ F/25V |
| C31 | 1510-03R00 | CAP MICA 3 pF 10% 500V | C90 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C32 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C91 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C33 | 1510-06200 | CAP MICA 62 pF 10% 500V | C92 | 1540-01050 | CAP TANT 1 μ F/25V |
| C34 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C93 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C35 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C94 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C36 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C95 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C37 | NOT USED | | C96 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C38 | NOT USED | | C97 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C39 | 1500-01030 | CAP CER 10 nF 20% 50V | C98 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C40 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C99 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C41 | 1510-06200 | CAP MICA 62 pF 10% 500V | C100 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C42 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C101 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C43 | 1500-01010 | CAP CER 100 pF 20% 50V | C102 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C44 | 1500-01010 | CAP CER 100 pF 20% 50V | C103 | 1540-01060 | CAP TANT 10 μ F 25V |
| C45 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C104 | 1540-01060 | CAP TANT 10 μ F 25V |
| C46 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C105 | 1533-01080 | CAP ELECTR 1000 μ F/25V |
| C47 | 1540-01060 | CAP TANT 10 μ F 25V | C106 | 1533-01080 | CAP ELECTR 1000 μ F/25V |
| C48 | 1560-01040 | CAP CHIP .1 μ F 50V | C107 | 1533-01070 | CAP ELECTR 100 μ F/25V |
| C49 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C108 | 1533-01070 | CAP ELECTR 100 μ F/25V |
| C50 | 1500-01010 | CAP CER 100 pF 20% 50V | C109 | 1532-01090 | CAP ELEC 10.000 μ F 16V |
| C51 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C110 | 1532-01090 | CAP ELEC 10.000 μ F 16V |
| C52 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C111 | 1532-04770 | CAP ELECTR 470 μ F/16V |
| C53 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C112 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C54 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C113 | 1500-02210 | CAP CER 220 pF 20% 50V |
| C55 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C114 | 1500-02210 | CAP CER 220 pF 20% 50V |
| C56 | 1540-01060 | CAP TANT 10 μ F 25V | C115 | 1500-01030 | CAP CER 0.01 μ F-20%+80% 50V |
| C57 | 1540-01060 | CAP TANT 10 μ F 25V | C116 | 1532-04770 | CAP ELECTR 470 μ F/16V |
| C58 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | C120* | 1500-01040 | CAP CER .1 μ F-20%+80% 50V |
| C59 | 1540-01060 | CAP TANT 10 μ F 25V | | | |

Table 8-1. Model 776 PARTS LIST - MAIN BOARD ASSEMBLY (CONTINUED)

| DWG PART REF NUMBER | DESCRIPTION | DWG PART REF NUMBER | DESCRIPTION |
|------------------------|---|------------------------|---|
| C121* | 1540-01060 CAP TANT 10 μ F 25V | K2 | 0900-01100 RELAY DUAL INLINE 1A 5V-6007 |
| C122* | 1540-01060 CAP TANT 10 μ F 25V | K3 | 0900-01000 RELAY DUAL INLINE 1C 5V-6007 |
| Q123* | 1500-01040 CAP CER .1 μ F-20%+80% 50V | K4 | 0900-01100 RELAY DUAL INLINE 1A 5V-6007 |
| C124* | 1550-01800 CAP VAR 5-18 pF DV11PS18A | K5 | 0900-01100 RELAY DUAL INLINE 1A 5V-6007 |
| C125 | SELECTED VALUE | K6 | 0900-01100 RELAY DUAL INLINE 1A 5V-6007 |
| C126* | 1550-01000 CAP VAR 2-10 pF JACKS 5750 | K7 | 0900-01000 RELAY DUAL INLINE 1C 5V-6007 |
| C127 | 1500-01040 CAP CER .1 μ F-20%+80% 50V | K8 | 0900-01100 RELAY DUAL INLINE 1A 5V-6007 |
| C128 | 1500-01040 CAP CER .1 μ F-20%+80% 50V | LK1A | 3000-40610 (*) CON JUMPER X2 |
| C129 | NOT USED | LK1B | 3000-40610 (*) CON JUMPER X2 |
| C130 | 1560-01040 CAP CHIP .1 μ F 50V | Q1 | 0400-00300 TSTR NPN 2N4124 |
| C131 | 1560-01040 CAP CHIP .1 μ F 50V | Q2 | 0400-40700 TSTR 2N4416A(SELECTED) |
| C133 | 1500-01040 CAP CER .1 μ F-20%+80% 50V | Q3 | 0400-40600 TSTR MRF 904 |
| C134 | 1560-01040 CAP CHIP .1 μ F 50V | Q4 | 0400-00700 TSTR NPN 2N5179 |
| CR1 | 0300-00400 DIODE SI 1N4151 | Q5 | 0400-00700 TSTR NPN 2N5179 |
| CR2 | 0301-10000 DIODE PIC AMP PAD 50 | Q6 | 0400-00300 TSTR NPN 2N4124 |
| CR3 | 0300-20400 DIODE ZENER 1N758A 10V | Q7 | 0400-40700 TSTR 2N4416A (SELECTED) |
| CR4 | 0300-20010 DIODE ZENER 1N751A 5.1V | Q8 | 0400-40600 TSTR MRF 904 |
| CR5 | 0300-10300 DIODE 2835- MATCHED WITH CR6 | Q9 | 0400-00700 TSTR NPN 2N5179 |
| CR6 | 0300-10300 DIODE 2835- MATCHED WITH CR5 | Q10 | 0400-00700 TSTR NPN 2N5179 |
| CR7 | 0300-10300 DIODE 2835- MATCHED WITH CR8 | Q11 | 0400-01340 TSTR 2N3906A |
| CR8 | 0300-10300 DIODE 2835- MATCHED WITH CR7 | Q12 | 0400-01340 TSTR 2N3906A |
| CR9 | 0300-00400 DIODE SI 1N4151 | Q13 | 0400-01340 TSTR 2N3906A |
| CR10 | 0301-10000 DIODE PIC AMP PAD 50 | Q14 | 0400-01200 TSTR 2N3904A |
| CR11 | 0300-20400 DIODE ZENER 1N758A 10V | Q15 | 0400-01200 TSTR 2N3904A |
| CR12 | 0300-20010 DIODE ZENER 1N751A 5.1V | Q16 | NOT USED |
| CR13 | 0300-10300 DIODE 2835- MATCHED WITH CR14 | Q17 | NOT USED |
| CR14 | 0300-10300 DIODE 2835 - MATCHED WITH CR13 | Q18 | NOT USED |
| CR15 | 0300-10300 DIODE 2835- MATCHED WITH CR16 | Q19 | NOT USED |
| CR16 | 0300-10300 DIODE 2835- MATCHED WITH CR15 | Q20 | 0400-01810 TSTR 2N4401 |
| CR17 | 0300-21100 DIODE REF 1N825A | Q21 | 0400-00300 TSTR NPN 2N4124 |
| CR18 | NOT USED | Q22 | NOT USED |
| CR19 | NOT USED | Q23 | 0400-00300 TSTR NPN 2N4124 |
| CR20 | NOT USED | Q24 | 0400-00300 TSTR NPN 2N4124 |
| CR21 | NOT USED | Q25 | NOT USED |
| CR22 | NOT USED | Q26 | NOT USED |
| CR23 | 0300-00400 DIODE SI 1N4151 | Q27 | NOT USED |
| CR24 | NOT USED | Q28 | NOT USED |
| CR25 | 0300-50100 DIODE BRIDGE WS005 | Q29 | NOT USED |
| CR26 | 0300-30000 DIODE RECT 1N4003 | Q30 | 0400-40100 TSTR 2N2219A |
| CR27 | 0300-30000 DIODE RECT 1N4003 | Q31 | 0400-40300 TSTR MJE 2955A |
| CR28 | 0300-50200 DIODE BRIDGE KBL-005 5A GI | Q32 | 0400-01500 TSTR PNP 2N2905A |
| CR29 | 0300-90300 DIODESA-5A | Q33 | 0400-40400 TSTR MJE 3055 |
| CR30 | 0300-90300 DIODESA-5A | Q34 | 0400-01200 TSTR 2N3904A |
| CR31 | 0300-00400 DIODE SI 1N4151 | Q35 | 0400-01200 TSTR 2N3904A |
| CR32 | 0300-00400 DIODE SI 1N4151 | R1 | 0104-1000B RES MTF 100 1% 1W |
| CR33 | NOT USED | R2 | 0104-1000B RES MTF 100 1% 1W |
| CR34 | NOT USED | R3 | 0104-9003A RES MF 900K 1% 1/2W |
| CR35* | 0300-00400 DIODE SI 1N4151 | R4 | 0104-9003A RES MF 900K 1% 1/2W |
| CR36* | 0300-00400 DIODE SI 1N4151 | R5 | 0104-10030 RES MF 100K 1% 1/4W |
| CR37 | 0300-90700 DIODE 1N5225 | R6 | 0100-01540 RES COMP 150K 5% 1/4W |
| DL1 | 0600-10000 DELAY LINE 7 ns 0402-0007-93 | R7 | 0100-03300 RES COMP 33 5% 1/4W |
| J1 | 3000-30260 CON MALE 2X10 BERG | R8 | 0100-01510 RES COMP 150 5% 1/4W |
| J2 | 3000-40120 CON 24PIN FOR SOLDER | R9 | 0100-01060 RES COMP 10M 5% 1/4W |
| J2 | 6800-50500 FLAT CABLE 24 PIN | R10 | 0100-04710 RES COMP 470 5% 1/4W |
| J2 | 3000-40300 CON GPIB 60924F MONO-6007 | R11 | 0100-01030 RES COMP 10K 5% 1/4W |
| K1 | 0900-01100 RELAY DUAL INLINE 1A 5V-6007 | R12 | 0100-03300 RES COMP 33 5% 1/4W |
| | | R13 | 0100-03910 RES COMP 390 5% 1/4W |

Table 8-1. Model 776 PARTS LIST - MAIN BOARD ASSEMBLY (CONTINUED)

| DWG PART REF NUMBER | DESCRIPTION | DWG PART REF NUMBER | DESCRIPTION | | |
|------------------------|-------------|------------------------|-------------|------------|-------------------------|
| R14 | 0100-01510 | RES COMP 150 5% 1/4W | R73 | 0104-30100 | RES MF 301 1% 1/4W |
| R15 | 0100-07520 | RES COMP 7.5K 5% 1/4W | R74 | 0104-11310 | RES MF 1.13K 1% 1/4W |
| R16 | 0100-01520 | RES COMP 1.5K 5% 1/4W | R75 | 0100-02210 | RES COMP 220 5% 1/4W |
| R17 | 0104-66530 | RES MF 665K 1% 1/4W | R76 | 0100-03310 | RES COMP 330 5% 1/4W |
| R18 | 0100-01810 | RES COMP 180 5% 1/4W | R77 | 0100-02220 | RES COMP 2.2K 5% 1/4W |
| R19 | 0100-02720 | RES COMP 2.7K 5% 1/4W | R78 | 0104-11030 | RES MTF 110K 1/4W 1% |
| R20 | 0100-03920 | RES COMP 3.9K 5% 1/4W | R79 | 0100-06210 | RES 620 1/4W 5% |
| R21 | 0104-86610 | RES MF 8.66K 1% 1/4W | R80 | 0203-02020 | RES VAR 2K 3386F-1-202 |
| R22 | 0104-10030 | RES MF 100K 1% 1/4W | R81 | 0203-02020 | RES VAR 2K 3386F-1-202 |
| R23 | 0104-28010 | RES MF 2.8K 1% 1/4W | R82 | 0203-01030 | RES VAR 10K 3386F-1-103 |
| R24 | 0104-28010 | RES MF 2.8K 1% 1/4W | R83 | 0203-01030 | RES VAR 10K 3386F-1-103 |
| R25 | 0104-10000 | RES MF 100 1% 1/4W | R84 | 0203-02020 | RES VAR 2K 3386F-1-202 |
| R26 | 0104-10020 | RES MF 10K 1% 1/4W | R85 | 0203-02020 | RES VAR 2K 3386F-1-202 |
| R27 | 0104-15020 | RES MF 15K 1% 1/4W | R87 | NOT USED | |
| R28 | 0104-10010 | RES MF 1K 1% 1/4W | R88 | NOT USED | |
| R29 | 0104-20020 | RES MF 20K 1% 1/4W | R89 | NOT USED | |
| R30 | 0104-10010 | RES MF 1K 1% 1/4W | R90 | 0100-05110 | RES COMP 510 5% 1/4W |
| R31 | 0100-03900 | RES COMP 39 5% 1/4W | R91 | 0100-01020 | RES COMP 1K 5% 1/4W |
| R32 | 0100-03300 | RES COMP 33 5% 1/4W | R92 | 0100-05110 | RES COMP 510 5% 1/4W |
| R33 | 0104-4R020 | RES MF 4.02 1% 1/4W | R93 | 0100-05110 | RES COMP 510 5% 1/4W |
| R34 | 0104-30100 | RES MF 301 1% 1/4W | R94 | 0100-02410 | RES COMP 240 5% 1/4W |
| R35 | 0104-11310 | RES MF 1.13K 1% 1/4W | R95 | 0100-05110 | RES COMP 510 5% 1/4W |
| R36 | 0100-02210 | RES COMP 220 5% 1/4W | R96 | 0100-03310 | RES COMP 330 5% 1/4W |
| R37 | 0100-03310 | RES COMP 330 5% 1/4W | R97 | 0100-02720 | RES COMP 2.7K 5% 1/4W |
| R38 | 0100-02220 | RES COMP 2.2K 5% 1/4W | R98 | 0100-02220 | RES COMP 2.2K 5% 1/4W |
| R39 | 0104-11030 | RES MTF 110K 1/4W 1% | R99 | 0100-03310 | RES COMP 330 5% 1/4W |
| R40 | 0104-1000B | RES MTF 100 1% 1W | R100 | 0100-05110 | RES COMP 510 5% 1/4W |
| R41 | 0104-1000B | RES MTF 100 1% 1W | R101 | 0100-05110 | RES COMP 510 5% 1/4W |
| R42 | 0104-9003A | RES MF 900K 1% 1/2W | R102 | 0100-06800 | RES COMP 68 5% 1/4W |
| R43 | 0104-9003A | RES MF 900K 1% 1/2W | R103 | 0100-02010 | RES COMP 200 5% 1/4W |
| R44 | 0104-10030 | RES MF 100K 1% 1/4W | R104 | 0100-06800 | RES COMP 68 5% 1/4W |
| R45 | 0100-01540 | RES COMP 150K 5% 1/4W | R105 | 0100-05110 | RES COMP 510 5% 1/4W |
| R46 | 0100-03300 | RES COMP 33 5% 1/4W | R106 | 0100-01220 | RES COMP 1.2K 5% 1/4W |
| R47 | 0100-01510 | RES COMP 150 5% 1/4W | R107 | 0100-01020 | RES COMP 1K 5% 1/4W |
| R48 | 0100-01060 | RES COMP 10M 5% 1/4W | R108 | 0100-05110 | RES COMP 510 5% 1/4W |
| R49 | 0100-04710 | RES COMP 470 5% 1/4W | R109 | 0100-05110 | RES COMP 510 5% 1/4W |
| R50 | 0100-01030 | RES COMP 10K 5% 1/4W | R110 | 0100-05110 | RES COMP 510 5% 1/4W |
| R51 | 0100-03300 | RES COMP 33 5% 1/4W | R111 | 0100-03310 | RES COMP 330 5% 1/4W |
| R52 | 0100-03910 | RES COMP 390 5% 1/4W | R112 | 0100-02410 | RES COMP 240 5% 1/4W |
| R53 | 0100-01510 | RES COMP 150 5% 1/4W | R113 | 0100-01010 | RES COMP 100 5% 1/4W |
| R54 | 0100-07520 | RES COMP 7.5K 5% 1/4W | R114 | 0100-05110 | RES COMP 510 5% 1/4W |
| R55 | 0100-01520 | RES COMP 1.5K 5% 1/4W | R115 | 0100-03310 | RES COMP 330 5% 1/4W |
| R56 | 0104-66530 | RES MF 665K 1% 1/4W | R116 | 0100-07520 | RES COMP 7.5K 5% 1/4W |
| R57 | 0100-01810 | RES COMP 180 5% 1/4W | R117 | 0100-03310 | RES COMP 330 5% 1/4W |
| R58 | 0100-0270 | RES COMP 2.7K 5% 1/4W | R118 | 0100-05120 | RES COMP 5.1K 5% 1/4W |
| R59 | 0100-03920 | RES COMP 3.9K 5% 1/4W | R119 | 0100-05110 | RES COMP 510 5% 1/4W |
| R60 | 0104-86610 | RES MF 8.66K 1% 1/4W | R120 | 0100-05110 | RES COMP 510 5% 1/4W |
| R61 | 0104-10030 | RES MF 100K 1% 1/4W | R121 | 0100-02720 | RES COMP 2.7K 5% 1/4W |
| R62 | 0104-28010 | RES MF 2.8K 1% 1/4W | R122 | 0100-05110 | RES COMP 510 5% 1/4W |
| R63 | 0104-28010 | RES MF 2.8K 1% 1/4W | R123 | 0100-02220 | RES COMP 2.2K 5% 1/4W |
| R64 | 0104-10000 | RES MF 100 1% 1/4W | R124 | 0100-05110 | RES COMP 510 5% 1/4W |
| R65 | 0104-10020 | RES MF 10K 1% 1/4W | R125 | 0100-05110 | RES COMP 510 5% 1/4W |
| R66 | 0104-15020 | RES MF 15K 1% 1/4W | R126 | 0100-05110 | RES COMP 510 5% 1/4W |
| R67 | 0104-20020 | RES MF 20K 1% 1/4W | R127 | 0100-05110 | RES COMP 510 5% 1/4W |
| R68 | 0104-10010 | RES MF 1K 1% 1/4W | R128 | 0100-05110 | RES COMP 510 5% 1/4W |
| R69 | 0104-10010 | RES MF 1K 1% 1/4W | R129 | 0100-05110 | RES COMP 510 5% 1/4W |
| R70 | 0100-03900 | RES COMP 39 5% 1/4W | R130 | 0100-05110 | RES COMP 510 5% 1/4W |
| R71 | 0100-03300 | RES COMP 33 5% 1/4W | R131 | 0100-05110 | RES COMP 510 5% 1/4W |
| R72 | 0104-4R020 | RES MF 4.02 1% 1/4W | R132 | 0100-05110 | RES COMP 510 5% 1/4W |

