MODEL 6000

(212) 255-2940

clarke·hess

COMMUNICATION RESEARCH CORP.

220 W. 19th STREET • NEW YORK, N.Y. 10011

INSTRUCTION MANUAL
MODEL 6000
PHASE METER

(212) 255-2940

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WARRANTY

All CLARKE-HESS instruments are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery of the instruments. The CLARKE-HESS Communication Research Corp. will repair or replace instruments that prove to be defective during the warranty period. For such repair or replacement the instrument must be returned to CLARKE-HESS and, in our opinion, the instrument must not have been subjected to unreasonable usage or to internal reworking. No other warranty is expressed or implied.

CLARKE-HESS assumes no liability for secondary damages or charges.

SPECIFICATIONS

PHASE

Ranges:	Two Ranges 0° to 360° and -180° to 180°. Range switching is accomplished automatically when operation approaches within 10° of the range limits.
Resolution:	10m° (0.01°)
Repeatability:	±10m° or better
Accuracy: (Sine Waves)	±200m° from 5Hz to 10Hz ±50m° from 10Hz to 50kHz $\pm[50 + 2(f_{kHz} - 50)]$m° from 50kHz to 100kHz $\pm[150 + 3.5(f_{kHz} - 100)]$m° from 100kHz to 500kHz
Accuracy: (Square Waves)	$\pm[50 + (f_{kHz})]$m° (Equal Amplitudes) $\pm[50 + 4.4(f_{kHz})]$m° (Unequal Amplitudes at Range Limits)
Offset:	The OFFSET toggle subtracts the current phase reading from all subsequent phase readings. The range about the Offset point is ±180° which is independent of phase autoranging.

INPUT CHARACTERISTICS-EITHER CHANNEL

Amplitude Range:	10mV RMS to 350V RMS in three ranges: 10mV to 500mV RMS, 500mV to 12.5V RMS and 12.5V to 350V RMS. Range switching is accomplished automatically when operation approaches within approximately 10% of the range limits. (From 10mV to 20mV derate phase accruacy by a factor of 2.)
Input Impedance:	1Mohm in parallel with less than 50pF. Front Panel BNC
Input Waveforms:	Sine, Triangle, Trapezoidal or Square. The Phase Meter provides a reading proportional to the average of the difference between the positive zero crossings and the difference between the negative zero crossings of the inputs. These zero crossings are determined after the waveforms are AC coupled.
Maximum DC Input:	The DC component of either input waveform should be 200V or less.
Frequency Range:	5Hz to 500kHz

RESPONSE TIME

Less than 6 seconds to specified accuracy

DISPLAY

0.5" High Efficiency LED Display for Phase. Small High Efficiency LED Lamps to indicate Phase Range, REMOTE, Phase OFFSET ON, and OVERRANGE and UNDERRANGE for both input channels.

CONTROLS

Front Panel: Phase OFFSET key switch, LOCAL key switch and Phase RANGE toggle key switch

Rear Panel: Five position IEEE-488 Address switch

ANALOG OUTPUT

+1.80 to -3.60V DC with a sensitivity of -10mV/° and an accuracy of ±0.5% + phase accuracy. 250ohm output impedance. Rear Panel BNC

IEEE-488 SUBSETS

SH1, AH1, T6, L4, SR1, RL1, PP0, DC1, DT0

WARMUP TIME

Less than 30 minutes for all specifications

TEMPERATURE RANGE

Specified Accuracy: 23°C ±5°C
Safe Operation: 0°C to 50°C

RELATIVE HUMIDITY

Specified Accuracy: 20% to 50% RH
Safe Operation: 15% to 80% RH

LINE VOLTAGE, FREQUENCY AND POWER CONSUMPTION

100V ±10%, 120V ±10%, 220V ±10%, 240V ±10% (Rear Panel switch selectable), 50Hz - 60Hz
Power Consumption less than 20W

PHYSICAL

Rack or bench mount. Bail allows 10° upward tilt.
Weight: 11 pounds (5.1kg)
Size: 19" x 3.5" x 13" (48.3cm x 8.9cm x 33.0cm)

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I OPERATION

1-1 INTRODUCTION

In this section an overview of the properties of the Model 6000 Phase Meter is first presented. This is followed by a more detailed look at the various controls and features available to the operator. Finally a step by step set of operating instructions is included.

1-2 GENERAL DESCRIPTION

The Model 6000 Phase Meter is a precision instrument which measures the phase angle difference between two similar voltage waveforms with the same frequency in the range from 5Hz to 500kHz with a typical accuracy of 0.02° and with a resolution of 0.01°. The voltage waveforms may have independent amplitudes anywhere in the range from 10mV to 350V RMS which the Meter accommodates automatically by autoranging. A peak to peak voltage waveform less than 56mV or greater than 882V is indicated respectively by the illumination of an UNDERRANGE or OVERRANGE LED lamp.

The phase angle is displayed in Degrees on a 5 Digit High Efficiency LED display over the span from -180° to +360° which is covered by two ranges of 0° to 360° and -180° to +180°. The Model 6000 autoranges from one range to the other whenever the phase angle approaches within 10° of the range limit. Phase angle discontinuities of ±360° are only apparent when autoranging occurs from the high end of the 0° to 360° range and from the low end of the -180° to +180° range. A RANGE toggle key on the front panel of the Meter permits manual transitions from one range to the other. The current range is always indicated by the illumination of an appropriate LED lamp. The RANGE toggle permits operation to be kept on the 0° to 360° range when the phase difference between two pulse waveforms is being measured.

An OFFSET toggle key is also located on the front panel. An LED lamp indicates the active or ON state of the OFFSET. Pressing this key once activates the OFFSET and causes the current phase angle indication to be subtracted from all subsequent phase angle indications with the result that a new "Phase Origin" is established. A new range of ±180° about this origin is also established. Within this range no ±360° discontinuities occur even if internal autoranging takes place. At ±180° discontinuities do however occur. Pressing the key a second time returns the Meter to its normal operating mode. The Offset toggle may be used to refine the calibration of the Phase Meter at higher frequencies. If the same signal is placed into both the SIGNAL and the REFERENCE INputs and the OFFSET is activated, small constant phase errors are removed.

The Model 6000 also allows the user to deactivate the internal low pass filtering to obtain higher accuracy when measuring the phase angle between two square waves of unequal amplitudes. The filtering is toggled by holding down the LOCAL key and then pressing the RANGE key. When the filtering is removed two parallel horizontal bars precede the phase angle indication on the Display.

The Model 6000 has as a standard feature the IEEE-488 interface which is accessible from the rear panel. A Controller may receive the Display indication as well as the status of the front panel lamps via the interface. The Controller may also send via the interface commands which place the Phase Meter in its remote state, toggle the RANGE, and toggle the internal low pass filtering. In the remote state, which is indicated by the illumination of the REMOTE LED lamp, the front panel key switches are disabled and any existing OFFSET is reset. A LOCAL key switch, however, allows the operator to regain local control.

An ANALOG OUTPUT on the rear panel provides a DC voltage proportional to the Display reading with a constant of proportionality of -10mV per degree. This voltage, which is useful in driving external meters or recorders, varies between -3.6V and +1.8V.

The Phase Meter is designed to operate with line voltages of 100V, 120V, 220V and 240V at frequencies from 50Hz to 400Hz. A switch in the line cord receptacle on the rear panel permits the voltage selection. This receptacle also contains a line filter which restricts the passage of high frequency signals both from the Meter to the line and from the line to the Meter.

The Phase Meter is contained in a 19" wide, 3.5" high and 14" deep (including rack handles) case and may be used on the bench or mounted in a standard relay rack.

1-3 SPECIFICATIONS

The detailed specifications for the Model 6000 are included in the table preceding this section.

1-4 CONTROLS AND TERMINALS

This sub-section describes in reasonable detail the function and properties of the various front and rear panel controls and terminals. The user of the Model 6000 Phase Meter should familiarize himself thoroughly with this material before attempting to operate the instrument.

Figure 1-4-1 illustrates the controls. Each control will be discussed in the numerical sequence shown in the figure.

1 POWER SWITCH

Depressing this on/off switch applies line power to the Phase Meter which is indicated by the illumination of the Display. It also initializes the main microprocessor and the microprocessor on the IEEE-488 interface card.

2 REMOTE INDICATOR / LOCAL KEY SWITCH

The REMOTE lamp indicates when the IEEE interface Controller has placed the Meter in its remote state and thus disabled the the front panel key switches.

When it is illuminated no manual control of the OFFSET or RANGE key switches is possible. Depressing the LOCAL key switch (provided that the interface has not placed the Meter in the Local Lockout state) allows the operator to restore the Meter to its local state for manual operation.

When the Phase Meter is not in its remote state, the LOCAL key acts as a "shift" key to access control of the internal low pass filtering. Pressing the RANGE key while holding the LOCAL key down toggles in and out the low pass filters in both channels of the Model 6000. When the filters are removed, two parallel horizontal bars appear on the left side of the Display and bit 7 in the Status Byte sent over the IEEE-488 Interface is set.

3 OFFSET KEY SWITCH AND INDICATOR

The OFFSET key is a toggle whose active state is indicated by the lamp above it. When it is activated it subtracts the current phase reading on the Display from all subsequent phase readings to establish a new phase origin. Consequently, the Display indicates 000.00 upon activation. If the phase angle between the two input signals is then changed, readings up to ±180° from the new origin are displayed. At ±180° the phase reading jumps to the opposite end of the ±180° range. When the OFFSET is active the RANGE key is disabled and the state of the internal low pass filters cannot be changed.

The OFFSET is cleared either by pressing the OFFSET key a second time or by placing the Model 6000 in its Remote state via the IEEE-488 Interface. The active state of this key is also indicated by the presence of bit 5 in the Status Byte sent over the IEEE-488 Interface when a Serial Poll is requested by the bus Controller.

The OFFSET should not be used when pulse waveforms are being measured.

4 RANGE KEY SWITCH AND INDICATORS

The RANGE key switch provides the means of manually toggling between the two phase ranges of the Model 6000: the -180° to +180° range and the 0° to 360° range. The current range is always indicated by one of the two lamps above the switch. Depending upon the Display reading when the key is pressed, one of several things happens. If the Display reading is between 10° and 170° the range changes without affecting the reading. If the Display reading is between -170° and -10° the range changes and the reading increases by 360°. If the Display reading is between 190° and 350° the range changes and the reading decreases by 360°. For the remaining Display readings, the range change would be within 10° of the new range limit; hence, the Phase Meter, after switching ranges, autoranges back to its original range. When the 0° to 360° range is active, bit 4 is set in the Status Byte sent over the Interface when a Serial Poll is requested by the Controller.

When measuring the phase angle between pulse waveforms, the 0° to 360° should be selected with the RANGE key whenever possible to avoid a possible 180° phase error. The -180° to 180° range may be used for angles between -15° and +15° to cover the portion of the 0° to 360° range excluded by autoranging.

If the OFFSET is active, the RANGE key is disabled; however autoranging still takes place.

If the RANGE key is pressed while the LOCAL key is held down, the internal low pass filters in both channels of the Model 6000 are toggled in and out. When the filters are removed, two parallel horizontal bars appear on the left side of the Display and bit 7 in the Status Byte sent over the IEEE-488 Interface is set.

5 DISPLAY

The 5 digit High Efficiency LED Display indicates the phase angle being measured, in degrees, from -180.00° to +360.00° and from -180° to +180° when the OFFSET has been activated. In all cases it is the actual Display reading which is sent over the IEEE-488 Interface when requested by the bus Controller.

When the internal low pass filtering of the Model 6000 has been deactivated, two parallel horizontal bars appear on the left of the display. One is directly above and the other is directly below the position which indicates negative polarity.

6 SIGNAL INPUT AND RANGE INDICATORS

A BNC connector accepts the SIGNAL INput waveform, which in the case of a sinewave may have any value from 10mV to 350V RMS (or 28mV to 990V peak to peak). Non-sinusoidal periodic waveforms have the same peak to peak range as a sinewave. The span of input voltages is accommodated on three voltage ranges which are selected automatically by the Phase Meter. The low range extends from 10mV to approximately 500mV RMS (28mV to 1.41V peak to peak), the middle range extends from 500mV to approximately 12.5V RMS (1.41V to 35.4V peak to peak) and the high range extends from 12.5V to 350V RMS (35.4V to 990V peak to peak). Approximately 10% range overlapping exists to allow for the hysteresis required with autoranging. When an input signal approaches the upper limit of a particular range, the OVERRANGE lamp is illuminated and the Meter switches to the next higher range which results in the lamp being extinguished. If the Meter is already on its highest range then the lamp remains illuminated. On the other hand, when an input signal approaches the lower limit of a particular range, the UNDERRANGE lamp is illuminated and the Meter switches to the next lower range. If the Meter is already on its lowest range the lamp remains illuminated. The OVERRANGE lamp remains on for signals above 312V RMS (880V peak to peak for non-sinusoidal waveforms) while the UNDERRANGE lamp remains on for signals below 20mV RMS (56mV peak to peak).