Table 8-1. Model 776 PARTS LIST - MAIN BOARD ASSEMBLY (CONTINUED)

| DWG PART REF NUMBER | DESCRIPTION | DWG PART REF NUMBER | DESCRIPTION |
|------------------------|------------------------------------|------------------------|---|
| R133 | 0100-05110 RES COMP 510 5% 1/4W | R201 | 0100-02R70 RES COMP 2.7 5% 1/4W |
| R134 | 0100-07520 RES COMP 7.5K 5% 1/4W | R202 | 0100-02R70 RES COMP 2.7 5% 1/4W |
| R135 | 0100-05110 RES COMP 510 5% 1/4W | R203 | 0102-03300 RES COMP 33 5% 1/8W BB2205 |
| R136 | 0100-07520 RES COMP 7.5K 5% 1/4W | | |
| R137 | 0100-01030 RES COMP 10K 5% 1/4W | RN1 | 0109-01500 RES NET MDP-16-03-150G 15/16 |
| R138 | 0100-01020 RES COMP 1K 5% 1/4W | RN2 | 0111-0103B RES NET 10K/10 MSP-10A-01-103G |
| R139 | 0100-02720 RES COMP 2.7K 5% 1/4W | RN3 | 0110-0103C CSC 05A-01-103Y 4X10K/5 PIN |
| R140 | 0100-08210 RES COMP 820 5% 1/4W | RN4 | 0110-0511B CSC 05A-01-511Y 4X510/5 PIN |
| R141 | 0100-08210 RES COMP 820 5% 1/4W | SP1 | 0900-01900 BEEPER AT-02 |
| R142 | 0100-01030 RES COMP 10K 5% 1/4W | SW1 | 2000-10600 SWON-OFF FOR 775 |
| R143 | 0100-01510 RES COMP 150 5% 1/4W | | |
| R144 | 0100-08210 RES COMP 820 5% 1/4W | U1 | 0540-01100 8 BIT SHIFT REGISTOR CD4094B |
| R145 | 0100-02020 RES COMP 2K 5% 1/4W | U2 | 0500-11600 BUFFER 9668 (L204) |
| R146 | 0100-03310 RES COMP 330 5% 1/4W | U3 | 0540-01100 8 BIT SHIFT REGISTOR CD4094B |
| R147 | 0100-01030 RES COMP 10K 5% 1/4W | U4 | 0560-00700 D-A 10 BIT CONVERTOR AD7533JN |
| R148 | NOT USED | U5 | 0500-56500 DUAL OP AMP LM1458N |
| R149 | NOT USED | U6 | 0540-01100 8 BIT SHIFT REGISTOR CD4094B |
| R150 | 0100-5110 RES COMP 510 5% 1/4W | U7 | 0540-01100 8 BIT SHIFT REGISTOR CD4094B |
| R151 | 0100-01020 RES COMP 1K 5% 1/4W | U8 | 0560-00700 D-A 10 BIT CONVERTOR AD7533JN |
| R152 | NOT USED | U9 | 0500-56500 DUAL OP AMP LM1458N |
| R153 | NOT USED | U10 | 0500-53400 SUPER GAIN OP AMP LN308A |
| R154 | 0100-01020 RES COMP 1K 5% 1/4W | U11 | 0500-53400 SUPER GAIN OP AMP LN308A |
| R155 | 0100-01020 RES COMP 1K 5% 1/4W | U12 | 0500-60500 AD 9687 BD |
| R156 | 0100-01030 RES COMP 10K 5% 1/4W | U13 | 0540-01100 8 BIT SHIFT REGISTOR CD4094B |
| R157 | 0100-01020 RES COMP 1K 5% 1/4W | U14 | 0540-01100 8 BIT SHIFT REGISTOR CD4094B |
| R158 | 0100-03310 RES COMP 330 5% 1/4W | U15 | 0540-01100 8 BIT SHIFT REGISTOR CD4094B |
| R159 | 0100-01020 RES COMP 1K 5% 1/4W | U16 | 0540-00630 HEX INVERTOR CD 4049B |
| R160 | 0100-03310 RES COMP 330 5% 1/4W | U17 | 0500-45300 ECL FLIP-FLOP MC10H131P |
| R166 | 0100-03320 RES COMP 3.3K 5% 1/4W | U18 | 0500-40910 ECLOR/NOR GATE MC10105P |
| R167 | 0100-01030 RES COMP 10K 5% 1/4W | U19 | 0500-40910 ECLOR/NOR GATE MC10105P |
| R168 | 0203-01010 RES VAR 100 3386F-1-101 | U20 | 0500-40900 ECL NOR MC10102P |
| R169 | 0104-12100 RES MF 121 1% 1/4W | U21 | 0500-45000 ECL NOR MC10H102P |
| R170 | 0104-10010 RES MF 1k 1% 1/4W | U22 | 0500-45300 ECL FLIP-FLOP MC10H131P |
| R171 | NOT USED | U23 | 0500-12600 D-FLIP-FLOP 74F74 |
| R172 | 0100-01010 RES COMP 100 5% 1/4W | U24 | 0500-45400 ECL XOR/XNOR MC10H107P |
| R173 | 0100-01520 RES COMP 1.5K 5% 1/4W | U25 | 0500-40900 ECL NOR MC10102P |
| R174 | 0100-02730 RES COMP 27K 5% 1/4W | U26 | 0500-40900 ECL NOR MC10102P |
| R175 | NOT USED | U27 | 0500-41200 ECL FLIP-FLOP MC1013P1 |
| R176 | NOT USED | U28 | 0500-45000 ECL NOR MC10H102P |
| R177 | NOT USED | U29 | 0500-45300 ECL FLIP-FLOP MC10H131P |
| R178 | NOT USED | U30 | 0500-45300 ECL FLIP-FLOP MC10H131P |
| R180 | 0100-01020 RES COMP 1K 5% 1/4W | U31 | 0500-40920 ECL TO TTL-TTL TRANS MC10125P |
| R181 | 0100-01210 RES COMP 120 5% 1/4W | U35 | 0500-11600 BUFFER 9668 (L204) |
| R182 | 0100-04720 RES COMP 4.7K 5% 1/4W | U36 | 0500-20700 KEYBOARD/DISPL.INT. P8279 |
| R183 | 0104-57610 RES MF 5.76K 1% 1/4W | U37 | 0540-00630 HEX INVERTOR CD4049B |
| R184 | 0100-01020 RES COMP 1K 5% 1/4W | U38 | 0510-02700 LOW POWER SCHOTTKY 74LS138 |
| R185 | 0100-01210 RES COMP 120 5% 1/4W | U39 | 0500-21420 SINGLE CHIP MICROCOMP P8031 |
| R186 | 0100-01020 RES COMP 1K 5% 1/4W | U40 | 0510-03650 LOW POWER SCHOTTKY 74LS373 |
| R187 | 0104-66510 RES MF 6.65K 1% 1/4W | U41 | 0520-07000 H-MOS-DEVIDER SN74HC4040 |
| R188 | 0104-80410 RES MF 6.04K 1% 1/4W | U42 | 0500-21230 EPROM 27256 |
| R189 | 0104-10020 RES MF 10K 1% 1/4W | U43 | 0500-11160 MK48ZO2B-20 MOSTEK |
| R190 | 0203-01020 RES VAR 1K 3386F-1-102 | U44 | 0550-00100 32BIT BINARY COUNTER LS7061 |
| R191 | 0100-02210 RES COMP 220 5% 1/4W | U45 | 0550-00100 32BIT BINARY COUNTER LS7061 |
| R192* | 0100-02210 RES COMP 220 5% 1/4W | U46 | 0510-03930 IOW POWER SHOTKEY 74LS393N |
| R193* | 0100-01820 RES COMP 1.8K 5% 1/4W | U47 | 0500-21300 G.P.I.B P8291A |
| R194* | 0100-05610 RES COMP 560 5% 1/4W | U48 | 0500-21510 BUFFER FOR GPIB DS75160N |
| R195 | 0100-01020 RES COMP 1K 5% 1/4W | U49 | 0500-21520 BUFFER FOR GPIB DS75161N |
| R196 | 0100-01020 RES COMP 1K 5% 1/4W | U50 | 0500-52200 VOLTAGE REGULATOR MC7812CP |
| R200 | 0100-01520 RES COMP 1.5K 5% 1/4W | U51 | 0500-52300 VOLTAGE REGULATOR MC7912CP |

Parts List

Table 8-1. Model 776 PARTS LIST - MAIN BOARD ASSEMBLY (CONTINUED)

| DWG PART | | | DWG PART | | |
|------------|------------|----------------------------|------------|------------|-------------------------------|
| REF NUMBER | | DESCRIPTION | REF NUMBER | | DESCRIPTION |
| U52 | 0500-56500 | DUAL OP AMP LM1458N | U57(*) | 0800-50000 | OSCILLATOR 10MHZ 5PPM |
| U55(*) | 0500-52000 | VOLTAGE REGULATOR MC7805CP | U58(*) | 0510-00110 | LOW POWER SCHTTKY 74LS02 |
| U56(*) | 0510-02600 | LOW POWER SCHOTTKY 74LS132 | U59(*) | 0560-00900 | DIGITAL TO ANALOG CONV AD6675 |
| | | | Y1 | 0800-30000 | CRYSTAL 16MHZ C.T.S |

Table 8-2. Model 776 PARTS LIST - 500 MHz MULTIPLIER ASSEMBLY

| DWG PART | | | DWG PART | | |
|------------|------------------|--------------------------------|------------|----------------|--------------------------------|
| REF NUMBER | | DESCRIPTION | REF NUMBER | | DESCRIPTION |
| C1 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | J1 | 3000-30520 | CON FEMALE 2X8-8200 |
| C2 | 1500-01030 | CAP CER 10 nF 20% 50V | L1 | 0600-03330 | COIL 3.3 μ H 1537-24 |
| C3 | 1560-01040 | CAP CHIP .1 μ F 50V | L3 | 4200-00000 | 2X FERR BEAD CERAMAG24 57-1355 |
| C4 | 1540-01060 | CAP TANT 10 μ F 25V | LK1 | 3000-30200 | 3 X CON BERG 75160-315 (1 PIN) |
| C5 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | LK2 | 3000-30200 | 3 X CON BERG 75160-315 (1 PIN) |
| C6 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | LK3 | 3000-30200 | 3 X CON BERG 75160-315 (1 PIN) |
| C7 | 1540-01060 | CAP TANT 10 μ F 25V | R1 | 0100-01010 | RES COMP 100 5% 1/4W |
| C8 | 1500-01040 | CAP CER .1 μ F-20%+80% 50V | R2 | 0100-01820 | RES COMP 1.8K 5% 1/4W |
| C9 | 1500-01010 | CAP CER 100 pF 20% 50V | R3 | 0100-05610 | RES COMP 560 5% 1/4W |
| C10 | 1560-01040 | CAP CHIP .1 μ F 50V | R4 | 0100-05610 | RES COMP 560 5% 1/4W |
| C11 | 1500-01R00 | CAP CER 1 pF | R5 | 0100-05610 | RES COMP 560 5% 1/4W |
| C12 | 1560-01040 | CAP CHIP .1 μ F 50V | R6 | 0100-01030 | RES COMP 10K 5% 1/4W |
| C13 | 1560-01040 | CAP CHIP .1 μ F 50V | R7 | 0100-04720 | RES COMP 4.7K 5% 1/4W |
| C14 | 1560-01040 | CAP CHIP .1 μ F 50V | R8 | 0100-01220 | RES COMP 1.2K 5% 1/4W |
| C15 | 1540-01060 | CAP TANT 10 μ F 25V | R9 | 0100-02040 | RES COMP 200K 5% 1/4W |
| C16 | 1540-01060 | CAP TANT 10 μ F 25V | R10 | 0100-01020 | RES COMP 1K 5% 1/4W |
| C17 | 1500-02030 | CAP CER 20 nF 20% 50V | R11 | SELECTED VALUE | |
| C18 | 1500-04720 | CAP SCR 4.7 nF 20% 50V | R12 | 0100-01020 | RES COMP 1K 5% 1/4W |
| C20 | 1540-01060 | CAP TANT 10 μ F 25V | R13 | 0100-03330 | RES COMP 33K 5% 1/4W |
| C21 | 1560-01040 | CAP CHIP .1 μ F 50V | R14 | 0100-01030 | RES COMP 10K 5% 1/4W |
| C22 | SELECTED VALUE | | R15 | 0100-02220 | RES COMP 2.2K 5% 1/4W |
| C23 | 1560-02200 | CAP CHIP 22 pF 50V | R16 | 0100-02220 | RES COMP 2.2K 5% 1/4W |
| C24 | 1560-02200 | CAP CHIP 22 pF 50V | R17 | 0101-05610 | RES COMP 560 5% 1/2W |
| C25 | 1560-02200 | CAP CHIP 22 pF 50V | R18 | 0113-01000 | RES CHIP 10 5% |
| C26 | * SELECTED VALUE | | R19 | 0101-02010 | RES COMP 200 5% 1/2W |
| C27 | 1540-01060 | CAP TANT 10 μ F 25V | U1 | 0510-02600 | LOW POWER SCHOTTKY 74LS132 |
| C28 | 1533-01070 | CAP ELECTR 100 μ F/25V | U2 | 0540-01600 | PHASE DIDECTOR MC4044 16 PIN |
| CR1 | 0300-00400 | DIODE SI 1N4151 | U3 | 0500-57400 | PRESALER DIVIDER:4 CA3199E |
| CR2 | 0300-00400 | DIODE SI 1N4151 | U4 | 0500-64300 | SP8629 |
| CR3 | 0300-20700 | DIODE ZENER 1N756A 8.2 V | U5 | 0510-02400 | LOW POWER SCHOTTKY 74LS93 |
| CR4 | NOT USED | | U6 | 0500-57200 | BI-MOS OP-AMP CA3140E |
| CR5 | 0301-00200 | DIODE 1N5445A | U7 | 0500-56310 | OP AMP LM741C |
| | | | U8 | 0500-90900 | ANALOG SW DG211CJ |
| J1 | 3000-30250 | CON MALE 2X8 | U9 | 0400-20500 | MAR 3 |
| J2 | 3000-16000 | CON RF MALE JACKSON | U10 | 0800-90000 | TCXO 10MHZ 1PPM - OPTION 51 |
| | | | U11 | 0500-52000 | VOLTAGE REGULATOR MC7805CP |

Table 8-3. Model 776 PARTS LIST - FRONT PANEL ASSEMBLY

| DWG PART REF NUMBER | DESCRIPTION | DWG PART REF NUMBER | DESCRIPTION | | |
|------------------------|-------------|--------------------------------|-------------|------------|----------------------------|
| CR1 | 0300-00400 | DIODE SI 1N4151 | R1 | 0100-02210 | RES COMP 220 5% 1/4W |
| CR2 | 0300-00400 | DIODE SI 1N4151 | R2 | 0100-02210 | RES COMP 220 5% 1/4W |
| CR3 | 0300-00400 | DIODE SI 1N4151 | R3 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS1 | | | R4 | 0100-02210 | RES COMP 220 5% 1/4W |
| TO | | | R5 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS9 | 1200-10800 | 7 SEGMENT LED DISPLAY MDSP5501 | R6 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS10 | 1200-10100 | LED HDSP 7507 +/- 16020 | R7 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS11 | 1200-10200 | LED HDSP 7501 7 SEG 776 | R8 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS12 | | | R9 | 0100-02210 | RES COMP 220 5% 1/4W |
| TO | | | R10 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS18 | 1000-00300 | MINI 3MM LED RED 5082-4480 | R11 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS19 | | | R12 | 0100-02210 | RES COMP 220 5% 1/4W |
| TO | | | R13 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS41 | 1000-00700 | LED RED MV 57124-18 G.I | R14 | 0100-02210 | RES COMP 220 5% 1/4W |
| DS42 | 1200-10800 | 7 SEGMENT LED DISPLAY MDSP5501 | R15 | 0100-02700 | RES COMP 27 5% 1/4W |
| J4 | 3000-40150 | CON 20 PIN MALE FOR SOLDER | R16 | 0100-02200 | RES COMP 22 5% 1/4W |
| Q1 | | | R99 | 0100-02210 | RES COMP 220 5% 1/4W |
| TO | | | S1 | | |
| Q14 | 0400-01800 | TSTR PNP 2N4403 | TO | | |
| | | | S16 | 2000-61600 | SWC PUSH MOMENTARY |
| | | | U1 | 0510-02700 | LOW POWER SCHOTTKY 74LS138 |
| | | | U2 | 0510-02700 | LOW POWER SCHOTTKY 74LS138 |

Table 8-4. Model 776 PARTS LIST - 2.4 GHZ INPUT ASSEMBLY

| DWG PART REF NUMBER | DESCRIPTION | DWG PART REF NUMBER | DESCRIPTION | | |
|------------------------|-------------|-------------------------|-------------|------------|-----------------------------|
| C1 | 1560-01020 | CAP CHIP .001 μ 50V | CR1 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C2 | 1560-01020 | CAP CHIP .001 μ 50V | CR2 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C3 | 1560-01020 | CAP CHIP .001 μ 50V | CR3 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C4 | 1560-01020 | CAP CHIP .001 μ 50V | CR4 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C5 | 1560-01020 | CAP CHIP .001 μ 50V | CR5 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C6 | 1560-01020 | CAP CHIP .001 μ 50V | CR6 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C7 | 1560-01020 | CAP CHIP .001 μ 50V | CR7 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C8 | 1560-01020 | CAP CHIP .001 μ 50V | CR8 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C9 | 1560-01020 | CAP CHIP .001 μ 50V | CR9 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C10 | 1560-01020 | CAP CHIP .001 μ 50V | CR10 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C11 | 1560-01020 | CAP CHIP .001 μ 50V | CR11 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C12 | 1560-01020 | CAP CHIP .001 μ 50V | CR12 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C13 | 1560-01020 | CAP CHIP .001 μ 50V | CR13 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C14 | 1560-01020 | CAP CHIP .001 μ 50V | CR14 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C15 | 1560-01020 | CAP CHIP .001 μ 50V | CR15 | 0300-10300 | DIODE HOT CARRIER 5082-2835 |
| C16 | 1560-01000 | CAP CHIP 10 pF 50V | J1 | 3000-30250 | CON MALE 2X8 |
| C17 | 1560-01020 | CAP CHIP .001 μ 50V | R1 | 0113-05100 | RES CHIP 51 5% |
| C18 | 1560-01020 | CAP CHIP .001 μ 50V | R2 | 0113-05100 | RES CHIP 51 5% |
| C19 | 1560-02200 | CAP CHIP 22 pF 50V | R3 | 0100-02020 | RES COMP 2K 5% 1/4W |
| C20 | 1560-01040 | CAP CHIP .1 μ F 50V | R4 | 0100-02020 | RES COMP 2K 5% 1/4W |
| C21 | 1560-01040 | CAP CHIP .1 μ F 50V | | | |
| C22 | 1560-01040 | CAP CHIP .1 μ F 50V | | | |

Table 8-4. Model 776 PARTS LIST - 2.4 GHZ INPUT ASSEMBLY (CONTINUED)

| DWG PART | | | DWG PART | | |
|------------|------------------|-----------------------|------------|------------|----------------------|
| REF NUMBER | | DESCRIPTION | REF NUMBER | | DESCRIPTION |
| R5 | 0100-03910 | RES COMP 390 5% 1/4W | R17 | 0100-08210 | RES COMP 820 5% 1/4W |
| R6 | 0100-03910 | RES COMP 390 5% 1/4W | R18 | 0113-03010 | RES CHIP 300 5% 1/8W |
| R7 | 0100-03910 | RES COMP 390 5% 1/4W | R19 | 0113-03300 | RES CHIP 33 5% 1/8W |
| R8 | 0100-01020 | RES COMP 1K 5% 1/4W | R20 | 0113-03010 | RES CHIP 300 5% 1/8W |
| R9 | 0100-01540 | RES COMP 150K 5% 1/4W | R21 | 0113-03010 | RES CHIP 300 5% 1/8W |
| R10 | 0100-01020 | RES COMP 1K 5% 1/4W | R22 | 0113-03010 | RES CHIP 300 5% 1/8W |
| R11 | 0100-01540 | RES COMP 150K 5% 1/4W | R23 | 0100-01020 | RES COMP 1K 5% 1/8W |
| R12 | 0100-01020 | RES COMP 1K 5% 1/4W | U1 | 0400-20600 | MAR-7 MINI CIRCUITS |
| R13 | * SELECTED VALUE | | U2 | 0400-20600 | MAR-7 MINI CIRCUITS |
| R14 | 0100-02250 | RES COMP 2.2M 5% 1/4W | U3 | 0400-20600 | MAR-7 MINI CIRCUITS |
| R15 | 0100-03310 | RES COMP 330 5% 1/4W | U4 | 0500-64400 | U.P.B. 588G - NEC |
| R16 | 0100-02710 | RES COMP 270 5% 1/4W | U5 | 0500-53700 | LM393N |

9

Schematic & Assembly Drawings

| Dwg. | Description | Page |
|-------------|---|-------------|
| 9-1 | Main Board - Input Amplifiers and Trigger Level Control | 9-1 |
| 9-2 | Main Board - Measurement Logic Circuit | 9-2 |
| 9-3 | Main Board - CPU Circuit..... | 9-3 |
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| 9-9 | 500 MHz Oscillator, and TCXO circuit | 9-9 |
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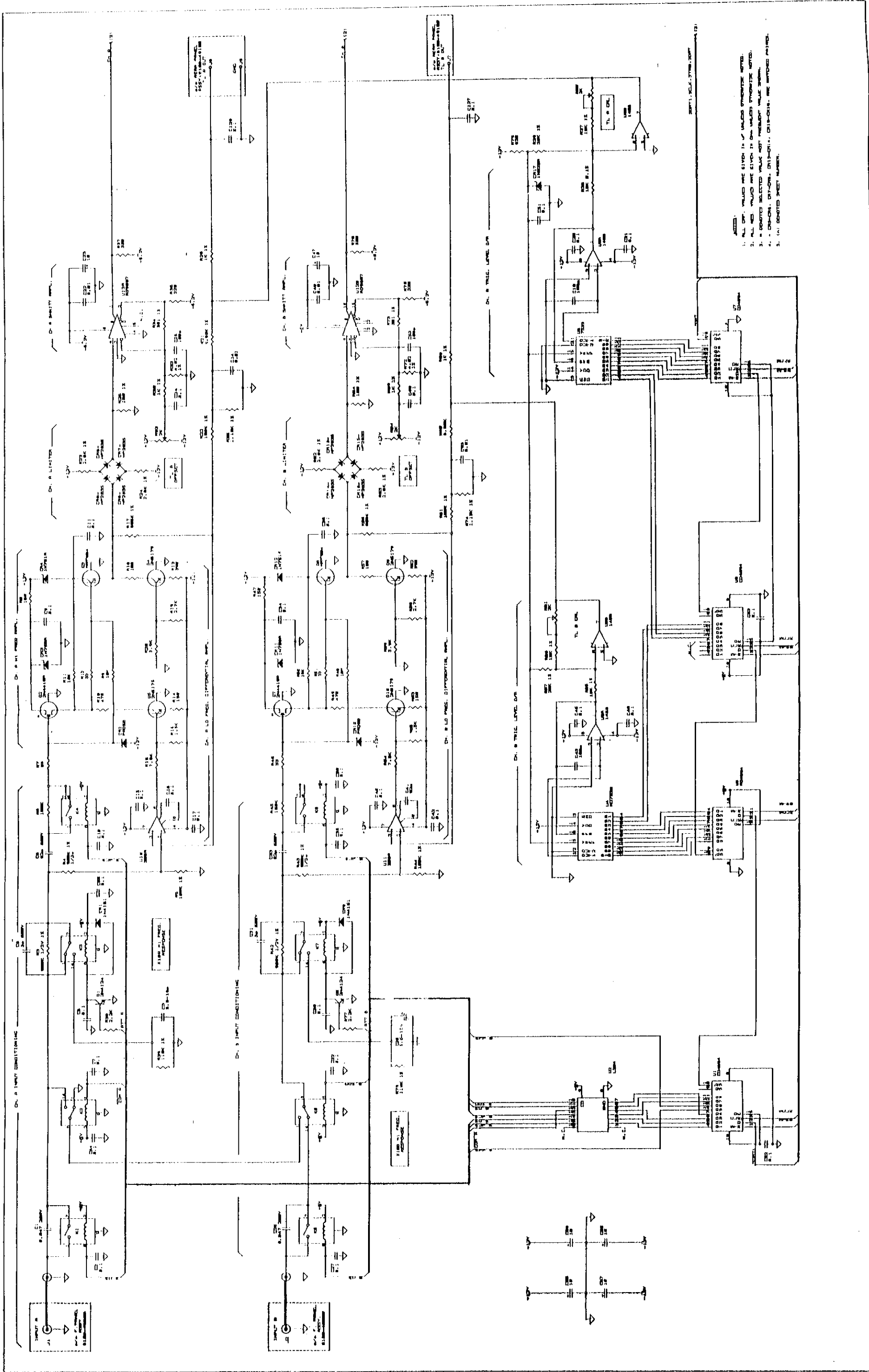