When the OVERRANGE lamp in the Signal channel is on, bit 3 in the Status Byte sent over the IEEE-488 Interface is set, whereas when the UNDERRANGE lamp is on bit 2 is set.

7 REFERENCE INPUT AND RANGE INDICATORS

A BNC connector accepts the REFERENCE INput waveform, which in the case of a sinewave may have any value from 10mV to 350V RMS (or 28mV to 990V peak to peak). Non-sinusoidal periodic waveforms have the same peak to peak range as a sinewave. The span of input voltages is accommodated on three voltage ranges which are selected automatically by the Phase Meter. The low range extends from 10mV to approximately 500mV RMS (28mV to 1.41V peak to peak), the middle range extends from 500mV to approximately 12.5V RMS (1.41V to 35.4V peak to peak) and the high range extends from 12.5V to 350V RMS (35.4V to 990V peak to peak). Approximately 10% range overlapping exists to allow for the hysteresis required with autoranging. When an input signal approaches the upper limit of a particular range, the OVERRANGE lamp is illuminated and the Meter switches to the next higher range which results in the lamp being extinguished. If the Meter is already on its highest range then the lamp remains illuminated. On the other hand, when an input signal approaches the lower limit of a particular range, the UNDERRANGE lamp is illuminated and the Meter switches to the next lower range. If the Meter is already on its lowest range the lamp remains illuminated. The OVERRANGE lamp remains on for signals above 312V RMS (880V peak to peak for non-sinusoidal waveforms) while the UNDERRANGE lamp remains on for signals below 20mV RMS (57mV peak to peak).

When the OVERRANGE lamp in the Reference channel is on, bit 1 in the Status Byte sent over the IEEE-488 Interface is set, whereas when the UNDERRANGE lamp is on bit 0 is set.

8 SIGNAL INPUT (REAR PANEL)

This opening in the rear panel is normally fitted with a hole plug. When the Rear Panel Input option is specified when ordering a Phase Meter, this opening is fitted with a BNC connector to accept the SIGNAL INput and the corresponding opening on the front panel is fitted with a hole plug. In no case can front and rear panel inputs be present at the same time.

9 ANALOG OUTPUT

A BNC connector provides a DC voltage which is proportional to the difference between the phase angle of the REFERENCE INput and the SIGNAL INput. The constant of proportionality is -10mV per degree; hence the output voltage varies between 1.8V and -3.6V as the displayed phase varies between -180° and +360°. This output has the same common connection as the two signal input connectors to the Phase Meter. Consequently, only "floating" recorders and meters should be connected to this terminal to avoid the introduction of "ground loops" which might have an adverse effect on the phase accuracy. The analog output is not affected by the OFFSET key switch.

10 REFERENCE INPUT (REAR PANEL)

This opening in the rear panel is normally fitted with a hole plug. When the Rear Panel Input option is specified when ordering a Phase Meter, this opening is fitted with a BNC connector to accept the REFERENCE INput and the corresponding opening on the front panel is fitted with a hole plug. In no case can front and rear panel inputs be present at the same time.

11 IEEE-488 INTERFACE CONNECTOR

This rear panel connector is the standard IEEE-488 connector which mates with standard, stackable cable connectors which permit parallel bus connections. To avoid possible mechanical damage, it is recommended that no more than three connectors be stacked on any one instrument.

12 INTERFACE ADDRESS SWITCH

This switch is set by the operator to be the address to which the instrument responds when under the control of the IEEE-488 Interface. The address may be set on the switch, which is binary weighted, to have any value between 0 and 30. The Phase Meter is set at the factory with an address of 5 as shown in Fig. 1-4-1. If a change in switch setting is made by the operator, the POWER switch must be turned off for 10 seconds and then back on again to enter the new address into the Phase Meter.

13 POWER RECEPTACLE

The Power Receptacle accepts the input line cord, provides a fuse for the high voltage line, includes the switch for configuration of the Meter to accept the desired input voltage, and incorporates a line filter for minimizing the interference from the Phase Meter back into the line. Both the line fuse and the line voltage selection switch may be reached by opening the back cover of the receptacle. This is accomplished by prying open the plastic cover from the top with the blade of a screwdriver.

With the back cover open, the fuse may be reached (and replaced if necessary by a 1/2 A AGC fuse) by pulling out the fuse cradle which is marked with a white arrow. This cradle should be replaced with the arrow in the same direction as the arrow on the inside of the back cover.

With the back cover open, the line voltage may be selected by removing the switch drum, rotating it so that the desired line voltage will show through the small window in the back cover, and then replacing it. The cover should then be closed and snapped in place.

NOTE

Any attempt to rotate the switch drum without first removing it will result in damage to the switch contacts.

1-5 INSTALLATION

The Model 6000 Phase Meter is shipped ready for either bench or rack operation. Before applying power to the Meter for the first time, the operator should check that his correct line voltage appears through the window of the POWER RECEPTACLE (see 13 in the previous sub-section). If it does not, the switch should be changed as described above.

1-6 OPERATION INSTRUCTIONS

To make precision phase angle measurements between two periodic waveforms, turn on the Model 6000 Phase Meter and allow it to warm up for approximately 10 minutes. After warm-up, apply the two waveforms, whose phase difference is to be measured, with equal length coaxial cables to the SIGNAL INput and the REFERENCE INput terminals of the Meter. The Phase Meter will automatically select the input ranges and the phase range for proper operation. Read the phase difference between the two inputs on the Display. If two positive pulse waveforms are being measured, use the RANGE key to ensure operation is on the 0° to 360° range except for Display readings between -15° and +15°. If two square waves of unequal amplitude are being measured, press the RANGE key while holding down the LOCAL key to remove the internal low pass filters. Note the two horizontal bars on the left of the Display.

During autoranging of the inputs, the OVERRANGE or UNDERRANGE lamps of both channels flash prior to the selection of a new range. The lamps should go out at the end of the process. If a lamp remains on it indicates that an input signal is either close to or has exceeded the range limits. The signal amplitude in this case should be checked with the use of an external voltmeter.

If the phase angle between the two input waveforms is in the vicinity of zero, the Model 6000 selects the -180° to 180° phase range. If the angle is then increased, the range automatically changes at 170° to the 0° to 360°range; however, no discontinuity in the Display reading results. If the phase angle is increased further the original range is automatically selected at 350°, but, in this case, a jump in the Display reading of -360° to -10° occurs. Further increases cause the cycle to repeat.

On the other hand, if the phase angle is decreased from zero, the range automatically changes at -170° with a jump in the Display reading of +360° to +190°. If the phase angle is decreased further, the original range is automatically selected at 10° without a discontinuity in the display reading. Further decreases cause the cycle to repeat.

The range may be toggled manually by pressing the RANGE key on the front panel. Confirmation of the range change is given by the lamp above the key. Such changes allow the user both to verify that the two ranges match in their region of overlap and also to change the Display reading from positive to negative angles, or vice versa, in the regions where the ranges do not overlap.

Relative phase angle readings about a fixed starting angle may be obtained by pressing the OFFSET key with the starting phase difference set between the two input waveforms. When the key is pressed the OFFSET lamp is illuminated and the Display reading is set at 000.00°. As the phase angle between the waveforms is varied, the Display reading becomes the algebraic difference between the current phase angle and the starting phase angle. The OFFSET feature may be used at higher frequencies to improve the accuracy of the Meter. This is accomplished by placing the same signal (usually the larger one of the two input signals) into both the REFERENCE INput and the SIGNAL INput terminals and then activating the OFFSET to eliminate any small phase angle errors.

With the OFFSET activated, the effective phase range becomes -180° to +180°. At 180° the Display reading jumps to -180° and vice versa. Even though autoranging of the main phase ranges may occur as the input phase angle is varied, the Display reading is adjusted internally to preserve the effective range.

The OFFSET feature should not be used when measuring pulse waveforms.

1-7 ERROR SOURCES IN PHASE MEASUREMENTS

The two main sources of error in making phase measurements is the presence of distortion or noise in one phase channel that does not exist in the same form in the other. To understand the reason behind these errors it is first necessary to have a general idea of how the Phase Meter performs its measurement of phase. In general terms, the Phase Meter first evaluates the time difference between the positive-going zero crossings of the two input waveforms, then evaluates the time difference between the negative-going zero crossing, averages the two differences and finally normalizes the result to the period of the waveforms to obtain a phase angle which appears on the Display. Any property of the input waveform which has an effect on its zero crossings has the potential of giving rise to a phase error. Because of the averaging operation however, if this property causes the positive going and the negative going zero crossings to be displaced by equal and opposite amounts, the effects cancel with the result that there is no net phase error.

1-7-1 DISTORTION

In general, if the two periodic waveforms being applied to the Phase meter are distorted from their original form by some external networks, no distortion induced phase meter errors occur provided that:

1. Both waveforms are identical (with the exception of voltage scaling) and are distorted in exactly the same fashion.

2. Either waveform is distorted in such a way that when its average value is removed, its zero crossings are the same as the undistorted waveform less its average value. If a waveform (less its average value) has odd symmetry about any conveniently chosen origin, i.e., if

$$f(x) = -f(-x),$$

then any distortion which preserves the odd symmetry (affects the top and bottom of the waveform in the same fashion) has no effect on the zero crossings. If the distortion has the form of odd harmonic distortion which has the same zero crossing as the waveform then the odd symmetry is preserved and no phase error results. In general, the odd harmonic distortion terms can be broken into two components: one with odd symmetry and one without it. It is the component without the symmetry which gives rise to phase errors.

3. Either waveform is distorted in such a way that its positive and negative going zero crossings change by an equal and opposite amount. If a waveform has even symmetry about any conveniently chosen origin, i.e., if

$$f(x) = f(-x),$$

then any distortion which preserves the even symmetry moves the two zero crossings an equal and opposite amount. (Sine waves, square waves and triangular waves have both odd and even symmetry with the origins of the two symmetry axes separated by 90°.) For example, if only the top of a waveform with even symmetry is clipped, the even symmetry is preserved and no phase error results. Similarly, if a DC component is added to the waveform by the internal circuitry of the Phase Meter, the even symmetry is preserved and no phase error results. If the distortion has an even harmonic form, it can be broken into two components: one with even symmetry and one without it. However, the component without the even symmetry has odd symmetry about an origin displaced by 90°; hence if either of the two components are zero no phase errors result. The worst error in this case occurs when both components are equal and even then the error is second order and quite small. The reason the error exists at all is that when the component with odd symmetry is combined with the waveform its even symmetry is modified slightly such that when the component with even symmetry is added the zero crossings do not shift exactly an equal and opposite amount.

In general it is the component of the odd harmonic distortion without odd symmetry, which is present on one input and not the other, that is responsible for any phase error which may exist. The magnitude of the error in radians is approximately the ratio of the harmonic amplitude to the signal amplitude. For example, 0.1% of third harmonic distortion (-60dB) which has no odd symmetry component produces a phase error of 1mradian or 57m°. Similarly if the third harmonic distortion is 1% (-40dB), a phase error of 0.573° results.

If the distortion on only one input signal is even harmonic distortion, then the worst phase error occurs when the two components with odd and even symmetry are equal. For this case the magnitude of the error in radians is approximately equal to the square of the ratio of the distortion component amplitude to the signal amplitude. For example, with 1.4% of second harmonic distortion (-37dB), both even and odd symmetry components are 1% and thus the error is 100microradians or 5.7m°. Clearly if the even harmonic is less than 1%, any phase error caused by it is smaller than the resolution of the Phase Meter in the worst case.

1-7-2 NOISE

When an input signal to the Phase Meter has an additive noise component, random fluctuations in the zero crossings result. These fluctuations have two distinct effects on the phase error depending whether they are higher in frequency content or lower in frequency content than the frequency of the input signal. If the frequency content of the noise is primarily lower than that of the input signal, the zero crossing is dominated by the signal but fluctuates in both a positive and negative direction because of the noise. The low frequency filters prior to the Display in general remove these fluctuations which have no average value and therefore no contribution to the phase.