Figure 9-1. Main Board - Input Amplifiers and Trigger Level Control

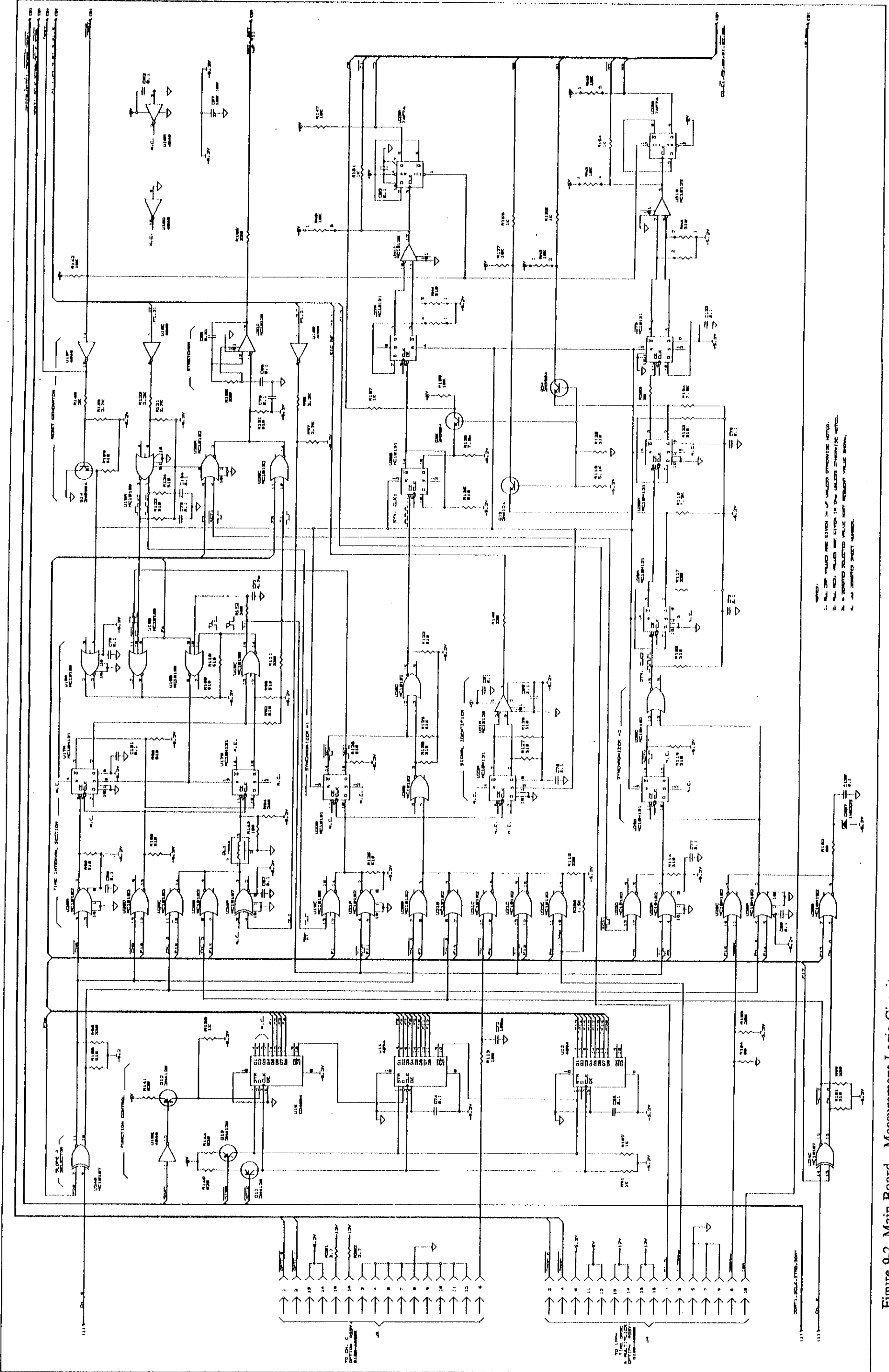


Figure 9-2. Main Board - Measurement Logic Circuit

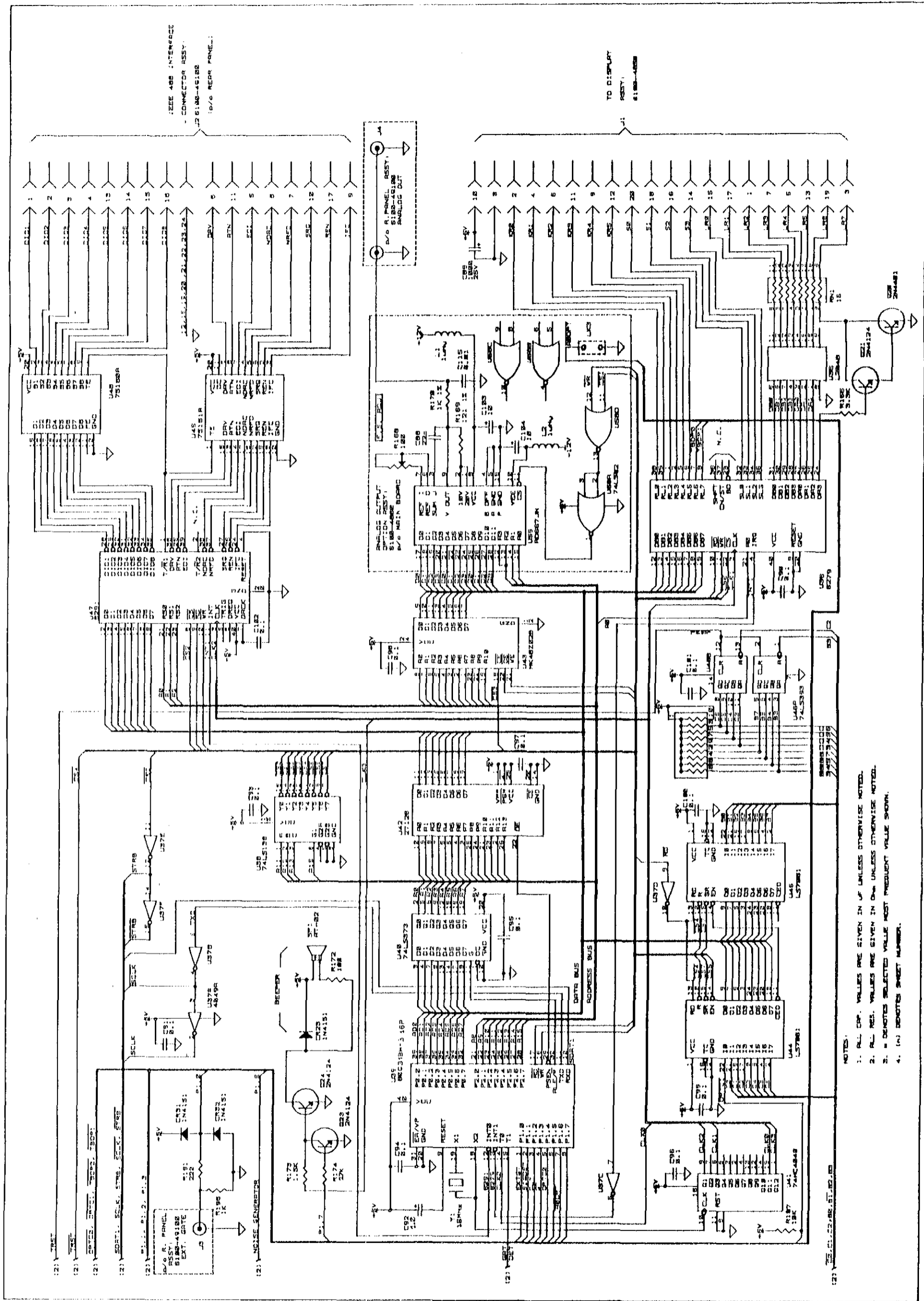


Figure 9-3. Main Board - CPU Circuit

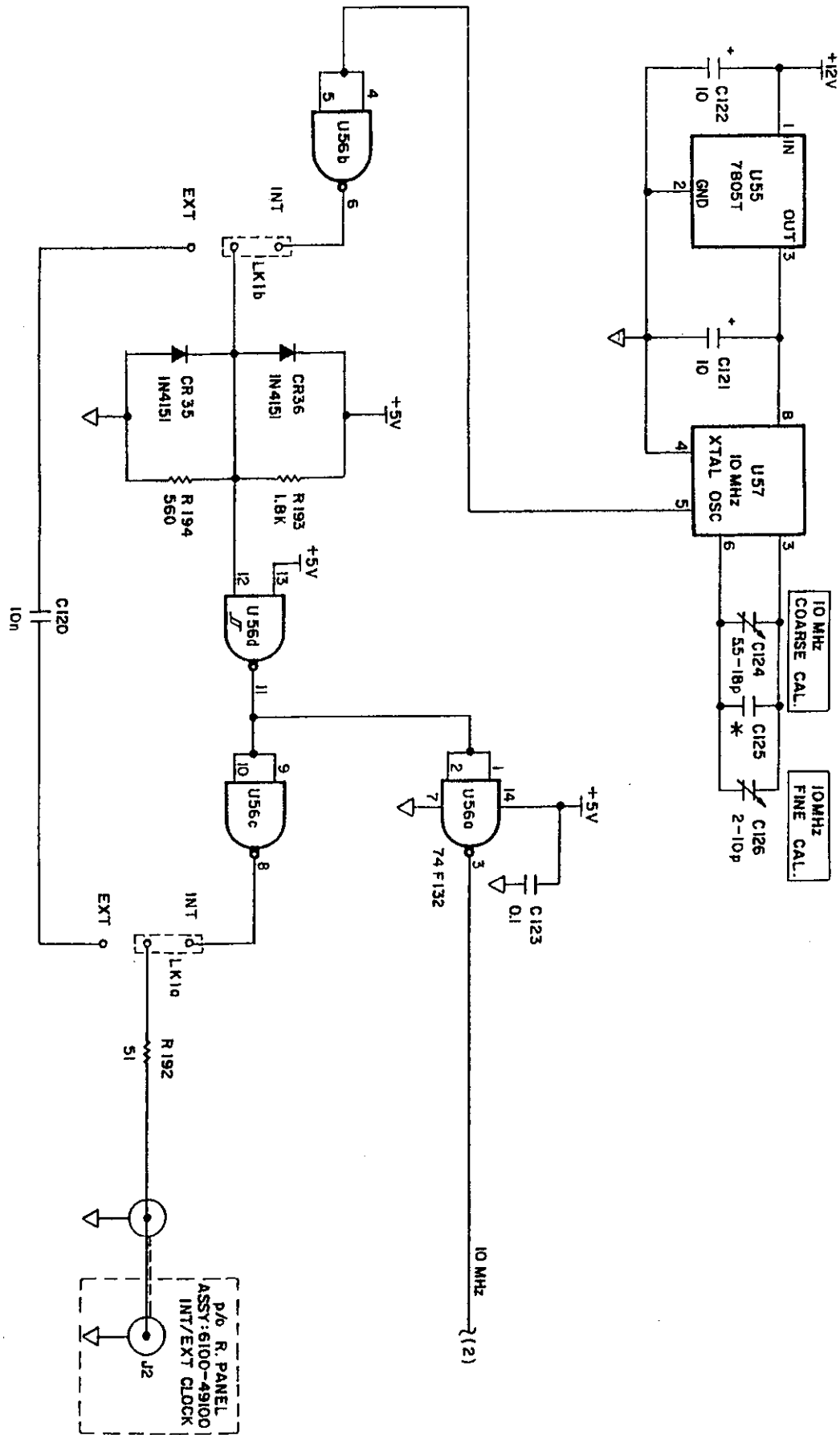


Figure 9-4. Main Board - Standard 5 PPM Time Base Circuit

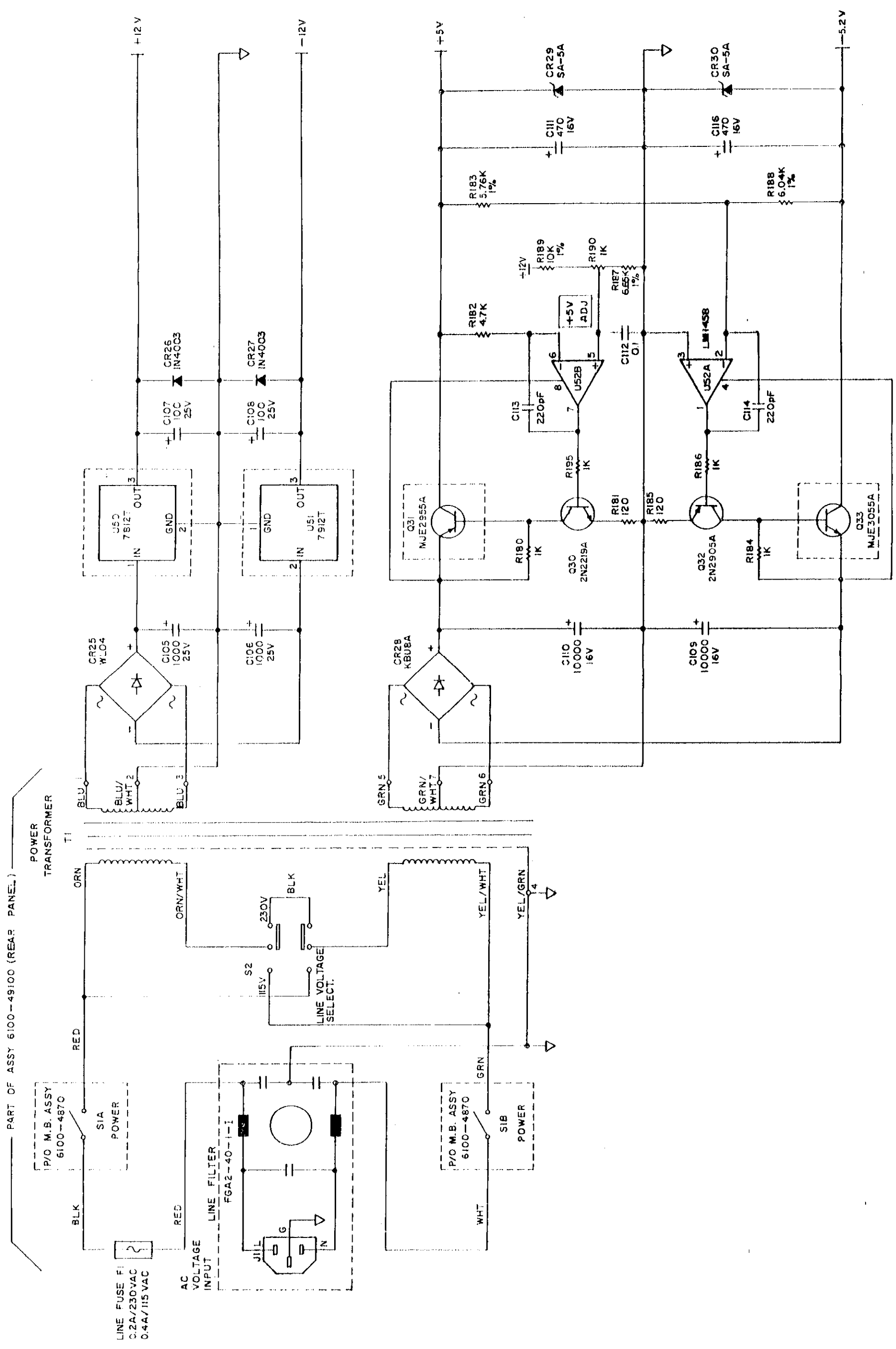


Figure 9-5. Main Board - Power Supply Circuit

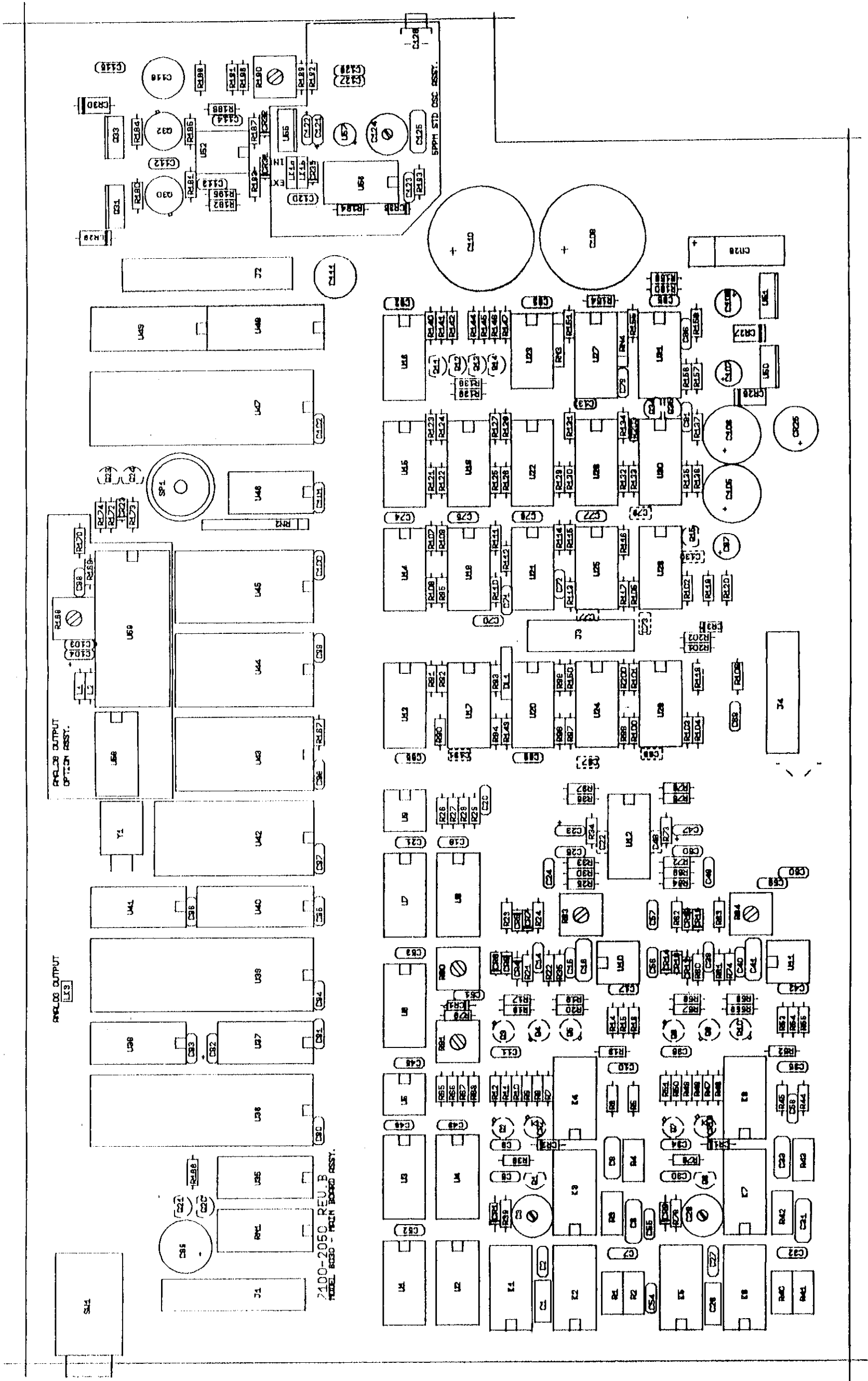
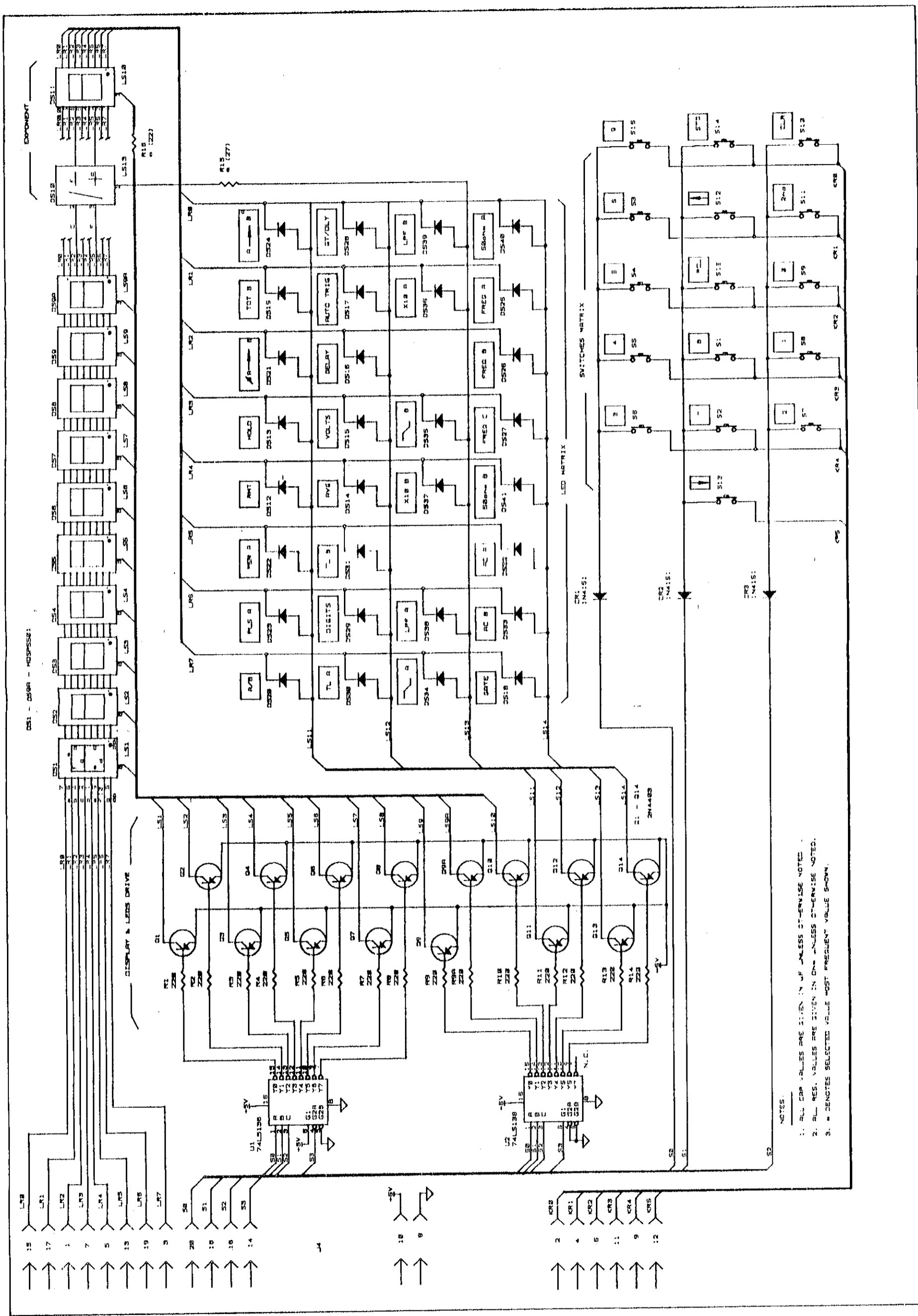


Figure 9-6. Main Board - Components Location Diagram



- NOTES:
1. ALL CRP VALUES ARE GIVEN IN Ω UNLESS OTHERWISE NOTED.
 2. ALL RES. VALUES ARE GIVEN IN Ω UNLESS OTHERWISE NOTED.
 3. * DENOTES SELECTED VALUE MOST FREQUENTLY SHOWN.

Figure 9-7. Front Panel - Keyboard and Display Circuit

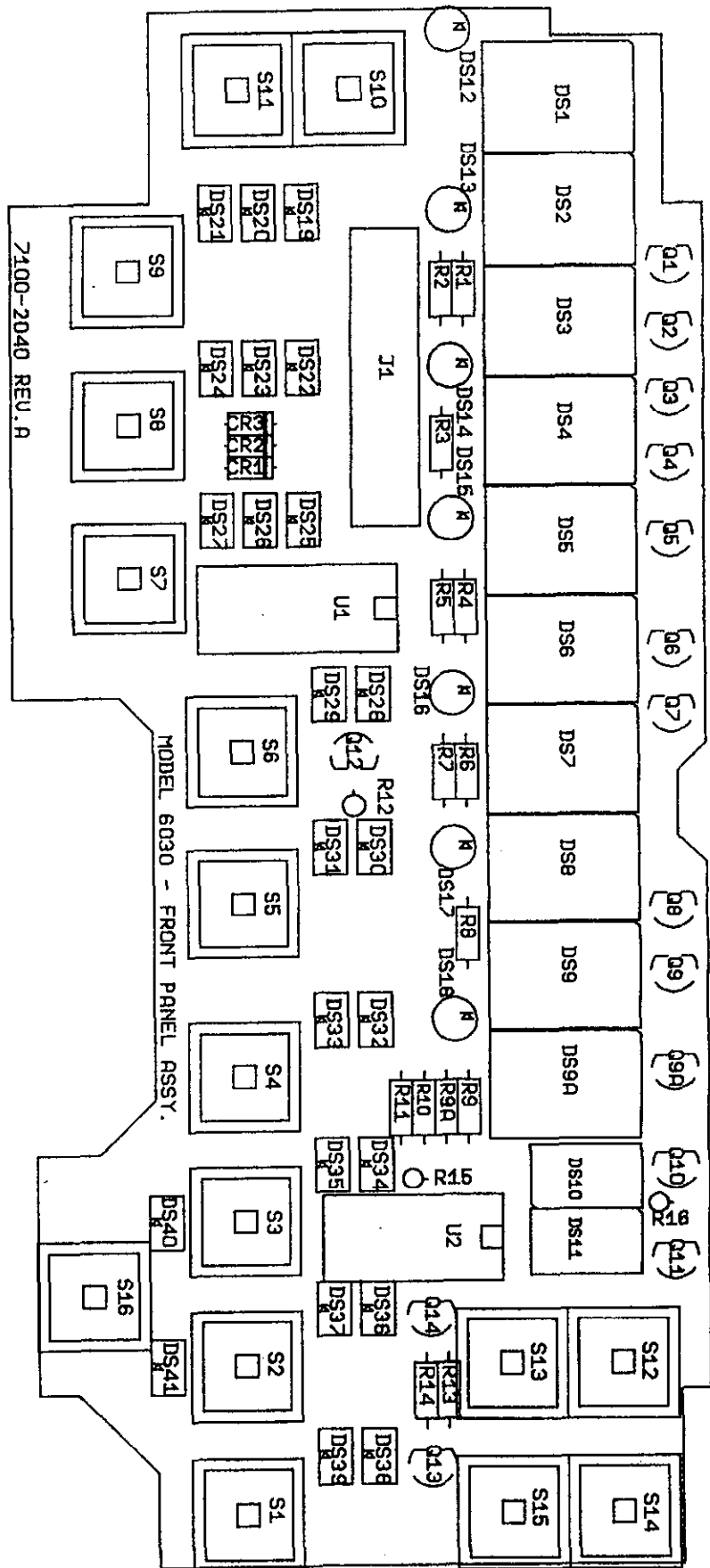


Figure 9-8. Front Panel - Components Location Diagram

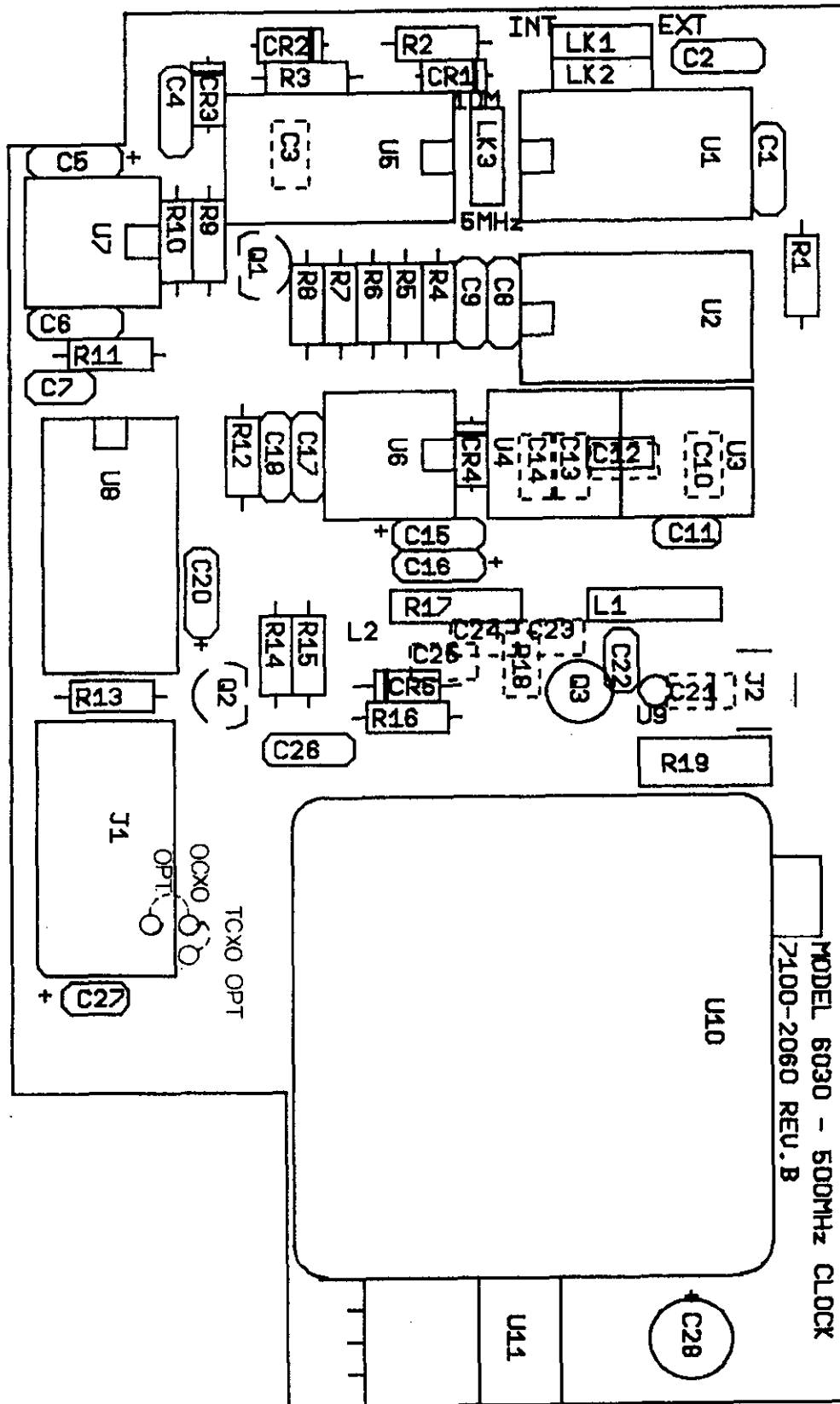


Figure 9-10. 500 MHz Oscillator, & Option 1 - TCXO circuit Components Location Diagram

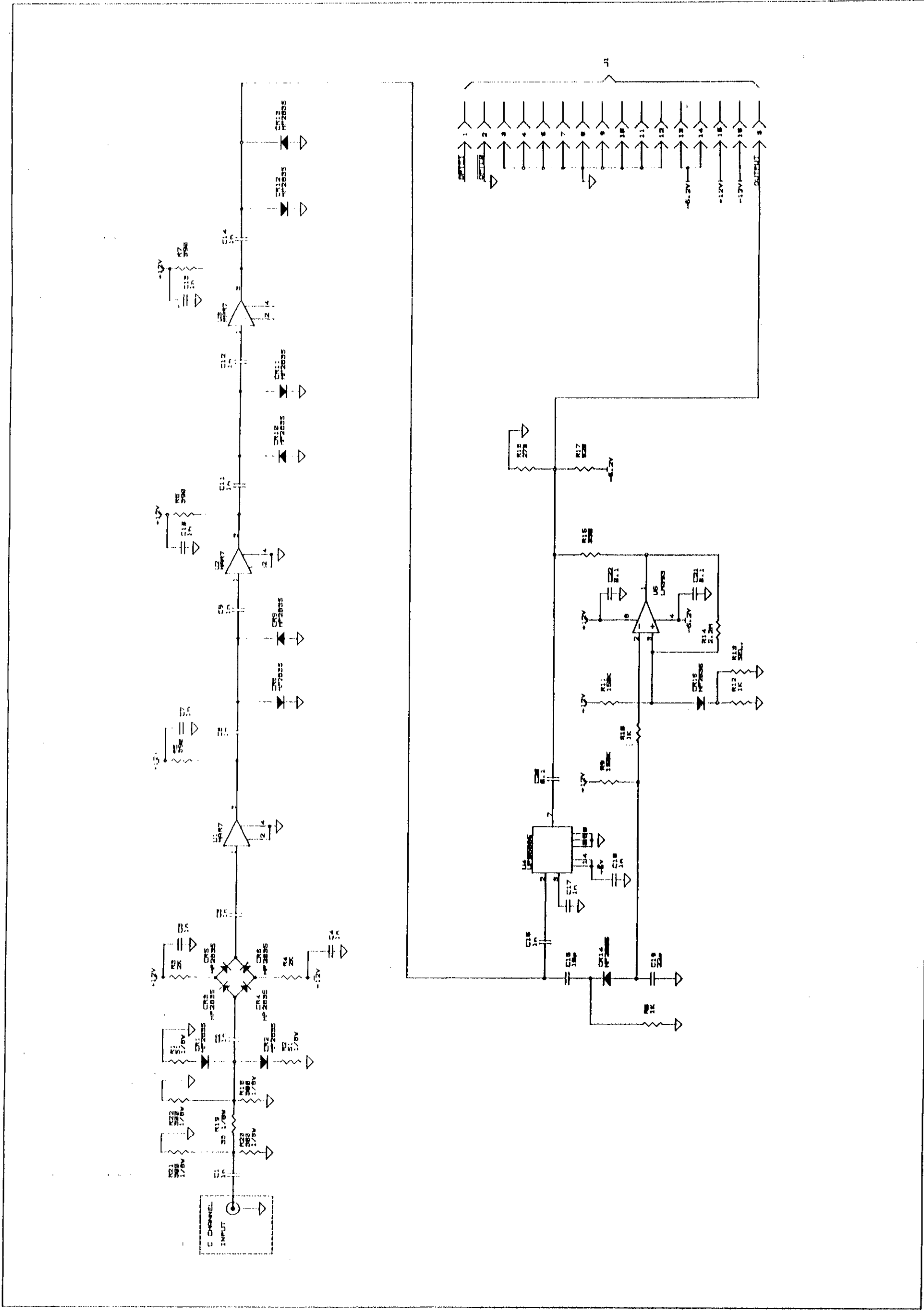


Figure 9-11. Option 2 - 2.4 GHz Input Amplifier Circuit

7100-2070 REV. A

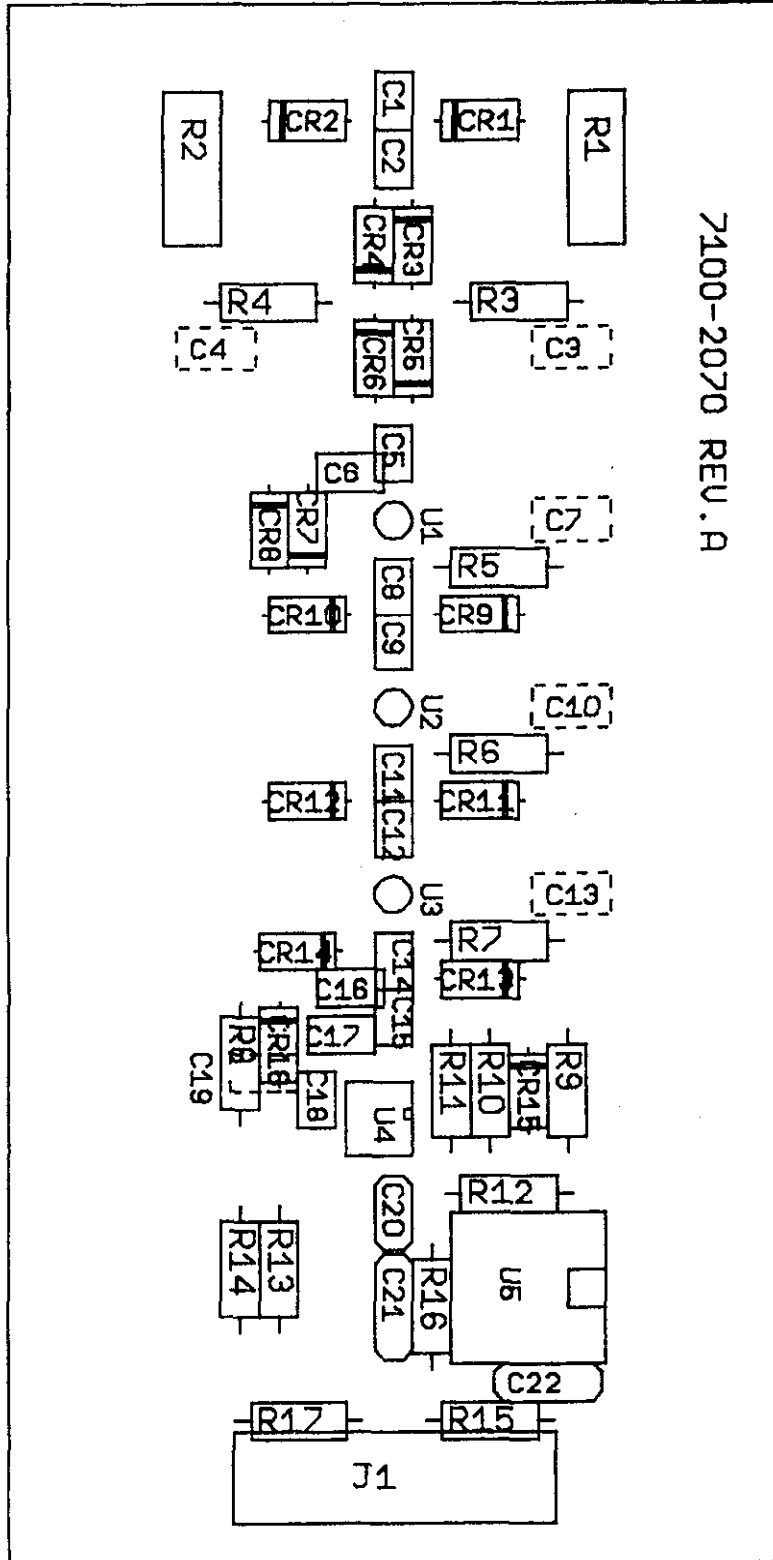


Figure 9-12. Option 2 - Components Location Diagrams

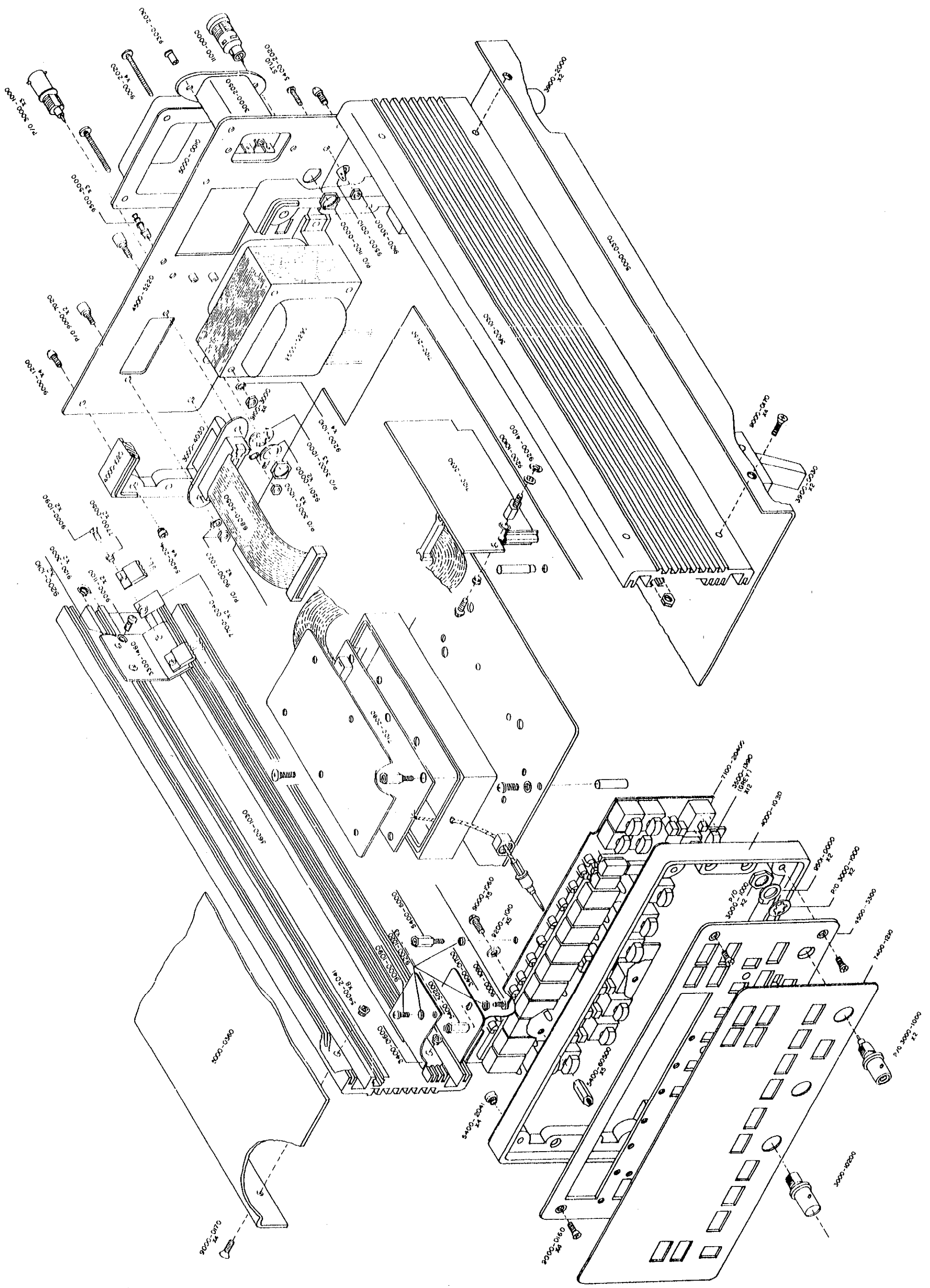


Figure 9-13. Model 776 - Exploded View.