If the frequency content of the noise is primarily higher than that of the input signal, the zero crossings are dominated by the noise, that is, in the vicinity of a signal zero crossing the higher frequency noise causes multiple zero crossings. Since the internal circuitry of the Phase Meter responds to the first crossing, high frequency noise always causes premature zero crossing detection. Hence, if the noise is in the Signal channel a positive phase error results; whereas if the noise is in the reference channel a negative phase error results.

The Model 6000 itself is designed with two internal filter banks in each channel to help remove the high frequency noise as the frequency of the signal is decreased. The first filter bank is switched in when the input frequency drops below 7000Hz and the second filter bank is switched in when the input frequency drops below 700Hz. Because of this filtering, signal to noise ratios of as low as 40dB may be applied to either channel without causing more than a 50m° phase error. As in the case of distortion, if an identical amount of noise with the same frequency spectrum is applied to both channels such that both channels have the same signal to noise ratio, no phase error results. The limit to the amount of noise that may exist, even though the same amount is applied to both channels, is set by the point where spurious zero crossings are generated by the noise. This results in large and rapid fluctuations in the Display reading.

Because of the rapid rise times of a square wave, noise has much less of an effect on its zero crossings than it would on a sine wave of corresponding amplitude; hence little or no filtering is required. In practice, such filtering causes more phase error with rapid rise time waveforms than the noise does. Consequently the filter banks should be removed when square waves or other rapid rise time waveforms are being measured. This is particularly true for waveform frequencies in the vicinity of 700 Hz and 7000 Hz, which correspond to the top of each filter bank. Of course, the filters need not be removed if the amplitudes of the square waves in both channels are equal since they are affected in exactly the same fashion by the filtering; hence no net phase error results.

1-8 REMOTE OPERATION

This sub-section is intended for the person who has a good working knowledge of the IEEE-488 interface and the associated Controller programming and needs only a knowledge of the device dependent functions to get started using the Phase Meter remotely. If the material in this sub-section is not sufficiently detailed for the reader, he should first read Section V where the interface is considered more thoroughly.

1-8-1 INTERFACE FUNCTIONS

The following tabulation lists the level to which each of the IEEE-488 interface functions are implemented in the Phase Standard.

SH1 Source Handshake Complete capability.

AH1 Acceptor Handshake Complete capability.

T6 Talker Basic talker with Serial Poll capability . Unaddressed if MLA.

L4 Listener Basic listener unaddressed if MTA.

SR1 Service Request Complete capability.

RL1 Remote local Complete capability.

PP0 Parallel poll No capability.

DC1 Device clear Complete capability.

DT0 Device trigger No capability.

1-8-2 DEVICE ADDRESS

The device address (between 0 and 30) is set via the five position rear panel switch. The switch is binary coded with the A0 position corresponding to a 1, the next position to a 2, the next position to a 4 and so on. The positions are activated by pushing them up (on). The Phase Meter is shipped from the factory set with an address of 5 (the left most switch position and the middle switch position up and all others down). After the address switch is set, the Meter must be turned off for 10 seconds and then back on to enter the address into it.

1-8-3 DEVICE DEPENDENT INTERFACE INPUT

The only device dependent interface inputs to which the Phase Meter responds is the command to toggle the RANGE, the command to set the Service Request Mask, the command to remove the internal filter banks and the command to reinstate the internal filter banks. It ignores anything else sent to it over the interface including terminators such a carriage return, line feed or EOI. An ASCII "S" sent to the Phase Meter toggles the RANGE between 0° to 360° and -180° to +180°. An ASCII "O" sent to the Phase Meter removes the internal filter banks while an ASCII "I" reinstates them. The SRQ Mask is considered below.

1-8-4 INTERFACE OUTPUT

The Phase Meter sends its Display reading over the interface as a sequence of 9 ASCII characters. The format of the sequence is the sign, the five digits and the decimal point corresponding to the Display reading in degrees, and the terminator comprising a carriage return and a line feed. An EOI is sent along with the line feed. The Display reading can be sent over the interface at a maximum rate of three per second which corresponds with the Display update rate.

1-8-5 SERIAL POLL

The Status byte returned when the Phase Standard responds to a Serial Poll has the following format.

Bit 0 being set indicates that the signal at the Reference channel input is less than 56mV peak to peak. This bit corresponds exactly to the front panel UNDERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 1 being set indicates that the signal at the Reference channel input is greater than 882V peak to peak. This bit corresponds exactly to the front panel OVERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 2 being set indicates that the signal at the Signal channel input is less than 56mV peak to peak. This bit corresponds exactly to the front panel UNDERRANGE lamp and thus may be set momentarily during an autoranging operation.

front panel UNDERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 3 being set indicates that the signal at the Signal channel input is greater than 882V peak to peak. This bit corresponds exactly to the front panel OVERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 4 being set indicates that the Model 6000 RANGE is set to 0-360°

Bit 5 being set indicates that the Model 6000 OFFSET is ON. If this is the case then the Display Reading sent over the bus will have an unknown constant in it. To remove this constant the Model 6000 should be placed in its Remote state or the OFFSET key on the front panel should be pressed.

Bit 6 being set indicates that the Phase Meter has requested service by activating the SRQ line. This condition results when a bit in the SRQ mask has been set and the corresponding bit in the Status byte occurs.

Bit 7 being set indicates that the low pass filter banks in both channels of the Model 6000 have been deactivated.

Bit 0 through bit 5 and bit 7 are reset when the state of the Model 6000 which causes them ceases to exist except when the SRQ line has been asserted. In this case the bits are reset following the next Serial Poll received by the Meter. Bit 6 is reset following the next Serial Poll request received by the Meter.

1-8-6 SRQ MASK

The SRQ Mask is set by sending MY, where M is ASCII "M" and Y is a byte whose bits correspond to the bits in the Status byte, over the interface to the Phase Meter. Only bit 0 through bit 5 may be masked by placing a 1 in the appropriate bit positions. When the mask is set to recognize a particular bit in the Status byte and this bit is set by the Phase Meter two things occur. Bit 6 in the Status byte is also set and the SRQ line is set true. There is no change in the Status byte until it is cleared by a Serial Poll which also sets the SRQ line false. With the aid of this mask and a controller that responds to a SRQ interrupt, there is no chance of missing a desired bit setting in the Status word.

Bit 3 being set indicates that the signal at the Signal channel input is greater than 882V peak to peak. This bit corresponds exactly to the front panel OVERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 4 being set indicates that the Model 6000 RANGE is set to 0-360°

Bit 5 being set indicates that the Model 6000 OFFSET is ON. If this is the case then the Display Reading sent over the bus will have an unknown constant in it. To remove this constant the Model 6000 should be placed in its Remote state or the OFFSET key on the front panel should be pressed.

Bit 6 being set indicates that the Phase Meter has requested service by activating the SRQ line. This condition results when a bit in the SRQ mask has been set and the corresponding bit in the Status byte occurs.

Bit 7 being set indicates that the low pass filter banks in both channels of the Model 6000 have been deactivated.

Bit 0 through bit 5 and bit 7 are reset when the state of the Model 6000 which causes them ceases to exist except when the SRQ line has been asserted. In this case the bits are reset following the next Serial Poll received by the Meter. Bit 6 is reset following the next Serial Poll request received by the Meter.

1-8-6 SRQ MASK

The SRQ Mask is set by sending MY, where M is ASCII "M" and Y is a byte whose bits correspond to the bits in the Status byte, over the interface to the Phase Meter. Only bit 0 through bit 5 may be masked by placing a 1 in the appropriate bit positions. When the mask is set to recognize a particular bit in the Status byte and this bit is set by the Phase Meter two things occur. Bit 6 in the Status byte is also set and the SRQ line is set true. There is no change in the Status byte until it is cleared by a Serial Poll which also sets the SRQ line false. With the aid of this mask and a controller that responds to a SRQ interrupt, there is no chance of missing a desired bit setting in the Status word.

The SRQ Mask can only be cleared by sending MY where Y comprises all zeros or by turning the POWER off and back on again.

II THEORY OF OPERATION

2-1 INTRODUCTION

In this section the theory required to understand the operation of the Model 6000 Phase Meter is presented on two levels. First the operation is considered from a block diagram point of view and then each block is explored in detail with the aid of the Phase Meter schematic diagrams.

2-2 GENERAL OPERATION

In most general terms, the Model 6000 measures the phase angle between the two periodic input waveforms by generating pulses which are proportional to the phase angle difference between the two waveforms, averaging and scaling the pulses, converting the resultant DC waveform into a 16 bit digital signal, and finally converting the digital signal into a form (with the aid of the system Microprocessor) which drives the front panel Display. The start and finish of the pulses correspond to the zero crossings of the SIGNAL INput waveform and the REFERENCE INput waveform respectively as shown at the bottom of Fig 2-2-1. Two pulses are generated each cycle and these two pulses are averaged in order to eliminate the effects of any inadvertent DC offset in either of the two waveforms. Two different phase ranges, 0° to 360° and -180° to +180°, are obtained by either starting and terminating the pulses with zero crossings having the same slope or starting and terminating the pulses with zero crossings having the opposite slope. When opposite slope zero crossings are employed for the ±180° range, a constant proportional to 180° must be subtracted from the averaged pulse waveform to compensate for the increased pulse duration.

The block diagram of the Model 6000 is shown in Fig. 2-2-1. From the figure it can be seen that both the SIGNAL INput terminal and the REFERENCE INput terminal are followed by identical channels comprising an Input Attenuator, an FET Amplifier, a Clipper, a second Amplifier, a Low Pass Filter Bank, and two Comparators. Each channel produces a normal and an inverted square wave whose transitions correspond to the zero crossings of the signal at the channel input. These square waves are differentiated to produce trigger pulses which are steered via a Multiplexing circuit to the two Bistable Flip Flops which generate the pulses proportional to the phase angle difference between the two input waveforms. The direction through the Multiplexor, which is controlled by a signal from the system Microprocessor, determines the phase RANGE of the Meter.

The pulse waveforms at the Flip Flop outputs are converted to corresponding pulses with precision amplitudes equal to Vref by means of electronic switches as shown in the block diagram. These pulses are then combined and placed through a low pass filter to extract their DC value. If the ±180° range has been selected, the average value is then combined with an inverted DC signal proportional to both Vref and a phase angle of 180°. Finally, the signal is placed through an additional low pass filter and applied to both a buffer for the ANALOG OUTPUT and the dual slope Analog to Digital converter (ADC) which produces a 16 bit output which corresponds to the phase angle. The reference signal for the ADC is also proportional to Vref; hence any dependence on Vref is eliminated when the input signal is normalized to the reference. The system Microprocessor samples the ADC output and converts it to seven segment form for the multiplexed display and an ASCII form for the IEEE-488 Interface.

Each input waveform is converted to a square wave in the same fashion. First it is placed through a compensated Input Attenuator with three possible attenuation ratios (1:1, 25:1 and 625:1). The system Microprocessor, with the aid of OVERRANGE and UNDERRANGE Detectors, selects the correct level to keep the attenuator output between 20mV and 500mV RMS (for sine waves). The attenuator is followed by a protection circuit which both AC couples the signal and limits the signal peaks to ±4.5V regardless of the input signal level or the ratio of the attenuator. The signal is then amplified by a factor of 11 such that it lies in the range of 220mV to 5.5V. At this point the signal is clipped by means of a pair of high speed hot carrier diodes and then amplified again by a factor of 11 in the High Frequency Amplifier. Finally the amplified signal is divided into two parts and each part is passed through a low pass filter whose bandwidth is decreased as the signal frequency decreases. Each filter output drives two comparators, one non-inverting and one inverting, to generate the channel output square waves.

A Frequency Detector, driven by the output of the inverting comparator in the SIGNAL INput channel, generates two gating signals which select the appropriate low pass filters in the Filter Bank and the corresponding frequency compensation of the high frequency amplifier. One gating signal is active for frequencies below 7000Hz while the other is active for frequencies below 700Hz. The additional filtering at low frequencies is required to eliminate high frequency noise which causes phase errors for low signal amplitudes. Because the waveform into the filter changes with signal amplitude, the filter itself introduces some amplitude dependent phase errors. The effect of these errors is minimized by the frequency compensation of the High Frequency Amplifier which is also controlled by the Frequency Detector gating signals.