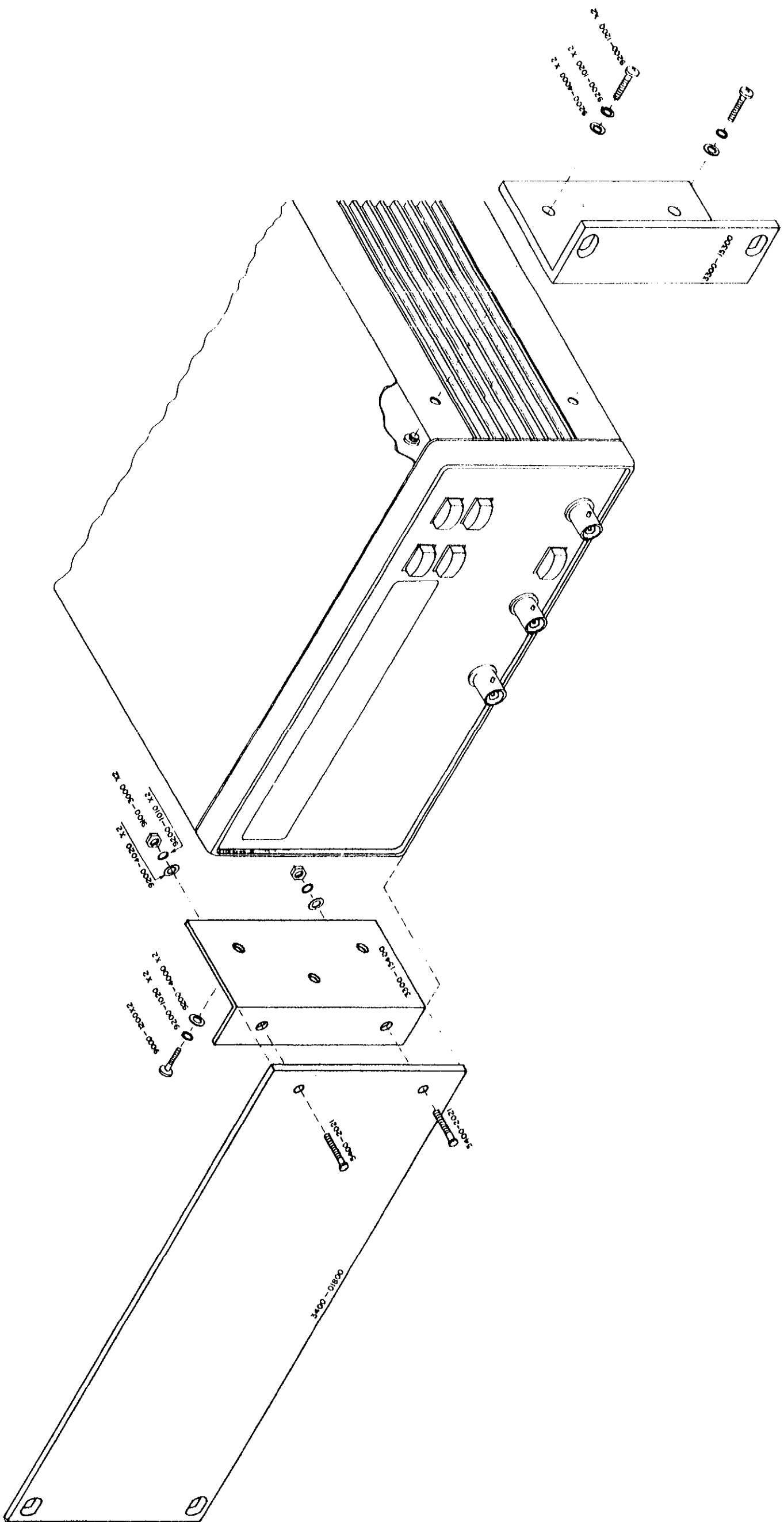


Figure 9-14. Model 776 - Rack Mounting Kit Assembly.

A

Programming the Model 776/2.4G/R

A.1 Introduction

This appendix contains programming information for the Model 776/2.4G/R Programmable Counter/Timer. Commands to program the instrument over the IEEE-488 bus are very similar to those defined by the IEEE-488.2-1987 standard and the SCPI 1992.0 (Standard Commands for Programmable Instruments) standard. For those familiar with device-dependent command (DDC) programming of a Model 776, there is a table at the end of this appendix listing equivalent commands.

IEEE-488.2 defines a syntax for sending data to and from instruments, how an instrument interprets this data, and what registers should exist to record the state of the instrument. This subset of commands (common commands) is used to perform basic operations, such as reading status registers, triggering measurements, and resetting the instrument.

The SCPI standard defines a command language protocol. It goes one step farther than IEEE-488.2 and defines a standard set of commands to control every programmable aspect of an instrument. It also defines the format of command parameters and the format for values returned by the instruments.

A.2 Standards information

The command set of the Model 776/2.4G/R consists of the following:

- The IEEE-488.2 common commands (listed in paragraph A.3).
- The SCPI signal oriented measurement commands (listed in paragraph A.4).

- The SCPI subsystem commands (listed in paragraph A.5).

Information on command format, syntax, parameter, and response types is in paragraph A.6. Detailed descriptions of the commands are in paragraphs A.7 through A.9.

A.3 Summary of IEEE-488.2 common commands

Common commands (see Table A-1) are common to all instruments on the bus. They are defined by the IEEE-488.2 standard. Common commands are recognized by the fact they all begin with an "*" (e.g., *OPC, *RST). They may also take the form of a query (e.g., *OPC?) to request information from the instrument.

A.4 Summary of SCPI signal oriented measurement commands

The signal oriented measurement commands (see Tables A-2 and A-3) acquire readings using a set of high-level instructions to control the measurement process. Signal oriented commands use a hierarchy relationship between levels, which is indicated by a colon character. Approval by the SCPI standard is indicated by a ✓ table entry.

A.5 Summary of SCPI subsystem commands

The subsystem commands (see Table A-4) are low-level instructions to control all programmable aspects of the instrument. Subsystem commands use a hierarchy relationship between levels, which is indicated by a colon character. Approval by the SCPI standard is indicated by a ✓ table entry.

Table A-1
Common commands and queries

| Mnemonic | Name | Description |
|------------|--------------------------------|---|
| *CLS | Clear status command | Clears status registers and error queue. |
| *ESE <NR1> | Event status enable command | Sets Standard Event Status Enable Register. |
| *ESE? | Event status enable query | Reads Standard Event Status Enable Register. |
| *ESR? | Event status register query | Reads Standard Event Status Register and clears it. |
| *IDN? | Identification query | Reads counter identification code. |
| *OPC | Operation complete command | Sets OPC bit in Standard Event Status Register after all pending commands are complete. |
| *OPC? | Operation complete query | Places a "1" in the Output Queue after all pending operations are complete. |
| *RCL <NR1> | Recall command | Returns to a setup stored in memory. |
| *RST | Reset command | Returns the instrument to default conditions. |
| *SAV <NR1> | Save command | Saves the present setup in memory. |
| *SRE <NR1> | Service request enable command | Sets the Service Request Enable Register. |
| *SRE? | Service request enable query | Reads the Service Request Enable Register. |
| *STB? | Status byte query | Reads the Status Byte Register. |
| *TRG | Trigger command | Sends a GPIB trigger to the instrument. |

Notes:

1. At least one space is required between the command and the parameter.
2. <NR1> is numeric data in integer form. Do not use angle brackets in the command.

Table A-2
Signal oriented measurement command summary

| Command | SCPI | Description |
|--|------|---|
| :CONFigure[:SCALar]:<function> <source_list> | √ | Configures instrument for specified function. |
| :CONFigure? | √ | Reads function configured by last :CONF or :MEAS command. |
| :MEASure[:SCALar]:<function>? <source_list> | √ | Configures instrument, initiates measurement, queries for result. |
| :READ? | √ | Initiates measurement and queries for result. |
| :FETCh? | √ | Queries for result. |

Notes:

1. You must enter all the upper case letters. Lower case letters are optional, but if you send any, you must send all.
2. [] indicate optional characters. Do not use brackets in the command.
3. At least one space is required between the <function> and <source_list>.
4. Angle brackets (<>) indicate measurement function and signal channel. Do not use angle brackets in the command.

Table A-3
 <function> and <source_list> for signal oriented commands

| <function> | <source_list> | SCPI | Description |
|---|---------------|------|---|
| [[:VOLTage]:FREQuency | [@1] | √ | Frequency on Channel A. |
| [[:VOLTage]:FREQuency | @2 @3 | √ | Frequency on Channel B or C. |
| [[:VOLTage]:FREQuency:RATio | [@1],[@2] | | Ratio of frequencies on Channels A and B. |
| [[:VOLTage]:PERiod | [@1] | √ | Period on Channel A. |
| [[:VOLTage]:PERiod:AVERage | [@1] | | Period average on Channel A. |
| [[:VOLTage]:PWIDth | [@1] | √ | Positive pulse width on Channel A. |
| [[:VOLTage]:PWIDth:AVERage | [@1] | | |
| [[:VOLTage]:NWIDth | [@1] | √ | Negative pulse width on Channel A. |
| [[:VOLTage]:NWIDth:AVERage | [@1] | | Average negative pulse width on Channel A. |
| [[:VOLTage]:TINterval | [@1],[@2] | | Time interval from Channel A to B. |
| [[:VOLTage]:TINterval:AVERage | [@1],[@2] | | Time interval from Channel A to B averaged. |
| [[:VOLTage]:TOTalize | [@2] | | Totalize on Channel B. |
| [[:VOLTage]:TOTalize:TIMed | [@2] | | Totalize on Channel B by Channel A. |
| [[:VOLTage]:PHASe | [@1],[@2] | √ | Phase from Channel A to B. |
| [[:VOLTage]:PTPeak | [@1] | √ | Peak-to-peak voltage on Channel A. |
| [[:VOLTage]:MAXimum | [@1] | √ | Maximum voltage on Channel A. |
| [[:VOLTage]:MINimum | [@1] | √ | Minimum voltage on Channel A. |
| Notes: 1. You must enter all the upper case letters. Lower case letters are optional. 2. [] indicate optional characters. Do not use brackets in the command. 3. At least one space is required between the <function> and <source_list>. 4. @2 @3 means use either @2 or @3. | | | |

Table A-4
Subsystem command summary

| Command | Parameter | Default | SCPI | Description |
|-------------------------|------------------|-----------|------|---|
| Input commands | | | | |
| :INPut[112] | | | √ | Subsystem. Controls input channels. |
| :ATTenuation | 1110 | 1 | √ | Sets input attenuation. |
| :ATTenuation? | | | √ | Reads input attenuation. |
| :COUPling | DCIAC | AC | √ | Sets input coupling. |
| :COUPling? | | | √ | Reads input coupling. |
| :FILTer | | | √ | Subtree. Inserts filter in measurement path. |
| [:LPASs] | | | √ | Subtree. Controls low pass filter. |
| [:STATe] | OFFION | OFF | √ | Enable/disable low pass filter. |
| [:STATe]? | | | √ | Reads filter state. |
| :IMPedance | 1e6150 | 1e6 | √ | Sets input impedance in ohms. |
| :IMPedance? | | | √ | Reads input impedance. |
| Sense commands | | | | |
| [:SENSe] | | | √ | Subsystem. Configures and controls measurement function. |
| :EVENt[112] | | | | Subtree. Defines trigger event. |
| :LEVel | | | | Subtree. |
| [:ABSolute] | <NR1> [V] | 0V | | Sets voltage level for event. |
| [:ABSolute]? | | | | Reads event voltage level. |
| :AUTO | OFFION | ON | | Enables/disables auto-trigger. |
| :AUTO? | | | | Reads auto-trigger state. |
| :SLOPe | POSitiveNEGative | POSitive | | Sets input signal edge for event. |
| :SLOPe? | | | | Reads input signal edge for event |
| :FREQuency | | | √ | Subtree. |
| :ARM | | | | Subtree. Synchronizes frequency start and stop with events. |
| [:STARt] | | | | Subtree. |
| :SOURce | IMMEDIATE | IMMEDIATE | | Sets start for measurements. |
| :SOURce? | | | | Reads start for measurements. |
| :STOP | | | | Subtree. |
| :DIGits | <NR1> | 4 | | Sets resolution in digits. |
| :DIGits? | | | | Reads resolution. |
| :SOURce | TIMerDIGits | TIMer | | Sets stop for measurements. |
| :SOURce? | | | | Reads stop for measurements. |
| :TIMer | <NR3> [S] | 100e-3 S | | Sets gate time in seconds. |
| :TIMer? | | | | Reads gate time. |
| System commands | | | | |
| :SYSTem | | | √ | Subsystem. Miscellaneous commands. |
| :ERRor? | | | √ | Reads error queue. |
| :VERSion? | | | √ | Reads counter's identification code. |
| Trigger commands | | | | |
| :ABORt | | | √ | Event. Aborts measurement in progress. |
| :INITiate | | | √ | Subsystem. Controls measurement triggers. |
| :CONTinuous | OFFION | OFF | √ | Enables/disables continuous triggers. |
| :CONTinuous? | | | √ | Reads continuous triggers state. |
| [:IMMEDIATE] | | | √ | Triggers one measurement. |

Notes:

1. You must enter all the upper case letters. Lower case letters are optional.
2. [] indicate optional characters. Do not use brackets in the command.
3. OFFION means use either OFF or ON, 0|1 is also acceptable.
4. At least one space is required between the command and the parameter.
5. <NR1> is numeric response data in integer form. <NR3> is numeric response data in exponent form. Do not use angle brackets in the command.

A.6 Command structure and syntax

The following information covers structure and syntax for both common commands and SCPI commands. For topics not covered here, refer to the IEEE-488.2 and SCPI standards.

A.6.1 Command tree

The organization of SCPI commands follows a tree structure similar to that used for disk directories in computer operating systems. Each subdirectory is known as a subsystem. As an example, the INPut subsystem is shown below:

```
:INPut[1|2]
  :ATTenuation      1110
  :ATTenuation?
  :COUPling         DCIAC
  :COUPling?
  :FILTer
    [:LPASs]
      [:STATe]      OFFION
      [:STATe]?
  :IMPedance        1e6150
  :IMPedance?
```

While a command summary table does document SCPI commands, it does not show the complete command names. The components must be joined together to form the complete command name. For example, the command for enabling or disabling the low pass filter in the INPut subsystem is the following:

```
:INPut[1|2]:FILTer[:LPASs][:STATe] OFFION
```

where square brackets indicate optional parts of the command and 1|2 indicates channel 1 or 2.

The tree structure allows a command to be used several times, each with a new meaning. For example, a :SOURce command can be contained within many subsystems but since the complete command is unique, so is the meaning of each :SOURce command.

A.6.2 Long and short form commands

There is a short form of every SCPI command and a long form of most SCPI commands. A short form command is made up of the first four characters of the full command name unless the fourth character is a vowel which shortens the command to three characters. The long form is made up of the full command name.

Documentation uses the notation of showing the short form in upper case, with the remainder of the name, the whole of which creates the long form, in lower case. Either the exact short or long form must be sent as a command. There are no intermediate forms. However, the mixed capitalization does not have to be used – commands are accepted in any combination of upper and lower case. All of the following are valid commands:

```
[[:sense]:frequency:arm:stop:source timer
[:sens]:freq:arm:stop:sour tim
[:SENS]:freq:ARM:stop:SouRce TiMer
```

A.6.3 Query commands

Most SCPI commands also have a corresponding query. A command will set a control point in the instrument; a query will determine the present setting of the control point and return the result to the controller. A query is formed by simply attaching a "?" to the command name.

Some queries have no corresponding command. For example, MEASure:FREQuency? will cause the instrument to return the latest reading. There is no corresponding command to send a frequency value to the instrument.

A.6.4 Default nodes

The concept of default nodes is used by SCPI. What is shown within square brackets is not required to be sent to the instrument but will be accepted if sent. The following are all valid forms of a :SOURce command in the :SENSe subsystem:

```
:SENSe:FREQuency:ARM:STARt:SOURce IMMEDIATE
:FREQuency:ARM:SOURce IMMEDIATE
:FREQuency:ARM:STARt:SOURce IMMEDIATE
:SENSe:FREQuency:ARM:SOURce IMMEDIATE
```

All of these commands are shown in their long form.

A.6.5 Command syntax

A leading colon instructs the instrument to interpret the command beginning at the root (the highest level) of the command tree. The instrument will also begin at the root every time you send a new command, so the leading colon is not necessary but will be accepted if sent.

You can send multiple commands in a single message by separating the commands with a semicolon character. When the instrument encounters a command following a semicolon, it attempts to interpret the command starting at the level

of the previous command, unless you precede the second command with a colon. For example, either of the following command strings programs the instrument for 10x attenuation, dc coupling, and turns on the low pass filter:

```
:input:att 10;coup dc;filter on
:input:att 10::input:coup dc::input:filter on
```

The two command strings are treated identically by the instrument. In the first string, when the instrument encounters ";coup dc", it notices the following:

- It is not the first command in the string.
- There is no leading colon on the command.
- The previous command was at the :input level.

Therefore, it interprets the command as if it were at the :input level.

A.7 Common commands

A.7.1 *CLS — clear status command

This command clears the bits of the Standard Event Status Register and the Error Queue. It also forces the instrument into the operation complete idle state and operation complete query idle state. This results in the disabling of any prior *OPC command.

A.7.2 *ESE <NR1> — event status enable command

*ESE? — event status enable query

These commands set or query the Standard Event Status Enable Register, shown in Figure A-1.

The parameter and query response are the decimal equivalent of the binary value that determines the desired state (0 or 1) of the bits in the register. The register is cleared on power-up.

This register is used as a mask for the Standard Event Status Register. When a standard event is enabled, the occurrence of that event sets the ESB bit in the Status Byte Register. For example, to set the CME and QYE bits of the Standard Event Status Enable Register, send the following command:

```
*ESE 36
```

where: CME (bit 5) = decimal 32
 QYE (bit 2) = decimal 4
 <NR1> = 36

Since the command error bit and query error bit are enabled, the occurrence of either event sets the ESB bit in the Status Byte Register.

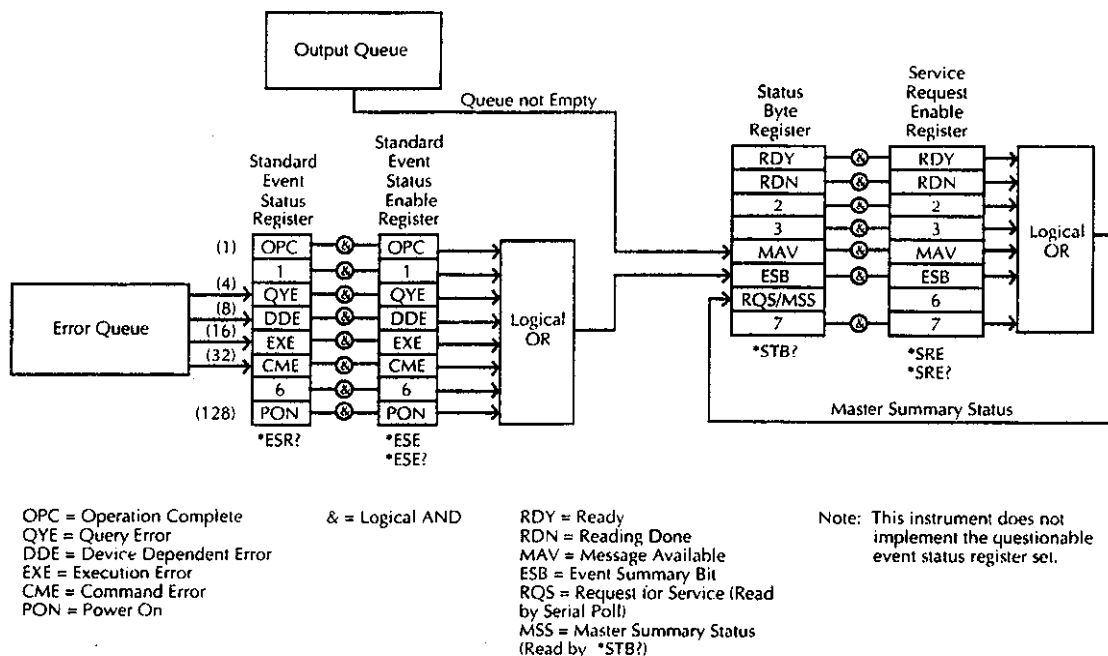


Figure A-1
 Model 776/2.4G/R status structure

A.7.3 *ESR? — event status register query

This query reads the decimal value of the Standard Event Status Register. The binary equivalent of the returned decimal value determines which bits in the register are set. This register is cleared on power-up or when *CLS is sent.

The bits of the Standard Event Status Register are as follows:

Bit 0, Operation Complete (OPC) — Set bit indicates that all pending device operations are complete and the instrument is ready to accept new commands. This bit only sets in response to the *OPC? query.

Bit 2, Query Error (QYE) — Set bit indicates that you attempted to read data from an empty Output Queue.

Bit 3, Device-dependent Error (DDE) — Set bit indicates that an instrument operation did not execute properly due to some internal condition.

Bit 4, Execution Error (EXE) — Set bit indicates that the instrument detected an error while trying to execute a command.

Bit 5, Command Error (CME) — Set bit indicates that a command error has occurred. Command errors include:

- IEEE-488.2 syntax error
- Semantic error indicating an unrecognized command
- The instrument received a Group Execute Trigger (GET) inside a program message.

Bit 7, Power On (PON) — Set bit indicates that the instrument has been turned off and turned back on since the last time this register has been read.

A.7.4 *IDN? — identification query

The identification code includes the manufacturer, model number, serial number, and firmware revision level. It is sent in the following format:

```
KEITHLEY,776,x,REVyyyy
```

where: x is the serial number
yyyy is the firmware revision level

A.7.5 *OPC — operation complete command

*OPC? — operation complete query

The *OPC command enables the OPC bit (bit 0) in the Standard Event Status Register to be set upon transition from a measuring state to an idle state, indicating that all pending operations have completed. The instrument is also in an idle state upon power-up, or when *CLS or *RST is executed.

The query produces a response upon transition from a measuring state to an idle state. This allows synchronization between the bus controller and instrument using the MAV bit (bit 4) in the Status Byte Register or a read of the Output Queue. An *OPC? has no effect on the OPC bit in the Standard Event Status Register.

A.7.6 *RCL <NR1> — recall command

This command returns the instrument to a setup (0-19) stored in memory. The *SAV command is used to store the present setup in memory.

A.7.7 *RST — reset command

When the *RST command is sent, the instrument performs the following operations:

- Returns to *RST default conditions (see Table A-4).
- Cancels all pending commands.
- Cancels response to previously received *OPC and *OPC?.

NOTE

The general bus commands DCL (device clear) and SDC (selected device clear) also reset the instrument.

A.7.8 *SAV <NR1> — Save command

The *SAV command saves the present instrument setup (0-19) in memory for later recall. Any control affected by *RST can be saved by the *SAV command. The *RCL command is used to restore the instrument to a saved setup.

A.7.9 *SRE <NR1> — service request enable command

*SRE? — service request enable query

These commands set or query the Service Request Enable Register, shown in Figure A-1.

The parameter and query response are the decimal equivalent of the binary value that determines the desired state (0 or 1) of the bits in the register. The register is cleared on power-up.

This enable register is used along with the Status Byte Register to generate service requests (SRQ). With a bit in the Service Request Enable Register set, an SRQ occurs when the corresponding bit in the Status Byte Register is set by an appropriate event. For example, to set the ESB and MAV bits of the Service Request Enable Register, send the following command:

*SRE 48

| | | |
|--------|-----------------------|-----------|
| where: | ESB (bit 5) = decimal | 32 |
| | MAV (bit 4) = decimal | 16 |
| | <NR1> = | <u>48</u> |

A.7.10 *STB? — status byte query

The *STB? query acquires the value of the Status Byte Register (see Figure A-1). The binary equivalent of the decimal value determines which bits in the register are set.

Bits in this register are set by the Standard Event Status Register and Output Queue. Bit 6 is set when one or more enabled conditions occur.

*STB? does not clear the Status Byte Register. This register can only be cleared by clearing the related register and queue. The bits of the Status Byte Register are described as follows:

Bit 0, Ready (RDY) — Set bit indicates instrument ready.

Bit 1, Reading Done (RDN) — Set bit indicates reading done.

Bit 4, Message Available (MAV) — Set bit indicates a message is present in the Output Queue. The message is sent to the bus controller when the instrument is addressed to talk.

Bit 5, Event Summary Bit (ESB) — Set bit indicates that an enabled standard event has occurred. The event can be identified with the *ESE? query.

Bit 6, Master Summary Status (MSS) / Request Service (RQS) — Set bit indicates that one or more enabled Status Byte conditions have occurred. The MSS bit can be read with *STB? query; the occurrence of a service request (RQS bit set) can be detected with a Serial Poll.

A.7.11 *TRG — trigger command

The *TRG command issues a GPIB trigger to the instrument. It has the same effect as a Group Execute Trigger (GET).

A.8 Signal — oriented commands

:FETCh <function>?

Description

The query requests the return of the measurement result to the controller when no function is specified with this query. A "0" will be returned when a function is specified with this query because the statements will not perform any post-processing.

This query command is used to request the latest post-processed reading. After sending this command and addressing the instrument to talk, the reading will be sent to the computer. This command does not affect the instrument setup.

This command does not trigger a measurement. It simply requests the last available reading.

:CONFigure <function>

Query

:CONFigure? Query configuration.

Description

This command is used to configure the instrument for subsequent measurements on the specified function. Basically, this command places the instrument in a "one-shot" measurement mode. The **:READ?** command can then be used to trigger a measurement and acquire a reading (see **:READ?**).

Example

| | |
|--------------------------------------|--|
| CONFigure:VOLTage:PWIDth (@1) | Positive pulse width on channel A. |
| INPut:IMPedance 1E6 | Sets the input impedance at 1M Ω . |
| READ? | Begins the measurement and returns the result. |

:READ <function>?

Description

The query will begin the data acquisition and return the result of the last requested measurement when no function is specified with this command. The statements will not perform any post-processing resulting in a "0" being returned when a function is specified with this command.

This command is typically used to acquire a post-processed reading after the instrument has been configured by the **:CONFigure** command. The **:CONFigure** command places the instrument in a "one-shot" measurement mode. Every time the **:READ?** command is then sent, a measurement conversion will occur and the reading will be acquired.

When this command is sent, the following commands will be executed in the order that they are presented:

```
:ABORt
:INITiate
:FETCh?
```

:MEASure <function>?

| | | |
|--------------------|--|---|
| Query | MEASure? | Returns the measurement result to the controller. |
| Description | <p>This command combines all of the other signal oriented measurement commands to perform a “one-shot” measurement and acquire the reading.</p> <p>When this command is sent, the following commands are executed in the order that they are presented.</p> <p>:ABORt:CONFIgure:<function>:READ?</p> | |

[:SCALar]

This is the subsystem for scalar measurements.

[:VOLTage]

This is the beginning of the command path for the voltage measurements desired to be performed.

:FREQuency

| | | |
|--------------------|---|--|
| | CONFIgure[:SCALar][:VOLTage]:FREQuency [(@1) (@2) (@3)] MEASure[:SCALar][:VOLTage]:FREQuency? [(@1) (@2) (@3)] | |
| Parameters | [(@1) (@2) (@3)] | Choose signal on Ch. A, Ch. B or Ch. C. The default is Ch. A. |
| Query | FREQuency? | Query the frequency of the voltage signal on the selected channel. |
| Description | This command configures or requests the instrument to measure the frequency of the voltage signal on the selected channel. | |

:RATio

| | | |
|--------------------|---|--|
| | CONFIgure[:SCALar][:VOLTage]:FREQuency:RATio [(@1) , (@2)] MEASure[:SCALar][:VOLTage]:FREQuency:RATio? [(@1) , (@2)] | |
| Parameters | [(@1) , (@2)] | Choose signals on Ch. A and Ch. B. |
| Query | RATio? | Query the ratio of the frequencies on the selected channels. |
| Description | This command configures or requests the instrument to calculate the ratio of the frequencies on the selected channels. | |

:PERiod

CONFigure[:SCALar][:VOLTage]:PERiod [(@1)]
 MEASure[:SCALar][:VOLTage]:PERiod? [(@1)]

| | | |
|--------------------|--|--|
| Parameters | [(@1)] | The signal on Ch. A will be the one measured. |
| Query | PERiod? | Query the period of the voltage signal on Ch. A. |
| Description | This command configures or requests the instrument to measure the period of the voltage signal on Ch. A. | |

:AVERage

CONFigure[:SCALar][:VOLTage]:PERiod:AVERage [(@1)]
 MEASure[:SCALar][:VOLTage]:PERiod:AVERage? [(@1)]

| | | |
|--------------------|--|--|
| Parameters | [(@1)] | The signal on Ch. A will be used for the calculation. |
| Query | AVERage? | Query the average value of the voltage signal period on Ch. A. |
| Description | This command configures or requests the instrument to calculate the average value of the voltage signal period on Ch. A. | |

:PWIDth

CONFigure[:SCALar][:VOLTage]:PWIDth [(@1)]
 MEASure[:SCALar][:VOLTage]:PWIDth? [(@1)]

| | | |
|--------------------|--|--|
| Parameters | [(@1)] | The signal on Ch. A will be used for the measurement. |
| Query | PWIDth? | Query the positive pulse width of the voltage signal on Ch. A. |
| Description | This command configures or requests the instrument to measure the positive pulse width (in seconds) of the voltage signal. The measurement is made from the first rising edge reference to the next falling edge reference. The default reference is half-way between the high and low levels of the signal. | |

:AVERage

CONFigure[:SCALar][:VOLTage]:PWIDth:AVERage [(@1)]
 MEASure[:SCALar][:VOLTage]:PWIDth:AVERage? [(@1)]

| | | |
|--------------------|--|--|
| Parameters | [(@1)] | The signal on Ch. A will be used for the calculation. |
| Query | AVERage? | Query the average positive pulse width value of the signal on Ch. A. |
| Description | This command configures or requests the instrument to calculate the average positive pulse width of the signal on Ch. A. | |

:NWIDth

CONFigure[:SCALar][:VOLTage]:NWIDth [(@1)]
 MEASure[:SCALar][:VOLTage]:NWIDth? [(@1)]

| | | |
|--------------------|--|--|
| Parameters | [(@1)] | The signal on Ch. A will be used for the measurement. |
| Query | NWIDth? | Query the negative pulse width of the signal on Ch. A. |
| Description | This commands configures or requests the instrument to measure the negative pulse width (in seconds) of the signal on Ch. A. The measurement is made from the first falling edge reference to the next rising edge reference. The default reference is half-way between the high and low levels of the signal. | |

:AVERage

CONFigure[:SCALar][:VOLTage]:NWIDth:AVERage [(@1)]
 MEASure[:SCALar][:VOLTage]:NWIDth:AVERage? [(@1)]

| | | |
|--------------------|--|--|
| Parameters | [(@1)] | The signal on Ch. A will be used for the calculation. |
| Query | AVERage? | Query the average negative pulse width value of the signal on Ch. A. |
| Description | This command configures or requests the instrument to calculate the average negative pulse width value of the signal on Ch. A. | |

:TINterval

CONFigure[:SCALar][:VOLTage]:TINterval [(@1) , (@2)]
 MEASure[:SCALar][:VOLTage]:TINterval? [(@1) , (@2)]

| | | |
|--------------------|--|---|
| Parameters | [(@1) , (@2)] | Select the signal on Ch. A or Ch. B for use in the measurement. |
| Query | TINterval? | Query the time interval of the signal on the selected channel. |
| Description | This command controls the time interval measuring capabilities of the instrument, including Time Interval, Rise Time, Fall Time, Duty Cycle, and Pulse Width. When no specifications follow the command the instrument will measure the Time Interval of the signal. | |

:AVERage

CONFigure[:SCALar][:VOLTage]:TINterval:AVERage [(@1) , (@2)]
 MEASure[:SCALar][:VOLTage]:TINterval:AVERage? [(@1) , (@2)]

| | | |
|--------------------|---|---|
| Parameters | [(@1) , (@2)] | Choose the signal on Ch. A or the one on Ch. B for use in the calculation. |
| Query | AVERage? | Query the average value of the Time Interval of the signal on the selected channel. |
| Description | This command configures or requests the instrument to calculate the average value of the Time Interval of the signal on the selected channel. | |

:TOTalize

CONFigure[:SCALar][:VOLTage]:TOTalize [(@2)]
 MEASure[:SCALar][:VOLTage]:TOTalize? [(@2)]

| | | |
|--------------------|--|--|
| Parameters | [(@2)] | The signal on Ch. B will be used for any measurements. |
| Description | This command controls the totalize measuring capabilities of the instrument. | |

:TIMed

CONFigure[:SCALar][:VOLTage]:TOTalize:TIMed [(@2)]
 MEASure[:SCALar][:VOLTage]:TOTalize:TIMed? [(@2)]

| | | |
|--------------------|--|---|
| Parameters | [(@2)] | The gate time on Ch. B will be the one measured or changed. |
| Query | TIMed? | Query the present gate time on Ch. B. |
| Description | This command configures or requests that the instrument either measure the current gate time on Ch. B or set a new gate time to be used for further measurements. With an external gate on Ch. A, the query will count the input events on Ch. B, not the gate time. | |

:PHASe

CONFigure[:SCALar][:VOLTage]:PHASe [(@1) , (@2)]
 MEASure[:SCALar][:VOLTage]:PHASe? [(@1) , (@2)]

| | | |
|--------------------|--|---|
| Parameters | [(@1) , (@2)] | Choose the signal on Ch. A or Ch. B for use in the measurement. |
| Query | PHASe? | Query the phase of the signal between the selected channels. |
| Description | This command configures or requests the instrument to measure the phase of the signal between the selected channels. | |

:PTPeak

CONFigure[:SCALar][:VOLTage]:PTPeak [(@1)]
 MEASure[:SCALar][:VOLTage]:PTPeak? [(@1)]

| | | |
|--------------------|--|---|
| Parameters | [(@1)] | The signal on Ch. A will be used for the measurement. |
| Query | PTPeak? | Query the Peak-to-Peak value of the signal on Ch. A. |
| Description | This command configures or requests the instrument to measure the Peak-to-Peak value of the signal on Ch. A. The instrument calculates this value by measuring the Maximum voltage level and subtracting the measured Minimum voltage level. | |

:MAXimum

CONFigure[:SCALar][:VOLTage]:MAXimum [(@1)]
MEASure[:SCALar][:VOLTage]:MAXimum? [(@1)]

| | | |
|--------------------|---|---|
| Parameters | [(@1)] | The signal on Ch. A will be used for the measurement. |
| Query | MAXimum? | Query the maximum voltage level of the signal on Ch. A. |
| Description | This command configures or requests the instrument to measure the maximum voltage level of the signal on Ch. A. | |

:MINimum

CONFigure[:SCALar][:VOLTage]:MINimum [(@1)]
MEASure[:SCALar][:VOLTage]:MINimum? [(@1)]

| | | |
|--------------------|---|---|
| Parameters | [(@1)] | The signal on Ch. A will be used for the measurement. |
| Query | MINimum? | Query the minimum voltage level of the signal on Ch. A. |
| Description | This command configures or requests the instrument to measure the minimum voltage level of the signal on Ch. A. | |

A.9 Subsystem commands

A.9.1 INPut Commands

:INPut [1 | 2]

The input subsystem is used to set input conditions on the selected channel.