In the sub-sections to follow, each block of the block diagram is explored in more detail with the aid of the circuit schematic diagrams.

2-3 INPUT ATTENUATOR (60000)

Drawing No. 60000 illustrates the Input Attenuator which comprises three independent attenuator sections each of which can be selected by closing relays at its input and output. The particular set of relays to be closed is selected by the system Microprocessor via I/O latch U2 and the relay driver U18 on the main board (60004). The 1:1 attenuator section only maintains the input impedance with R1 and C1 and requires no compensating. The 25:1 attenuator is compensated by means of C5, while the 625:1 attenuator is compensated by means of C9. The resistive portion of the input impedance of the three attenuator sections is matched by proper component selection, whereas the capacitive portion of the two higher attenuators is matched to that of the 1:1 attenuator by means of variable capacitors. C3 performs this function for the 25:1 section while C7 performs it for the 625:1 section.

2-4 INPUT PROTECTION (60000)

The input protection is accomplished with the use of a small coupling capacitor C14, two transistors Q1 and Q2 which act as diodes, and two zener diodes Z1 and Z2 which are biased "on" by the two resistors R16 and R17 respectively. If the peak signal level at C14 becomes too large, the transistors shunt the output of C14 to either one or the other zener diodes which is acting as a voltage source. Because C14 is small and therefore has a high impedance, only a small amount of current flows through it and only a small amount of power is dissipated in the transistor-zener diode combination. The duration of this power dissipation is also limited to 330mseconds since, by the end of this time interval, the Meter automatically autoranges.

2-5 FET AMPLIFIER (60000)

The FET Amplifier comprises an integrated FET amplifier U1 followed by a low impedance, high frequency driver U3. Feedback from the output of U3 to the input of U1 via resistors R8 and R7 sets the amplification factor at 11. Because of the small size of C14 for the purpose of protection, the input resistance of U1 needs to be extremely high to preserve the low frequency response of the Phase Meter and yet not so high as to generate an enormous DC input voltage as the leakage current from U1 flows through it. This conflict is resolved by extracting the DC component from the output of U3, comparing it with 0V in a low input offset amplifier U2 and using the amplified difference to control the DC offset of U1. The low pass filter in this feedback loop which comprises C10, C11, R13 and R14 has been optimized for both a good low frequency response and a reasonably rapid settling time.

2-6 CLIPPER (60003)

The Clipper consists of a series resistor R108 and two anode to cathode hot carrier diodes, D101 and D102, to ground. The diodes limit the signal to ±0.4V such that additional amplification is possible without over-driving the amplifier. (The part numbers for the Signal channel are being used in this section. Add 100 for the part numbers in the Reference channel.)

2-7 HIGH FREQUENCY AMPLIFIER (60003)

The High Frequency Amplifier U101 further increases the signal level by a factor of 11 before it is applied to the comparators so that slight variations in the comparator threshold levels become negligible. The amplification factor of the amplifier is determined by the resistors R102 and R103. C103 is used to compensate for the high frequency portion (C121, C124, C115 and C118) of the low pass filter. C102 is used to both trim C103 and to equalize the phase shift between the Signal and the Reference channel. The additional networks connected to the inverting input of the amplifier are for frequency compensation and are discussed in sub-section 2-9.

2-8 LOW PASS FILTER BANK (60003)

Beyond the High Frequency Amplifier the signal is broken into two parts. Each part is placed through an identical set of low pass filters prior to being applied to its respective comparator. For the top filter (as shown in the schematic diagram), the capacitors are selected by the Frequency Detector in such a fashion that C120 is placed in parallel with C121 and C123 is placed in parallel with C124 for frequencies below 7000Hz while C122 is placed in parallel with C120 and C121 and C125 is placed in parallel with C123 and C124 for frequencies below 700Hz. A particular capacitor is placed in parallel by changing the state of the transistor between the capacitor and ground from "open" to "saturated". This is accomplished by the Frequency Detector by reducing the voltage on the base resistor of the transistor from +15V to -15V.

The net result is that the filter bandwidth is approximately 4MHz for frequencies above 7000Hz, approximately 300kHz for frequencies between 7000Hz and 700Hz and approximately 25kHz for frequencies below 700Hz. With this approach, the noise components higher than the signal frequency, which are responsible for errors at low signal levels, are greatly reduced.

In order to prevent the filters themselves from causing phase errors, corresponding filter components in each channel are matched. These filters may be removed and reinstated by user activated commands from the front panel. Removal of the filters is recommended when measuring square waves of unequal amplitudes.

2-9 FREQUENCY COMPENSATION (60003)

When the clipped waveform is placed through the low pass filter, amplitude dependent phase errors result. To compensate for these errors as well as provide a means for correcting any filter mismatch between channels, compensation networks are placed at the inverting input of the High Frequency Amplifier. C102 and C103 provide compensation for the 4MHz filter, R104, C105 and P102 provide compensation for the 300kHz filter and R105, C106, and P103 provide compensation for the 25kHz filter. The compensation networks are switched in place by the Frequency Detector at the same frequencies as the low pass filters.

2-10 INVERTING AND NON-INVERTING COMPARATORS (60013)

The two high speed comparators generate the square waves corresponding to the zero crossings of the clipped and amplified input waveforms. A single package has been selected for the two comparators so that they have identical drift vs. temperature characteristics. Each comparator has a feedback resistor-diode combination and a capacitor connected from its output to its non-inverting input. This positive feedback causes the output to switch from a low output level to a high output level with a risetime that is independent of the slope of the input waveform. The feedback also introduces hysteresis which has some effect on the position in time of the high to low output transition; however this transition is not used for subsequent triggering. The inverting comparator has the provision for a DC offset, controlled by P104, to be added into its non-inverting input. This offset provides the means for correcting for any slight mismatch between the input offsets of the two comparators. Such a mismatch produces an amplitude dependent phase error which doubles each time the amplitude is decreased by a factor of 2. The inverting comparator also includes the network D106, R122, C128, and R121. This network provides a frequency dependent offset correction which comes into play for signal frequencies above approximately 10kHz. Such a correction is required to compensate for experimentally observed frequency dependent offset differences.

2-11 MULTIPLEXOR (60004)

The Multiplexor U12 is a quad 2-input Multiplexor. A single RANGE signal controls which input of all four Multiplexors is sent to the corresponding output. In principle, the two trigger pulses from the Signal channel, which are generated from the positive going edges of the comparator outputs by C17 and C16, need not be multiplexed. They are however, passed through two of the four Multiplexors, each of whose two inputs are tied together, in order to equalize the phase of both channels. The two trigger pulses from the Reference channel, which are generated from the positive going edges of the comparator outputs by C22 and C21, are each connected to an input of both the two remaining Multiplexors in such a fashion that when the ±180 RANGE line is low, the two output trigger pulses have the same correspondence to the comparators as the corresponding trigger pulses in the Signal channel. This is the configuration for the 0° to 360° range. With the ±180 RANGE line high the two output trigger pulses are reversed and the configuration for the -180° to +180° range results.

2-12 FLIP FLOPS (60004)

The two Flip Flops (#1 and #2) are contained in a single package U11 and are driven directly by the Multiplexor outputs to produce the waveforms shown at the bottom of Fig. 2-2-1.

2-13 ELECTRONIC SWITCHES AND OUTPUT FILTERS (60004)

The quad high speed Electronic Switches U9 and U10 are driven respectively by the outputs of Flip Flop #1 and Flip Flop #2. When the output of Flip Flop #1 is high, a switch section in U9 connects Vref to U6 via R23. When the output is low a second switch section in U9, driven by the inverted output of Flip Flop #1, connects R23 to ground. When the output of Flip Flop #2 is high, a switch section in U10 connects Vref to U6 via R22. When the output is low a second switch section in U10, driven by the inverted output of Flip Flop #2, connects R22 to ground. U6 averages and filters the two signals from the switches. The resistors R20, R23, and R22 set the transmission through U6 from each input to -1/2. C25 sets the filter bandwidth at approximately 3Hz. The output of U6 is a negative DC signal which is proportional to both Vref and the phase angle between the SIGNAL INput waveform and the REFERENCE INput waveform (plus 180° when the Phase Meter RANGE is ±180°).

The output of U6 is fed via R19 to the input of U7 which is a summing amplifier and low pass filter. When the ±180 RANGE line is high, Vref is also connected via P4, R17 and R18 to the input of U7. A third switch section in U10 performs this connection while the fourth switch section shorts the resistor pot combination to ground when the 0-360 RANGE line is high. The resistors R16 and R19 set the amplification factor of U7 at -1 for the signal from U6. R17, R18 and P4 set the transmission of Vref through U7 at -1/2. C20 sets the filter bandwidth to approximately 1.5Hz. The output of U7 is an inverted version of the output of U6 minus a DC signal proportional to Vref and 180° when the Phase Meter RANGE is ±180°. Adjustment of P4 permits the subtraction of a term proportional to exactly 180°. Consequently, the output of U7 is a DC signal which is directly proportional to Vref and the phase angle between the SIGNAL INput waveform and the REFERENCE INput waveform.

Potentiometer P2, in conjunction with R9, R14 and R15, provides an adjustable DC offset for U7. Proper adjustment of P2 removes the effect of any offset errors from either U6 or U7.

The output of U7 is buffered by U8 whose output provides the ANALOG OUTPUT which is a negative DC signal proportional to the phase angle between the two input waveforms. R12, R13 and P3 set the amplification of U8 such that a 340.00° phase angle produces an output of -3.400V. Adjustment of P3 allows the exact ratio of output voltage to phase angle of -10mV/° to be obtained. R10 sets the output impedance of the ANALOG OUTPUT.

2-14 ANALOG TO DIGITAL CONVERTER (60004)

The output of U7 supplies the input to the 16 bit, dual slope, auto-zeroing ADC which comprises U3, U4 and the surrounding resistors and capacitors. The ADC supplies to the Microprocessor a 16 bit digital output which is proportional to the ratio of the analog input signal (U4, pin 32) and the reference input signal (U4, pin 37). If the ratio is 2:1 the digital signal is $2^{16} - 1 =$ 65535. With any smaller ratio the digital signal is proportionally smaller. The main reference signal Vref is generated internally in U3 and is available at pin 6. This signal is attenuated by the combination of R6, P1 and R7 to derive the reference signal for U4. Since both the analog and the reference signals are proportional to Vref, it cancels when the ratio is formed to obtain the digital signal. The adjustment of P1 permits the precise full scale calibration of the digital signal.

2-15 FREQUENCY DETECTOR (60004)

Two structurally identical detectors provide output transitions between +15V and -15V when the frequency of their input signal decreases below a specific value. The high frequency detector has its low-to-high transition at approximately 7000Hz; the low frequency low-to-high transition is at approximately 700Hz. Both detectors contain hysteresis, such that the input frequency required to cause a low-to-high transition is 15% higher than the frequency required for the corresponding high-to-low transition. Each detector consists of a monostable negative pulse generator, a low pass filter and a bistable threshold circuit which provides the hysteresis. The average value of the negative pulse generator output decreases with frequency since the constant duration pulse occupies more of the period. This average value is extracted by the low pass filter and applied to the bistable circuit whose threshold has been adjusted to provide output switching at the proper frequencies.

The trigger pulse for both monostable pulse generators is provided by the combination of C35, R44 and R45. The high frequency monostable pulse generator comprises a comparator from U19, R43, R51, D5 and C34. The trigger pulse cause the comparator to change state causing its output to drop to approximately -15V. The capacitor C34 then begins to discharge through R51 until the non-inverting input of the comparator reaches a sufficiently positive value to cause the comparator to switch back to its original state. D5 prevents a large overshoot at the termination of the pulse.

The low pass filtering is provided by R50 and C32 and a second comparator from U19 acts as the bistable threshold circuit. Resistor R48 sets the amount of hysteresis, while R42 and R46 set the threshold level. R47 is a pull up resistor for the open collector output of the comparator.

A peak detector comprising D18 and C54 biases the input to the frequency detectors in such a fashion that if the signal disappears from the comparator output, the output of both detectors rise to +15V. This removes the low pass filters from the signal path until the input signal reappears.

The Microprocessor also provides an input to the detector which deactivates it in order to remove the low pass filter banks.

2-16 180° DETECTOR (60004)

The 180° DETECTOR provides an input to the microprocessor which has a high value when the SIGNAL INput and the REFERENCE INput signals are in phase and has a low value when the signals are out of phase. This input is used by the microprocessor when it is autoranging the phase range to remove ambiguities introduced by the Flip Flops at 0° and 180°. These ambiguities arise at the phase values where the Flip Flops are on the edge between their maximum pulse width and their minimum pulse width. Since one of the two Flip Flops driving the Electronic Switches will transition before the other, a phase output which is 180° in error occurs at this point. Such an error would give a Display indication that would inhibit autoranging. For example, when on the 0° to 360° RANGE, a phase difference between the two inputs of 360° could give rise to a Display indication of 180°. The microprocessor would interpret this as the correct range thus giving rise to a 180° error. However, the high input from the 180° detector indicates that the reading should be 0° and that autoranging is required.

The 180° Detector comprises an AND gate U20 and a low pass filter (R53 and C36) to extract the average value of output of the AND gate. The AND gate is driven by the non-inverting comparator of the signal channel and the non-inverting comparator of the reference channel. When the signals of the two channels are in phase the pulse width at the output of the AND gate is maximum with a maximum average value. When the signals are out of phase the output of the AND gate and its average value are zero.

2-17 OVERRANGE/UNDERRANGE DETECTOR (60003)

Each channel has a pair of detectors at the output of its FET amplifier which generate not OVERRANGE and not UNDERRANGE signals which are used by the microprocessor, via I/O latch U2, for amplitude autoranging and for driving the corresponding lamps on the front panel via the inverting drivers contained in U3. The OVERRANGE Detector comprises a threshold circuit set at approximately 0.5V, a negative peak detector, and a second threshold circuit to remove the variations of the peak detector at low frequencies. The UNDERRANGE Detector comprises a threshold circuit set at approximately 20mV, a negative peak detector, and a second inverting threshold circuit to remove the variations of the peak detector at low frequencies. The inversion in the second threshold circuit provides the desired output when the input signal is less than the first threshold value.

In the Signal channel, R127, R128 and R129 set the threshold levels for both the OVERRANGE and UNDERRANGE Detector U102 while D104, R133 and C134 and D105, R132 and C133 act respectively as the negative peak detectors. The second threshold circuits are the two remaining comparators in U102. R124 and R126 attenuate the input signal to the proper level for the OVERRANGE Detector and D103 and D107 prevent over driving U102 on the negative peaks of the signal. R125 buffers the output of the FET amplifier from the Detector and R130 and R131 are pull up resistors for the open collector outputs of the second set of comparators. C135 and C136 provide frequency compensation.

2-18 MICROPROCESSOR (60004)

The microprocessor (U1) provides the intelligence for the Phase Meter. It performs the functions of reading the ADC, monitoring the input key switches, monitoring the OVERRANGE and UNDERRANGE Detector (via U2), providing the signals to drive the display, providing the signals to set the amplitude ranges (via U2), providing the signals to drive the REMOTE, OFFSET ON, ±180° and 0° - 360° lamps (via U2), sending serial data to the IEEE-488 Interface board and receiving serial data from the IEEE-488 Interface board. The basic timing for the Microprocessor is provided by the 5.185mHz crystal (XL1). The circuit comprising D0, C1, and R1 provides a reset when power is applied.

2-19 DISPLAY, INDICATOR LAMPS, INPUT KEYS (60001)

The display Board contains the Display, the front panel LED's and the key switches for RANGE, OFFSET, and LOCAL. The Display comprises 6 seven segment LED display modules (U1-U6), 7 transistor segment drivers (Q1-Q6), their associated drive resistors (R8A-R8G), 6 digit drivers (U8A-U8F), and an I/O latch U7. The display is multiplexed by the microprocessor at a rate of one digit every 3.33mseconds; that is, the microprocessor activates U1 by setting the appropriate latches of U7 in such a fashion that the desired segments of U1 and the digit drive for U1 are active, then 3.33mseconds later activates U2, and so on. After U6 is activated the cycle returns to U1 with the result that each digit in the Display is activated 50 times each second. This rate is sufficient so that no "flickers" is perceived by the observer.

Each of the 8 LED indicator lamps (LD1-LD8) have a series current limiting resistor (R1-R4 and R9-R12). The OVERRANGE/UNDERRANGE lamps (LD5-LD8) are driven by U3 (60004). The REMOTE (LD1), OFFSET ON (LD2), +180° (LD3) and the 0° -360° (LD4) lamps are driven directly to the microprocessor. When a switch is pressed it connects 5V directly to the microprocessor. When the switches are not pressed, R3, R2 and R1 respectively hold the signals near zero volts. C3, C2 and C1 eliminate any high frequency pick-up from the lines to the microprocessor.

2-20 IEEE-488 INTERFACE (60006)

The IEEE-488 Interface board comprises a General Purpose Bus Controller (U8), a set of bus driver modules (U9 and U10), a microprocessor (U6), a pair of optical isolators (U2 and U3) and their associated drivers (U1 and U5), and a 5V regulator (U4) to supply isolated power to the board. The microprocessor on the main board (60004) communicates serially with the microprocessor on the Interface board via the two unidirectional, optically isolated channels. The Display indication, the status byte, and the state of the LOCAL key switch are sent asynchronously to the Interface board with a baud rate of 600 bits/second and a format of 1 start bit, 8 data bits, and 2 stop bits. Messages indicating transitions of the Interface from the REMOTE to LOCAL state or a RANGE change request are sent asynchronously from the Interface board with a baud rate of 50 bits/second and a format of 1 start bit, 8 data bits, and 2 stop bits.

In addition to sending information to and receiving information from the main board serially, the interface microprocessor reads the address switch at "turn on" and initializes the Bus Controller and formats the received serial information into 8 bit parallel messages which it sends to the Bus Controller. It also receives 8 bit parallel messages and status from the Bus Controller and formats if for serial transmission. The Bus Controller and Drivers provide all the protocol required by the IEEE-488 Standard.

2-21 POWER SUPPLY (60002)

The Power Supply, located on the main printed circuit board, is driven from a single power transformer (X1) with three secondary windings. The top winding shown in the schematic diagram is center tapped and drives a full wave diode bridge (D10-D13) followed by a set of filter capacitors (C37-C40) which provide the unregulated DC voltages for the positive and negative 15V supplies. Regulator U14 regulates the positive 15V supply while regulator U17 regulates the negative 15V supply. Regulator U15, whose input is driven by the +15V supply, provides the 12V supply and regulator U16, whose input is driven by the -15V supply, provides the -6V supply.

The middle transformer winding drives a full wave diode bridge (D6-D9) and a filter capacitor (C36) which provide the unregulated DC voltage for the 5V isolated supply on the Interface board (60006).

The bottom winding drives a full wave diode bridge (D14-D17) and two filter capacitors (C41 and C42) in parallel which provide the unregulated DC voltage for the 5V supply on the main board. Regulator U13 regulates the 5V supply.

Repeat the above procedure with a frequency of 50kHz.

When checking the phase meter performance at frequencies above 6.25kHz, it should be kept in mind that the Model 5000 (or equivalent) Phase Standard also has phase accuracy specifications. With equal amplitude signals the Model 5000 could contribute as much as 25m° from 6.25kHz to 50kHz and as much as 50m° from 50kHz to 100kHz. With a 100/1 amplitude ratio between the two Phase Standard outputs the possible error from 6.25kHz to 50kHz is doubled to 50m°. While it is not expected that the errors from the Phase Standard will approach these limits they should be kept in mind, particularly when investigating large signal amplitude ratios at frequencies above 25kHz.

3-4 AMPLITUDE LINEARITY

This test ensures that the Display indication of the Phase Meter is essentially independent of input voltage level on a particular amplitude range. The middle range is chosen for this test and then in a subsequent test it is verified that the lower and upper range track the middle range. The reference channel is checked first and then the signal channel.

With equal length cables connect the REFERENCE output and the VARIABLE output of the Phase Standard to the REFERENCE INput and the SIGNAL INput of the Phase Meter respectively. Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	VARIABLE:	4.000V
FREQUENCY:	100Hz	REFERENCE:	0.600V

Place the Standard in its OPERATE mode and note that the Phase Meter Display indicates 60.000° ±0.05 (typically ±0.02°). Now enter the following set of REFERENCE voltages and note that the Display indication remains within ±0.05°(typically ±0.02°) of 60.00°.

0.600V	2.00V	8.00V
0.800V	4.00V	10.00V
1.000V	6.00V	12.00V

Repeat the above procedure for frequency settings of 20Hz, 500Hz, 5000Hz, 20kHz, 50kHz and 100kHz. At 100kHz the tolerance should be tripled.

Now return the frequency to 100Hz. Set the REFERENCE output of the Phase Standard to 4.000V and set the VARIABLE output to the 9 different voltage values in the preceding table. Here again the Display indication should remain within ±0.05° (typically ±0.02°) of 60.00° for each voltage setting. Here again the procedure should be repeated for frequencies of 20Hz, 500Hz, 5000Hz, 20kHz, 50kHz and 100kHz. Allow ±0.15° at 100 kHz.

3-5 AMPLITUDE RANGE TRACKING

This test ensures that the three amplitude ranges in both the signal and reference channels are tracking one another.

III PERFORMANCE TESTS

3-1 INTRODUCTION

This section contains the procedures to verify that the Phase Meter is operating within its specified accuracy limits. The performance tests may be used as a basis for "incoming inspection". They may also be used on an annual basis to ensure that the meter has maintained its calibration.

The performance tests should be performed after power has been applied to the Phase Meter for at least 30 minutes.

3-2 TEST EQUIPMENT REQUIRED

1. Phase Standard. Clarke-Hess Model 5000 or equivalent.
2. DC voltmeter, 1mV to 10V, 0.1% accuracy.
3. Bus Controller. Hewlett-Packard HP-85 or equivalent.

3-3 ANGLE TRACKING ACCURACY

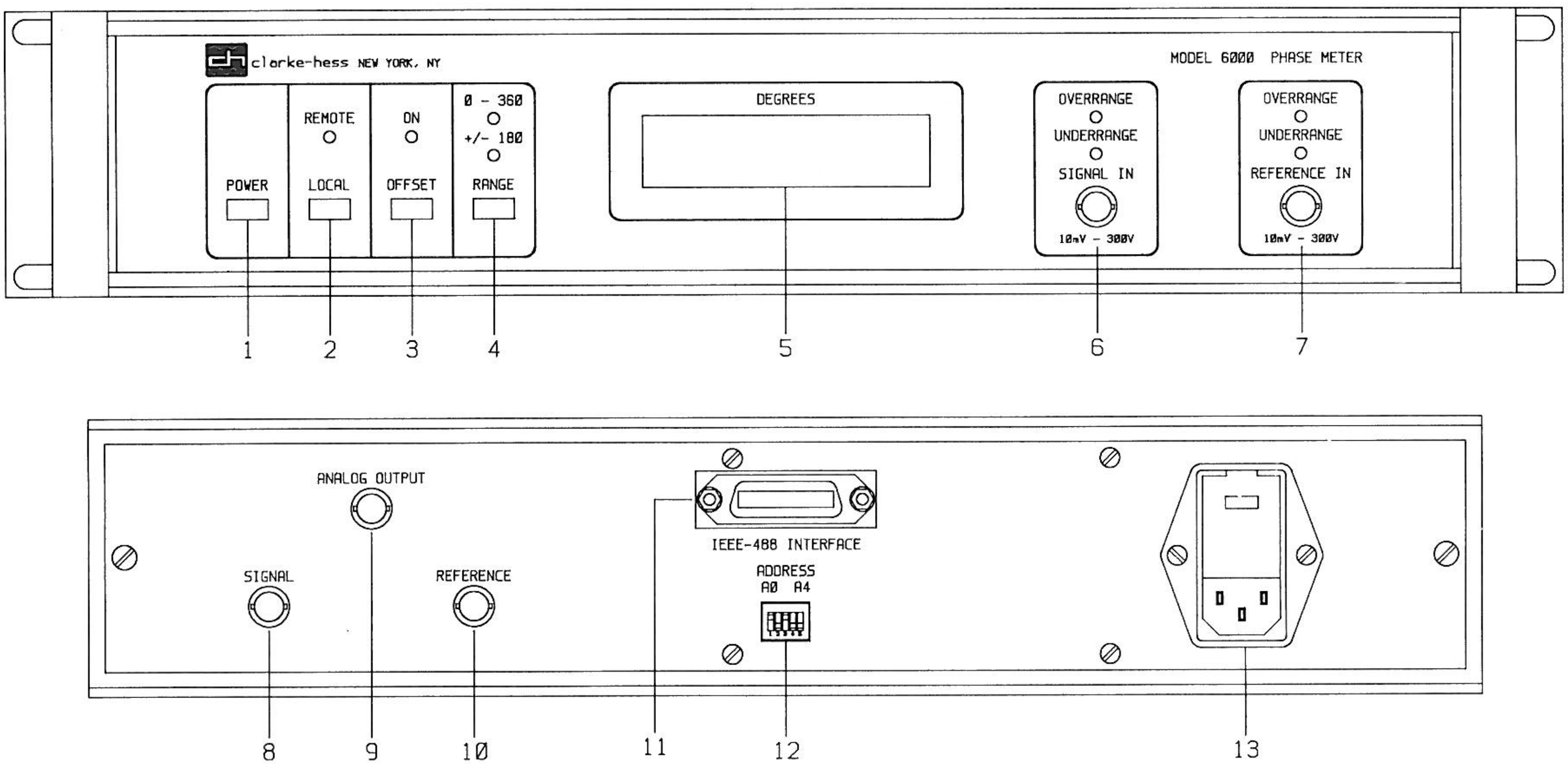
This test ensures that the Phase Meter accuracy is maintained over the entire range of angles displayed by the phase meter. It also ensures that the -180° to +180° range and the 0° to 360° range are tracking properly. The test is performed on the lowest amplitude range.