:ATTenuation

INPut[1|2]:ATTenuation 1|10

| | | |
|--------------------|--|---|
| Parameters | 1 10 | X1 or X10 attenuation. The default X1. |
| Query | ATTenuation? | Query the present setting of attenuation. |
| Description | This command is used to set the input attenuation to either X1 or X10. | |

:COUpling

INPut[1|2]:COUpling DCIAC

| | | |
|--------------------|--|--|
| Parameters | DCIAC | DC or AC. The default is AC. |
| Query | COUpling? | Query the present setting of the coupling. |
| Description | This command is used to set the input coupling to either DC or AC. | |

:FILTer

INPut[1|2]:FILTer

| | | |
|--------------------|---|---|
| Query | FILTer? | Query the present status of the filter. |
| Description | This command is the start of the command path to enable or disable the low-pass filter on the input signal. Including OFF or ON in the command statement will enable or disable the filter, the following two commands can be included before OFF or ON but are optional. | |

[:LPASs]

INPut[1|2]:FILTer[:LPASs]

| | |
|--------------------|---|
| Description | This command specifies the filter type as low-pass. |
|--------------------|---|

[:STATe]

INPut[1|2]:FILTer[:LPASs][:STATe] OFF|ON

| | | |
|--------------------|--|--|
| Parameters | OFF ON | OFF or 0 disables the filter. ON or 1 enables the filter. |
| Query | STATe? | Query the present status of the filter. |
| Description | This command instructs the instrument to enable or disable the low-pass filter on the input signals. | |

:IMPedance

INPut[1|2]:IMPedance 1e6|50

| | | |
|--------------------|---|---|
| Parameters | 1e6 50 | 1e6 ohms or 50 ohms. The default is 1e6 ohms. |
| Query | IMPedance? | Query the present setting of the input impedance. |
| Description | This command is used to set the input impedance on the selected channel. Entering parameter values other than 50 or 1e6 yield on error message. | |

A.9.2 SENSE Commands

[:SENSe]

The Sense subsystem is used to configure and control measurement functions that are not related to signal-oriented characteristics.

:EVENT [1 | 2]

[[:SENSe]:EVENT [1|2]

| | | |
|--------------------|--|--------------------------------|
| Parameters | [1 2] | Select Ch. A or Ch. B. |
| Query | EVENT? | Query present channel setting. |
| Description | This command is used to set the channel whose event will be counted as the start/stop edge for later frequency measurements. | |

:SLOPe

[[:SENSe]:EVENT{1|2}]:SLOPe POSitive|NEGative

| | | |
|--------------------|---|---|
| Parameters | POSitive NEGative | POSitive denotes the rising edge. NEGative denotes the falling edge. The default is POSitive. |
| Query | SLOPe? | Query the present edge setting. |
| Description | This command instructs the instrument as to which edge of the signal to consider an event for frequency measurements. | |

:LEVel

The LEVel command path is used to set the level at the center of the hystersis window.

[[:ABSolute]]

[[:SENSe]:EVENT{1|2}]:LEVel[:ABSolute] <NR1> [V]

| | | |
|--------------------|---|--|
| Parameters | <NR1> [V] | The level range is -5.00 V to +5.00 V when input attenuation is X1. The level range changes to -50.0 V to +50.0 V when input attenuation is X10. The default is 0 V. |
| Query | [ABSolute]? | Query the present level at the center of the hystersis window. |
| Description | This command is used to set the level at the center of the hystersis window. The actual trigger event is at the top of the hystersis window for POSitive slope or at the bottom for NEGative slope. | |

This setting has no effect while [[:SENSe]:EVENT:LEVel:AUTO] is ON. Sending this command does not turn off AUTO.

:AUTO

[[:SENSe]:EVENT[1|2]:LEVel:AUTO OFF|ON

| | | |
|--------------------|--|---|
| Parameters | OFF ON | OFF or 0 disables the "auto-trigger". ON or 1 enables the "auto-trigger". The default is ON. |
| Query | AUTO? | Query the present setting of the "auto-trigger" enable. |
| Description | This command is used to set the "auto-trigger" enable. When ON the instrument will automatically select a trigger level. | |

:FREQuency

The frequency command path is used to control the frequency measuring capabilities of the instrument.

:ARM

This subtree is used to synchronize the frequency start and stop arm with events.

[[:START]

This command is the alias for the first arming sequence.

:SOURce

[[:SENSe]:FREQuency:ARM[:START]:SOURce IMMEDIATE

| | | |
|--------------------|---|---|
| Parameters | IMMEDIATE | IMMEDIATE specifies that the instrument will not wait for an event. |
| Query | SOURce? | Query the present setting of the start arm. |
| Description | This command instructs the instrument how long to wait for an event. The only option (for amount of time delay) for this instrument is IMMEDIATE. | |

:STOP

This command is the alias for the second arming sequence.

:DIGits

[[:SENSe]:FREQuency:ARM:STOP:DIGits <NR1>

| | | |
|--------------------|---|--|
| Parameters | <NR1> | The range of digits is from 3 to 10. The default is 4. |
| Query | DIGits? | Query the present resolution. |
| Description | This command is used to set the resolution (in digits) the instrument is to use in arming frequency measurements. | |

:SOURce

[[:SENSe]:FREQuency:ARM:STOP:SOURce TIMer]DIGits

| | | |
|--------------------|--|--|
| Parameters | TIMer]DIGits | The TIMer, the internal periodic signal, or the DIGits value is used as an indicator for the stop arm. |
| Query | SOURce? | Query the present setting. |
| Description | This command instructs the instrument what to use as the indicator for the stop arm. | |

:TIMer

[[:SENSe]:FREQuency:ARM:STOP:TIMer <NR3>][S]

| | | |
|--------------------|--|--|
| Parameters | <NR3> [S] | The TIMer range is from 100E-6 seconds to 100E+0 seconds. The default is 100E-3 seconds. |
| Query | TIMer? | Query the gate time. |
| Description | This command is used to set the gate time used in arming the frequency measurements. | |

A.9.3 SYSTEM Commands

:SYSTEM

The system command path is used to query the contents of the error queue and the identification code of the instrument.

:ERROR?

SYSTEM:ERROR?

Query ERROR? Query the contents of the error queue. The error codes are listed in Table A-5.

Table A-5
Errors

| Number | Error name | Cause |
|--------|----------------------------|---|
| 0 | No Error | The error queue has been cleared by a power-on or *CLS or all errors in the queue have been read (with :SYSTEM:ERROR?). |
| -100 | Command Error | When the counter cannot detect more specific errors this is the generic syntax error used. |
| -102 | Syntax Error | An unrecognized data type or command was received. |
| -104 | Data Type Error | A data element differing from the one allowed was recognized by the parser. For example, string data was sent when numeric data was expected. |
| -109 | Missing Parameter | Fewer parameters than the number required by the header were received. |
| -113 | Undefined Header | The header is undefined for the counter though it is syntactically correct. |
| -120 | Numeric Data Error | When the counter cannot detect a more specific error when parsing a numeric data element this generic error message is sent. |
| -131 | Invalid Suffix | The suffix is inappropriate for the counter or its syntax does not follow that described in IEEE 488.2. |
| -213 | Init Ignored | Another measurement was in progress causing a request for measurement initiation to be ignored. |
| -222 | Data Out Of Range | The legal data element received could not be used because its value is outside the valid range defined by the counter. |
| -224 | Illegal Parameter Value | A value not included on a list of possible values was received. |
| -350 | Queue Overflow | An error occurred but was not recorded because the error queue is full. |
| -410 | Query Interrupted | A condition occurred causing an Interrupted Query error. |
| +2009 | No Valid External Timebase | External reference has been selected but the external signal is not an allowed frequency, or there is no external reference applied to the rear-panel Ref In connector. |

:VERSION?

SYSTEM:VERSION?

Query VERSION? The identification code includes manufacturer, model number, serial number, and firmware revision level:

KEITHLEY, 776, x, REV yyyy

Where: x is the serial number

yyyy is the firmware revision level

A.9.4 Trigger Commands

:ABORt

:ABORt

Description

This command aborts the measurement in progress. If continuous trigger cycles have been enabled with INIT:CONT ON, measurements then continue. If continuous trigger cycles are disabled, measurements stop.

:INITiate

The INITiate command path is used to enable or disable the continuous initiation of trigger cycles.

:CONTinuous

INITiate:CONTinuous OFF|ON

Parameters

OFF|ON

OFF or 0 disables continuous trigger cycles.
ON or 1 enables continuous trigger cycles. The default is OFF.

Query

CONTinuous?

Query the present setting.

Description

This command is used to instruct the instrument whether or not to initiate continuous trigger cycles. Disabling continuous cycles will result in the instrument initiating only a single trigger cycle.

[:IMMediate]

INITiate[:IMMediate]

Description

This command instructs the instrument to initiate a single trigger cycle. It is optional because the instrument will do that on its own if CONTinuous is set to OFF.

A.10 Program examples

Example 1

'Example program demonstrating the commands used to change input
'coupling and filter settings

'Edit the following line to where the QuickBASIC libraries are on
'your computer
'\$INCLUDE:'e:\qb45\ieeqb.bi'

'Initialize the CEC interface as address 21
CALL initialize (21,0)

'Reset all subsystem settings
CALL SEND (14,"*rst",status%)

'Change Input Coupling and Filter settings from their defaults
'All possible optional commands are also included
CALL SEND (14,"input:coupling DC",status%)
CALL SEND (14,"input:filter:lpass:state ON",status%)

'Configure Pulse Width and request measurement
CALL SEND (14,"configure:pwidth 10e-5",status%)
CALL SEND (14,"fetch?",status%)
reading\$ = spaces (80)
CALL ENTER (reading\$,length%,14,status%)
PRINT reading\$

Example 2

'Example program to demonstrate initiating continuous
'triggering

'Edit the following line to where the QuickBASIC libraries
'are on your computer
'\$INCLUDE:'e:\qb45\ieeqb.bi'

'Initialize the CEC interface as address 21
CALL initialize (21,0)

'Reset controls
CALL SEND (14,"*rst",status%)

'Set instrument in continuous trigger
'cycle mode
CALL SEND (14,"initiate:continuous ON",status%)

Example 3

'Example program to demonstrate some of the commands
'used with the Status Model

'Edit the following line to where the QuickBASIC libraries
'are on your computer
'\$INCLUDE:'e:\qb45\ieeqb.bi'

'Initialize the CEC interface as address 21
CALL initialize (21.0)

'Clear all event registers
CALL SEND (14, "*cls", status%)

'Set OPC bit in the Standard Event Status Register
CALL SEND (14, "*opc?", status%)

'Read the Standard Event Status Register
CALL SEND (14, "*esr?", status%)

A.11 Device-dependent commands and SCPI commands

Table A-6 cross-references the command set of the Models 776 and 776/2.4G with the command set of the Model 776/2.4G/R.

Table A-6
Device-dependent commands to SCPI commands and common commands

| DDC | SCPI command or common command equivalent |
|-------|--|
| F0 | :CONFigure[:SCALar][:VOLTage]:FREQuency [(@1)] |
| F1 | :CONFigure[:SCALar][:VOLTage]:FREQuency (@2) |
| F2 | :CONFigure[:SCALar][:VOLTage]:FREQuency (@3) |
| F3 | :CONFigure[:SCALar][:VOLTage]:PERiod [(@1)] |
| F4 | :CONFigure[:SCALar][:VOLTage]:PWIDth [(@1)] |
| F5 | :CONFigure[:SCALar][:VOLTage]:TINterval [(@1).(@2)] |
| F6 | :CONFigure[:SCALar][:VOLTage]:TOTalize [(@2)] |
| F7 | :CONFigure[:SCALar][:VOLTage]:FREQuency:RATio [(@1).(@2)] |
| F8 | :CONFigure[:SCALar][:VOLTage]:PHASe [(@1).(@2)] |
| F9 | :CONFigure[:SCALar][:VOLTage]:PTPeak [(@1)] |
| F10 | :CONFigure[:SCALar][:VOLTage]:PERiod:AVERage [(@1)] |
| F11 | :CONFigure[:SCALar][:VOLTage]:PWIDth:AVERage [(@1)] |
| F12 | :CONFigure[:SCALar][:VOLTage]:TINterval:AVERage [(@1).(@2)] |
| F6;M1 | :CONFigure[:SCALar][:VOLTage]:TOTalize:TIMed [(@2)] |
| AS0 | [:SENSe]:EVENt1:SLOPe POSitive |
| AS1 | [:SENSe]:EVENt1:SLOPe NEGative |
| BS0 | [:SENSe]:EVENt2:SLOPe POSitive |
| BS1 | [:SENSe]:EVENt2:SLOPe NEGative |
| ALn | [:SENSe]:EVENt1:LEVel[:ABSolute] <NR1> [V] |
| BLn | [:SENSe]:EVENt2:LEVel[:ABSolute] <NR1> [V] |
| L0 | [:SENSe]:EVENt2:LEVel:AUTO OFF |
| L1 | [:SENSe]:EVENt2:LEVel:AUTO ON |
| Gn | [:SENSe]:FREQuency:ARM:STOP:TIMer <NR3> [S] |

Table A-6(cont.)

Device-dependent commands to SCPI commands and common commands

| DDC | SCPI command or common command equivalent |
|-----|---|
| AA0 | :INPut1:ATTenuation 1 |
| AA1 | :INPut1:ATTenuation 10 |
| BA0 | :INPut2:ATTenuation 1 |
| BA1 | :INPut2:ATTenuation 10 |
| AC0 | :INPut1:COUPling DC |
| AC1 | :INPut1:COUPling AC |
| BC0 | :INPut2:COUPling DC |
| BC1 | :INPut2:COUPling AC |
| AF0 | :INPut1:FILTer[:LPASs][:STATe] OFF |
| AF1 | :INPut1:FILTer[:LPASs][:STATe] ON |
| BF0 | :INPut2:FILTer[:LPASs][:STATe] OFF |
| BF1 | :INPut2:FILTer[:LPASs][:STATe] ON |
| AIO | :INPut1:IMPedance 1e6 |
| AI1 | :INPut1:IMPedance 50 |
| BI0 | :INPut2:IMPedance 1e6 |
| BI1 | :INPut2:IMPedance 50 |
| S0 | :INITiate:CONTInuous ON |
| S1 | :INITiate:CONTInuous OFF |
| T | :INITiate[:IMMEDIATE] |
| STn | *SAV |
| REn | *RCL |

Note:

The following DDCs have no SCPI or common command equivalent:
 GU, Wn, WU, I0, I1, V0, V1, M2, C0, C1, S2, S3, and Q0 through Q4.



Service Form

Model No. _____ Serial No. _____ Date _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

- | | | |
|--|--|--|
| <input type="checkbox"/> Intermittent | <input type="checkbox"/> Analog output follows display | <input type="checkbox"/> Particular range or function bad; specify |
| <input type="checkbox"/> IEEE failure | <input type="checkbox"/> Obvious problem on power-up | <input type="checkbox"/> Batteries and fuses are OK |
| <input type="checkbox"/> Front panel operational | <input type="checkbox"/> All ranges or functions are bad | <input type="checkbox"/> Checked all cables |

Display or output (check one)

- | | |
|-----------------------------------|--|
| <input type="checkbox"/> Drifts | <input type="checkbox"/> Unable to zero |
| <input type="checkbox"/> Unstable | <input type="checkbox"/> Will not read applied input |
| <input type="checkbox"/> Overload | |

- | | |
|---|--|
| <input type="checkbox"/> Calibration only | <input type="checkbox"/> Certificate of calibration required |
| <input type="checkbox"/> Data required | |

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

Be sure to include your name and phone number on this service form.

Specifications are subject to change without notice.

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28775 Aurora Road • Cleveland, Ohio 44139 • 440-248-0400 • Fax: 440-248-6168
1-888-KEITHLEY (534-8453) www.keithley.com

Bergensesteenweg 709 • B-1600 Sint-Pieters-Leeuw • 02/363 00 40 • Fax: 02/363 00 64
Yuan Chen Xin Building, Room 705 • 12 Yumin Road, Dewai, Madian • Beijing 100029 • 8610-6202-2886 • Fax: 8610-6202-2892
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