With equal length cables, connect the REFERENCE output and the VARIABLE output of the Phase Standard to the REFERENCE INput and the SIGNAL INput of the Phase Meter respectively. Enter the following set of parameters into the phase standard. (In this case and all cases to follow the OFFSET should be 0.000°.)

PHASE:	-160.000°	REFERENCE:	0.160V
FREQUENCY:	100Hz	VARIABLE:	0.160V

Place the Standard in its OPERATE mode and note that the Phase Meter Display indicates -160.00° ± 0.05° (typically ± 0.02), and that the ±180° range indicator is illuminated. If it is not press the RANGE key momentarily. Now increment the PHASE positively in 10° increments up to 340.000° and note that the Phase Meter Display tracks the incrementing with an accuracy of ±0.05° (typically ±0.02°).

During the incrementing it should be noted that autoranging to the 0° to 360° range occurs when the Display indication passes +170.00°. After the incrementing is completed set the PHASE to 60° and press the RANGE key switch to toggle the RANGE. Note that the Display indications on the two ranges agree within ±0.01°.



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION
PARTS LIST			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS ± DECIMALS XX ± XXX ± ANGLES ±

MATERIAL

FINISH

DO NOT SCALE DRAWING

CONTRACT NO

APPROVALS	DATE
DRAWN	
CHECKED	

NEXT ASSY	USED ON
APPLICATION	

clarke·hess COMMUNICATION RESEARCH CORP
NEW YORK NY 10011 • (212) 255-2940

FIGURE 1-4-1
FRONT AND REAR PANELS

SIZE C | CODE IDENT NO | DRAWING NO

SCALE | SHEET OF

With equal length cables, connect the REFERENCE output and the VARIABLE output of the Phase Standard to the REFERENCE INput and the SIGNAL INput of the Phase Meter respectively. Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	VARIABLE:	0.160V
FREQUENCY:	100Hz	REFERENCE:	0.160V

Place the Standard in its OPERATE mode and note that the Phase Meter Display indicates 60.00° ±0.05° (typically ±0.02°). Now enter the various combinations of REFERENCE and VARIABLE voltages from the following table and note that the Display indication remains within ±0.05° (typically ±0.02°) of 60.00°.

REFERENCE	VARIABLE
0.160V	0.160V
0.160V	4.00V
0.160V	100.0V
4.000V	0.160V
4.000V	4.000V
4.000V	100.0V
100.0V	0.160V
100.0V	4.000V
100.0V	100.0V

Repeat the above procedure for frequency settings of 50kHz and 100kHz. At 100kHz the indication should remain within ±0.15°.

3-6 OFFSET CONTROL

This test verifies the proper operation of the OFFSET function of the Phase Meter.

With equal length cables, connect the REFERENCE output and the VARIABLE output of the Phase Standard to the REFERENCE INput and the SIGNAL INput of the Phase Meter respectively. Enter the following set of parameters into the Phase Standard.

PHASE:	-90.000°	REFERENCE:	0.160V
FREQUENCY:	100Hz	VARIABLE:	0.160V

Place the Standard in its operate mode and note that the Phase Meter Display indicates -90.00° ±0.05° on the ±180° RANGE. Press the OFFSET key switch and observe that the ON lamp is illuminated and the Display indicates 000.00°. Now increment the Phase Standard positively in 10° steps to 90.000° and note that the Display indication increases by 10.00° ± 0.01° with each incrementing. When the incrementing has reached 90.000°, press the OFFSET key switch again and note that the Display indicates 90.00° ±0.05°.

3-7 ANALOG OUTPUT

This test checks the proper operation of the ANALOG OUTPUT. Connect the DC voltmeter to the ANALOG OUTPUT terminal and, with equal length cables, connect the REFERENCE output and the VARIABLE output of the Phase Standard to the REFERENCE INput and the SIGNAL INput of the Phase Meter respectively. Enter the following set of parameters into the Phase Standard.

PHASE:	-160.000°	REFERENCE:	0.160V
FREQUENCY:	100Hz	VARIABLE:	0.160V

Place the Standard in its OPERATE mode and note that the voltmeter indicates +1.60V ±0.1%. Now enter a PHASE of 0.000° into the Standard. The voltmeter should indicate 0V within ±500 microvolts. Finally enter a PHASE of 340.000° into the standard. The voltmeter should indicate -3.40V ±0.1%. Typically the error should be significantly less than 0.1%.

3-8 IEEE-488 INTERFACE

This test is sufficient to check the operation of the IEEE-488 Interface, as well as the REMOTE lamp and the LOCAL key switch.

Set the bus address of the Phase Meter at 05 with the DIP switch on the rear panel and connect the bus controller. Connect the Phase Standard to the Phase Meter in the same fashion as done previously and enter the following parameters into the Standard.

PHASE:	-60.000°	REFERENCE:	0.160V
FREQUENCY:	100Hz	VARIABLE:	0.160V

Place the Standard in its OPERATE mode and then send a REMOTE 705 command (for a the HP-85 controller) or a similar command for any other controller. Observe that the REMOTE lamp is illuminated. Press the OFFSET key switch and the RANGE key switch; note that neither switch has any effect. Now press the LOCAL key switch and note that the REMOTE lamp goes off.

Finally (if using an HP-85 controller) send the two commands, ENTER 705; N$ and DISP N$ and note that the Phase Meter Display indication appears on the CRT display of the controller. With any other controller perform the same operations of entering and displaying the display reading from the Phase Meter.

IV TROUBLE SHOOTING

4-1 INTRODUCTION

In normal usage none of the defects outlined in this section should ever occur. The procedures for locating possible troubles have been added to cover those rare cases where some accident does occur and immediate restoration of operation is desirable.

If the trouble cannot be eliminated through the use of these service instructions, please write or telephone our Service Department giving the instrument type number, the serial number, the trouble and the steps taken to remedy it. By return mail, or on the telephone, you will receive simple instructions as to the cause and repair of the defect, or authorization to return the instrument for repair or replacement.

Instruments no longer covered by warranty will be repaired or recalibrated after proper customer authorization is received to cover the estimated costs.

After some general servicing considerations, this Section will concern itself with the solution to some of the most common problems which possibly could occur with the Phase Meter.

4-2 GENERAL CONSIDERATIONS

At the first indication of any problem, a thorough visual inspection of the Phase Meter should be performed. In particular, it should be determined that the fuse is not blown, that all internal interconnecting cables are securely in place and that all integrated circuits are firmly in their sockets. The power supply should then be checked as described in sub-section 4-3. If no problem is uncovered then a systematic replacement of the integrated circuits can be attempted since all of the circuits are in sockets. This procedure requires a complete set of replacement circuits, including the factory programmed microprocessor. To help narrow down the problem and reduce the need for so many replacement parts, specific problems and the techniques for locating the component causing them are discussed in sub-section 4-4 and those that follow.

The equipment required for the procedures outlined in these sub-sections includes an oscilloscope with at least a 5mHz bandwidth and a voltage range from 10mV/cm to 20V/cm, a dc voltmeter with ranges from at least 1mV to 50V, a sine wave generator with a frequency range from 10Hz to 100kHz and a variable output signal level up to 7V RMS, and an IEEE-488 controller.

To gain access to the components on the main board the cover must be lifted off. This is accomplished by first removing the two screws in each side of the cover fastening it to the chassis. To reach the components on either of the input attenuator boards, the cover must be removed from the enclosing box by unfastening the six screws holding it in place. Removal of the three front screws requires that the top trim which secures the front panel be removed by unscrewing the two phillips head screws on either end. Removal of this trim also allows the front panel to be lifted out (after the cables from the Display board, the POWER switch, and the two input attenuator boards have been unfastened) in order to gain access to the Display board. The Interface board can be removed by removing the four screws securing it to the rear panel and then releasing the rear panel by removing the two screws on either end of it.

4-3 POWER SUPPLY FAILURE

In response to almost any malfunction the first items to check are the power supply voltages. If any voltage is found to be more than 5% different from its normal value a malfunction should be suspected. If the voltage is low the problem may be with one of the integrated circuits connected to the supply and not the supply itself. In this case all interconnecting cables from the other boards to the main board should be disconnected and the low supply re-measured. If the problem disappears the boards should be reconnected one by one until the offending board is found. The integrated circuits on this board should then be removed individually until the culprit is uncovered.

If the problem lies on the main board, all integrated circuits connected to the low supply should be removed. If this raises the low voltage, the circuits should be replaced one by one until the offending circuit is found.

The power supply voltages may be measured directly between the corresponding regulator pin which is closest to the rear panel of the Phase Meter and ground. A convenient ground connection is on the ANALOG OUTPUT terminal. If a supply is found to be in error, the most probable cause of trouble is the regulator itself. Prior to replacing it however; its input voltage should be checked to insure that it is at least 5V DC greater than the regulated voltage with no more than 1V p-p of double frequency ripple. If this is not the case the corresponding rectifier diodes and filter capacitors should be checked and replaced if necessary.

4-4 DISPLAY NOT ILLUMINATED

If the Display does not come on when POWER is applied to the Phase Meter the first thing to check is the fuse (see 1-4 (13)). If the fuse is not the problem and the cable between the main board and the Display board is securely fastened in place, apply a 4V RMS 100Hz input from the sine-wave generator to both inputs of the Phase Meter and attempt to read the Phase Meter via the IEEE-488 interface. If this is successful, i.e., a reading of approximately 0° is obtained, then the problem exists on the Display board with either U7 or U8. If the interface does not handshake and "hangs up" the problem is the main board microprocessor U1.

4-5 DISPLAY INDICATION DOES NOT VARY

If the display indication does not vary regardless of the phase angle between the two signals applied to the Phase Meter, the most probable output is the analog to digital converter on the main board. In this case U4 and U5 should be checked and replaced if necessary. If this does not cure the problem

U6, U7, U8, U9, U10, U11, and U12 should be checked and replaced if necessary. If the problem still is not solved proceed with sub-section 4-6.

4-6 DISPLAY JITTERS EXCESSIVELY

If the Display indication jumps continuously regardless of the Phase Meter inputs, the problem probably lies with a defective integrated circuit in one of the input channels. To determine which circuit has the problem apply a 4V RMS, 100Hz input from the sine-wave generator to both inputs of the Phase Meter and observe the waveforms on the rear of R106 and R206. In both cases a 100Hz, 1.8V RMS sine wave should exist. If it does not, the problem lies with the relay driver U18, the input/output latch U2 or the input attenuator board of either the signal channel or reference channel. If the problem is one of the input attenuator boards, the integrated circuits on the suspected board should be interchanged with those of the functioning board until the offending circuit is found.

If the signals on R106 and R206 exist, next observe the waveforms on pin #10 of U101 and on pin #10 of U201. If either waveform is not a 100Hz, 8V p-p clipped sinewave, replace the offending integrated circuit. If both waveforms exist, check pin #1 and pin #8 of U104 and pin #1 and pin #8 of U204. If any of the waveforms is not a 100Hz, 0V to 4.5V square wave, replace the integrated circuit with the improper output.

4-7 PHASE ERRORS WITH LARGE INPUT SIGNALS

If a phase error occurs for an input sine wave greater than 0.8V but not for a sine wave less than 0.4V in a particular channel, the chances are good that the OVERRANGE/UNDERRANGE detector in that channel is not functioning properly. Check U102 for the signal channel and U202 for the reference channel and replace either one if necessary.

4-8 ACTIVE COMPONENT REPLACEMENT

In general there is no problem in selecting a component to replace an active component which has failed. Some care must be taken, however, when a component in one of the input channels must be replaced. This is particularly true of the FET amplifier on the input attenuator board. If this amplifier has to be replaced, it should be matched to a second amplifier and the new set should be placed in the corresponding positions on both input boards. Matching is best accomplished by selecting two amplifiers which produce the same Display indication when the Phase Meter has both of its channels driven by a 1.2V peak to peak, 500kHz square wave and the same Display indication when both of its channels are driven by a 0.5V peak to peak 500kHz square wave.

V CALIBRATION

5-1 INTRODUCTION

The following procedures are necessary only if the Performance Tests of Section III indicate that the Phase Meter is not operating within its specified accuracy or if a repair has been made to the Meter. If calibration is undertaken, only the adjustments indicated with an asterisk (*) should be performed. The remaining adjustments are performed at the factory initially and should not have to be repeated. The adjustments outlined in sub-sections 5-3-1, 5-3-2 and 5-3-3 are the basis for all subsequent adjustments; hence they should be performed first.

The Phase Meter should be allowed to warm up for at least 30 minutes with its cover on before its top cover is removed to make an adjustment. It should be replaced after each adjustment. The location of the potentiometers and variable capacitors are shown in drawing (60002). All adjustments should be made with a non-conducting screwdriver.

5-2 TEST EQUIPMENT REQUIRED

1. Phase Standard. Clarke-Hess Model 5000 or equivalent.
2. Voltmeter, DC, lmV to 10V, 0.1% accuracy.
3. Resistive attenuator, 25:1 attenuation, 25k ohm input resistance.
4. Series impedance, 10Kohm resistor.

A diagram of two small metal boxes, one containing the 25:1 attenuator and one containing the series impedance is shown in Fig. 5-2-1. Metal boxes to enclose the components are recommended so that unwanted pickup is eliminated. A BNC plug rather than a BNC jack should be placed on one end of the series impedance box so that it can be connected directly to the Phase Meter without an intervening cable. A cable adds unknown and, in general, unwanted capacitance.

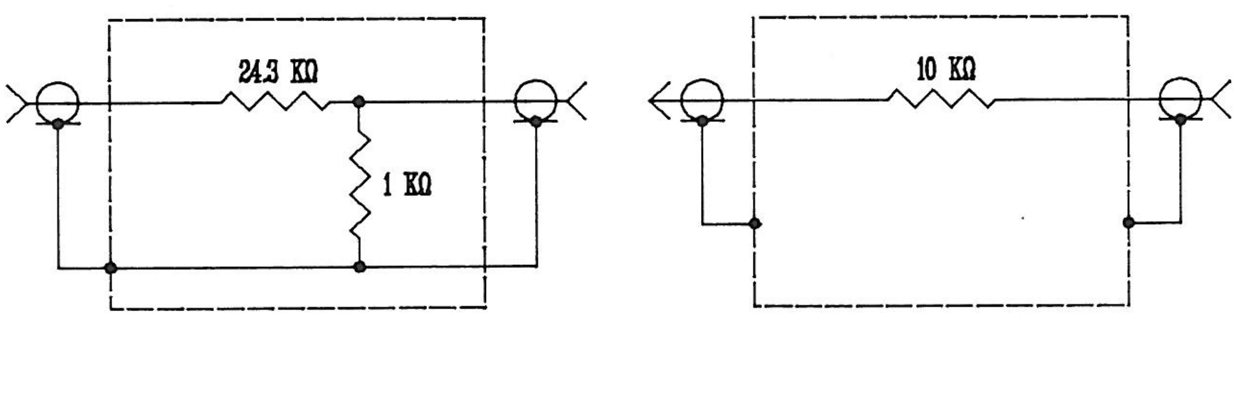


Figure 5-2-1 25:1 Attenuator Box and Input Impedance Box

The 25:1 attenuator is used for relative amplitude comparisons and not for absolute phase measurements; hence no attempt need be made to compensate the attenuator.

5-3 CALIBRATION PROCEDURES

For all the following procedures the Phase Standard REFERENCE output and SIGNAL output should be connected to the Phase Meter REFERENCE INput and SIGNAL INput respectively with equal length cables made of the same material. When the series impedance box is required it should be placed directly on the required input and the corresponding cable from the Phase Standard connected to it. When the 25:1 attenuator box is required, it should be connected to the Phase Standard with a short cable at its input and with a cable similar to that used in the other channel between its output and the Phase Meter.

In all of the following procedures the OFFSET set into the Phase Standard should be 0.000°.

5-3-1 FULL SCALE ADJUSTMENT* - P1

This adjustment and the following two (5-3-2 and 5-3-3) must be performed prior to any subsequent adjustments.

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	340.000°	REFERENCE:	0.160V
FREQUENCY:	100Hz	VARIABLE:	0.160V

(b) Set the Phase Meter on the 0° to 360° RANGE and adjust P1 for a Display indication of 340.00°.

5-3-2 ANALOG OFFSET ADJUSTMENT* - P2

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	15.000°	REFERENCE:	0.160V
FREQUENCY:	100Hz	VARIABLE:	0.160V

(b) Set the Phase Meter on the 0° to 360° RANGE and adjust P2 for a Display indication of 15.00°.

(c) Repeat the procedure in sub-section 5-3-1 and this procedure until no adjustment is required for either setting of the Phase Standard.

5-3-3 RANGE EQUALIZATION ADJUSTMENT* - P4

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	15.000°	REFERENCE:	0.160V
FREQUENCY:	100Hz	VARIABLE:	0.160V

(b) Set the Phase Meter on the -180° to +180° RANGE and adjust P4 for a Display indication of 15.00°.

5-3-4 ANALOG GAIN ADJUST* - P3

(a) Place the DC voltmeter on the ANALOG OUTPUT of the Phase Meter.
(b) Enter the following set of parameters into the Phase Standard.

PHASE:	340.000°	REFERENCE:	4.000V
FREQUENCY:	400Hz	VARIABLE:	4.000V

(c) Set the Phase Meter on the 0° to 360° RANGE and adjust P3 for a voltmeter indication of -3.40V ±0.1%.

5-3-5 LOW REFERENCE AMPLITUDE COMPENSATION* - P204

(a) Place the 25:1 attenuator box between the REFERENCE output of the Phase Standard and the REFERENCE INput of the Phase Meter.
(b) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	4.000V
FREQUENCY:	400Hz	VARIABLE:	4.000V

(c) Set the Phase Meter on the 0° to 360° RANGE and record the Display indication of the Phase Meter which should be close to 60.00°.
(d) Enter 0.250V for the REFERENCE output of the Phase Standard and adjust P204 until the value recorded in step (c) is obtained.

5-3-6 LOW SIGNAL AMPLITUDE COMPENSATION* - P104

(a) Place the 25:1 attenuator box between the VARIABLE output of the Phase Standard and the SIGNAL INput of the Phase Meter.
(b) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	4.000V
FREQUENCY:	400Hz	VARIABLE:	4.000V

(c) Set the Phase Meter on the 0° to 360° RANGE and record the Display indication of the Phase Meter which should be close to 60.00°.
(d) Enter 0.250V for the VARIABLE output of the Phase Standard and adjust P104 until the value recorded in step (c) is obtained.

5-3-7 HIGH FREQUENCY REFERENCE AMPLITUDE COMPENSATION - C202

(a) Place the 25:1 attenuator box between the REFERENCE output of the Phase Standard and the REFERENCE INput of the Phase Meter.
(b) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	11.00V
FREQUENCY:	50000Hz	VARIABLE:	4.000V

(c) Increase the REFERENCE amplitude to 12.00V while observing the OVER-RANGE LED. If it flashes repeat step (b) and then step (c) with the REFERENCE amplitude slightly smaller. Steps (b) and (c) ensure that operation is on the lowest amplitude range in the Reference channel.

(d) Set the Phase Meter on the 0° to 360° RANGE and record the Display indication of the Phase Meter.

(e) Enter 4.000V for the REFERENCE output of the Phase Standard and adjust C202 to the value recorded in step (d) and then beyond by 100%. For example, if the Display indication in step (d) was 62.04° and the first Display indication in step (e) is 62.12°, adjust C202 for a Display indication of 61.96°.

(f) Repeat this procedure until the Display indication with the REFERENCE output at 12.00V is equal to that with the REFERENCE output at 4.000V.

5-3-8 HIGH FREQUENCY SIGNAL AMPLITUDE COMPENSATION - C102

(a) Place the 25:1 attenuator box between the VARIABLE output of the Phase Standard and the SIGNAL INput of the Phase Meter.

(b) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	4.000V
FREQUENCY:	50000Hz	VARIABLE:	11.00V

(c) Increase the VARIABLE amplitude to 12.00V while observing the OVER-RANGE LED. If it flashes repeat step (b) and then step (c) with the VARIABLE amplitude slightly smaller. Steps (b) and (c) ensure that operation is on the lowest amplitude range in the Signal channel.

(d) Set the Phase Meter on the 0° to 360° RANGE and record the Display indication of the Phase Meter.

(e) Enter 4.000V for the VARIABLE output of the Phase Standard and adjust C102 to the value recorded in step (d) and then beyond by 100%.

(f) Repeat this procedure until the Display indication with the VARIABLE output at 12.00V is equal to that with the VARIABLE output at 4.000V.

5-3-9 HIGH FREQUENCY PHASE ADJUSTMENT* - C102,C202

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	VARIABLE:	0.160V
FREQUENCY:	50000Hz	REFERENCE:	0.160V

(b) Set the Phase Meter on the 0° to 360° RANGE. If the Display indication is different from 60.00° , adjust it to 60.00° by adjusting C102 and C202 equal amounts. For example, if the initial display indication is 60.06°, adjust C102 for and indication of 60.03° and then C202 for an indication of 60.00°.

When this adjustment is completed, apply the same 0.160V, 50000Hz signal via a "tee" from the REFERENCE output of the Phase Standard to both inputs of the Phase Meter and verify that a Display indication of 000.00° results. If it does not repeat the procedures of this sub-section.

5-3-10 MIDDLE INPUT ATTENUATOR ADJUSTMENT (REFERENCE)* - C5R

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	4.000V
FREQUENCY:	50000Hz	VARIABLE:	0.160V

(b) Set the Phase Meter on the 0° to 360° RANGE and adjust CR5 with a non-conducting screwdriver through the marked opening in the input attenuator box until a Display indication of 60.00° is obtained.

5-3-11 MIDDLE INPUT ATTENUATOR ADJUSTMENT (SIGNAL)* - C5S

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	0.160V
FREQUENCY:	50000Hz	VARIABLE:	4.000V

(b) Set the Phase Meter on the 0° to 360° RANGE and adjust C5S with a non-conducting screwdriver through the marked opening in the input attenuator box until a Display indication of 60.00° is obtained.

When this adjustment is completed, apply a 4.000V, 50000Hz signal via a "tee" from the REFERENCE output of the Phase Standard to both inputs of the Phase Meter and verify that a Display indication of 00.00° results. If it does not repeat the procedures of this and the previous sub-section.

5-3-12 HIGH INPUT ATTENUATOR ADJUSTMENT (REFERENCE)* - C9R

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	100.0V
FREQUENCY:	50000Hz	VARIABLE:	0.160V

(b) Wait 30 seconds and AUTOZERO the Phase Standard.
(c) Set the Phase Meter on the 0° to 360° RANGE and adjust C9R with a non-conducting screwdriver through the marked opening in the input attenuator box until a display indication of 60.00° is obtained.

5-3-13 HIGH INPUT ATTENUATOR ADJUSTMENT (SIGNAL)* - C9S

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	0.160V
FREQUENCY:	50000Hz	VARIABLE:	100.0V

(b) Wait 30 seconds and AUTOZERO the Phase Standard.
(c) Set the Phase Meter on the 0° to 360° RANGE and adjust C9S with a non-conducting screwdriver through the marked opening in the input attenuator box until a Display indication of 60.00° is obtained.

When this adjustment is completed, apply a 100.0V, 50000Hz signal via a "tee" from the REFERENCE output of the Phase Standard to both inputs of the Phase Meter and verify that a Display indication of 00.00° results. If it does not repeat the procedures of this and the previous sub-section.

5-3-14 INPUT IMPEDANCE ADJUSTMENT (REFERENCE) - C3R, C7R

(a) Place the series impedance box between the REFERENCE output of the Phase Standard and the REFERENCE INput of the Phase Meter as described in sub-section 5-2.

(b) Enter the following set of parameters into the Phase Standard.

PHASE:	0.000°	REFERENCE:	0.160V
FREQUENCY:	50000Hz	VARIABLE:	4.000V

(c) Set the Phase Meter on the 0° to 360° RANGE and record its Display indication.

(d) Enter 4.000V for the REFERENCE output of the Phase Standard and adjust C3R through the marked opening in the input attenuator box for a Display indication equal to the value recorded in step (c). Further increase the REFERENCE output of the Phase Standard to 30.0V. Wait 30 seconds and AUTOZERO the Standard then adjust C7R through the marked opening in the input attenuator box for a Display indication equal to the recorded value.

5-3-15 INPUT IMPEDANCE ADJUSTMENT (SIGNAL) - C3S,C7S

(a) Place the series impedance box between the VARIABLE output of the Phase Standard and the SIGNAL INput of the Phase Meter as described in sub-section 5-2.

(b) Enter the following set of parameters into the Phase Standard.

PHASE:	0.000°	REFERENCE:	4.000V
FREQUENCY:	50000Hz	VARIABLE:	0.160V

(c) Set the Phase Meter on the 0° to 360° RANGE and record its Display indication.

(d) Enter 4.000V for the VARIABLE output of the Phase Standard and adjust C3S through the marked opening of the input attenuator box for a Display indication equal to the recorded value. Further increase the VARIABLE output to 30.00V. Wait 30 seconds and AUTOZERO the Standard and then adjust C7S through the marked opening in the input attenuator box for a Display indication equal to the recorded value.

5-3-16 LOW FREQUENCY FILTER COMPENSATION (REFERENCE) - P203

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	11.00V
FREQUENCY:	500Hz	VARIABLE:	4.000V

(b) Increase the REFERENCE output of the Phase Standard to 12.00V while monitoring the OVERRANGE LED to ensure that it doesn't flash and that operation is on the middle amplitude range in the Reference channel.

(c) Set the Phase Meter on the 0° to 360° RANGE and adjust P203 for a Display indication of 60.00°.

5-3-17 MIDDLE FREQUENCY FILTER COMPENSATION (REFERENCE) - P202

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	11.00V
FREQUENCY:	5000Hz	VARIABLE:	4.00V

(b) Increase the REFERENCE output of the Phase Standard to 12.00V while monitoring the OVERRANGE LED to ensure that it doesn't flash and that operation is on the middle amplitude range in the Reference channel.

(c) Set the Phase Meter on the 0° to 360° RANGE and adjust P202 for a Display indication of 60.00°.

5-3-18 LOW FREQUENCY FILTER COMPENSATION (SIGNAL) - P103

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	4.000V
FREQUENCY:	500Hz	VARIABLE:	11.00V

(b) Increase the VARIABLE output of the Phase Standard to 12.00V while monitoring the OVERRANGE LED to ensure that it doesn't flash and that operation is on the middle amplitude range in the Signal channel.

(c) Set the Phase Meter on the 0° to 360° RANGE and adjust P103 for a Display indication of 60.00°.

5-3-19 MIDDLE FREQUENCY FILTER COMPENSATION (SIGNAL) - P102

(a) Enter the following set of parameters into the Phase Standard.

PHASE:	60.000°	REFERENCE:	4.000V
FREQUENCY:	5000Hz	VARIABLE:	11.00V

(b) Increase the VARIABLE output of the Phase Standard to 12.00V while monitoring the OVERRANGE LED to ensure that it doesn't flash and that operation is on the middle amplitude range in the Signal channel.

(c) Set the Phase Meter on the 0° to 360° RANGE and adjust P102 for a Display indication of 60.00°.

VI IEEE-488 INTERFACE OPERATION

6-1 INTRODUCTION

This Section deals with the important hardware and software aspects of the IEEE-488 interface operation. In particular, after the interconnection of the instrument with the bus is discussed, the general bus commands, the device dependent commands, the data output command, the Serial Poll status byte, and the Service Request procedure are considered in detail. In each case examples are given using the Hewlett-Packard Model 85 BASIC.

6-2 HARDWARE CONSIDERATIONS

The Model 6000 is connected to the bus via its 24 pin rear panel connector which conforms to the IEEE-488 1978 standard. Two or more bus cables can be fastened in parallel to the connector such that a number of instruments may be "Daisy chained" onto the bus. Each cable connector should be tightened in place with its knurled screws when it is applied. A maximum of 15 instruments may be connected to the bus and the maximum length of the cable between each instrument is 15 meters. Because of mechanical considerations, a maximum of three cable connectors should be fastened to the rear of any one instrument.

6_3 ADDRESS SELECTION

Each instrument on the bus must be assigned a unique address between 0 and 30 for proper bus operation (31 is used by the bus controller for UNTALK and UNLISTEN commands). In the most general case an instrument may have two distinct addresses; one for listening and the other for talking. The usual instrument configuration is a single address for both talking and listening. The Phase Meter is shipped with its single address set to 5 (see Fig. 1-4-2); however, any other address may be set via the ADDRESS switch on the rear panel. Table 5-3-1 indicates the binary settings of the individual positions of the switch for any of the allowed addresses. In the table U implies that the switch section should be up, and D implies that the switch section should be down. It should be noted that the address is read from the switch by the microprocessor on the interface Buscard when power is applied to the Phase Meter; hence each time a new address is set into the ADDRESS switch, the POWER on the front panel should be turned off for 10 seconds and then reapplied.

6-4 BUS HARDWARE

The bus connector comprises 24 lines of which one is a shield, six are ground connections, eight are data lines (DI01 - DI08), and eight are the control lines (see J2 on Dwg. No.60006). Of the eight control lines, three are for handshaking. These comprise DAV (Data AVailable), NRFD (Not Ready For Data) and NDAC (Not Data ACcepted). The other five lines employed for bus management comprise IFC (InterFace Clear), ATN (ATteNtion), SRQ (Service ReQuest), REN (Remote ENable), and EOI (End Or Identify). For a more detailed discussion of the handshaking lines the reader is referred to IEEE Standard 488-1978. The digital signal on each of the bus lines is inverted such that low is true and high is false. In the sub-sections to follow a 1 refers to a true situation and thus a low voltage on the bus line.

Table 6-3-1 Switch Settings for Required Addresses

Address	Switch Setting A0	A1	A2	A3	A4	Address	Switch Setting A0	A1	A2	A3	A4
0	D	D	D	D	D	16	D	D	D	D	U
1	U	D	D	D	D	17	U	D	D	D	U
2	D	U	D	D	D	18	D	U	D	D	U
3	U	U	D	D	D	19	U	U	D	D	U
4	D	D	U	D	D	20	D	D	U	D	U
5	U	D	U	D	D	21	U	D	U	D	U
6	D	U	U	D	D	22	D	U	U	D	U
7	U	U	U	D	D	23	U	U	U	D	U
8	D	D	D	U	D	24	D	D	D	U	U
9	U	D	D	U	D	25	U	D	D	U	U
10	D	U	D	U	D	26	D	U	D	U	U
11	U	U	D	U	D	27	U	U	D	U	U
12	D	D	U	U	D	28	D	D	U	U	U
13	U	D	U	U	D	29	U	D	U	U	U
14	D	U	U	U	D	30	D	U	U	U	U
15	U	U	U	U	D						

6-5 GENERAL BUS COMMANDS

The bus commands which must be implemented by the bus controller (the HP 85 in the examples to follow), fall into three general categories.

1. Uniline commands
2. Multiline commands (Universal and Addressed)
3. Device dependent commands

The Uniline commands are those commands which are sent over the bus by activating a single bus management line. The multiline commands are those sent as a byte over the eight data lines while the ATN line is True. The device dependent commands are those sent as a byte over the eight data lines while the ATN line is False. Both the multiline and the device dependent commands require proper Handshaking via the three handshaking lines prior to placing a byte on the data lines. Table 5-5-1 summarizes these commands. Only those commands which pertain to the Phase Meter are covered in this Section. In the Table UL indicates Uniline, MU indicates Universal Multiline and MA indicates Multiline Addressed. In the sub-sections to follow these commands are outlined in more detail and wherever one exists, the corresponding HP-85 BASIC statement is presented.

6-5-1 UNILINE COMMANDS

The ATN, IFC and the REN commands are sent by the system controller. The SRQ command is requested by any external device. The EOI command may be sent by the controller or the external device, usually with the final data byte. A brief description of each command follows.

1. IFC (Interface Clear). This command sets the bus to a known initial state. In particular the Model 6000 is set to its power-on Talker and Listener states which are outlined in the IEEE-488 Standard. The HP-85 statement for this command is ABORTIO 7. (7 is the general designation for the bus.) The RESET 7 command also sets the IFC line true; however it also sets the REN line false which causes all instruments on the bus to exit their REMOTE states.

2. ATN (Attention). This command (true) indicates the presence of a multiline command on the data lines. The absence of this command indicates the presence of a device dependent command on the data lines.

3. SRQ (Service Request). This command is sent by a device requesting service. A Serial Poll should then be performed by the controller to determine which device has activated the line.

4. REN (Remote Enable). This command is sent by the controller to set up the interface for remote operation. Without it, no instrument connected to the interface can be placed in its REMOTE state. Generally this command should be sent before attempting to program over the bus. The HP-85 statement for this command is REMOTE 7.

5. EOI (End or Identify). This command is usually sent with the final byte of a multibyte data transmission.

Table 6-5-1 Summary of Bus Commands

Type	Command	Data Line Byte (hex)	ATN Line	Comments
U	IFC (Interface Clear)			Clears Interface
U	ATN (Attention)		True	
U	SRQ (Service Request)			Sent by Device
U	REN (Remote Enable)			Remote Operation
U	EOI (End or Identify)			EOI line True
MA	GTL (Go to Local)	01	True	Local Control
MA	SDC (Selective Device Clr)	04	True	Initializes Device
MA	LLO (Local Lock Out)	11	True	Inhibits Local Sw.
MU	DCL (Device Clear)	14	True	Initializes Device
MU	SPE (Serial Poll Enable)	18	True	Enables S Polling
MU	SPD (Serial Poll Disable)	19	True	Disables S Polling
MU	UNL (Unlisten)	3F	True	Removes Listeners
MU	UNT (Untalk)	5F	True	Removes Talkers
MA	MLA (My Listen Address)	40 + AD*	True	Device Listens
MA	MTA (My Talk Address)	80 + AD*	True	Device Talks

*AD is the address of the instrument in hex (05 for the factory setting of the Phase Meter).

6-5-2 UNIVERSAL COMMANDS (MULTILINE)

Universal Commands are multiline commands which require no addressing and are sent over the data lines with the ATN line true. A brief description of the pertinent commands follows.

1. DCL (Device Clear). This command performs the same function as a hardware RESET. Upon receipt of this command the Phase Meter performs its complete initialization routine as described in Section 1. The HP-85 statement for this command is CLEAR 7.

2. SPE (Serial Poll Enable). This command is the first step in the serial polling sequence which returns the status byte to the controller.

3. SPD (Serial Poll Disable). This command is sent by the controller to remove all instruments on the bus from the serial poll mode. The HP-85 statement for the complete Serial Poll procedure is N = SPOLL(705) where N is the status byte returned and 05 is the address of the instrument being polled.

4. UNL (Unlisten). This command simultaneously removes all listeners from the bus. The HP-85 statement for this command is SEND 7; UNL

5. UNT (Untalk). This command simultaneously removes all talkers from the bus. The HP-85 statement for this command is SEND 7; UNT

6-5-3 ADDRESSED COMMANDS (MULTILINE)

Each of these commands must be preceded by a Listen command such that only the addressed instrument responds. The Listen command is sent over the bus by sending MLA (My Listen Address) over the data lines with the ATN line true. The Listen command places the addressed instrument in its REMOTE state. The following commands are germane to the Phase Meter.

1. GTL (Go to Local). This command removes the addressed instrument from its REMOTE state. In the Model 6000 it is equivalent to pressing the front panel LOCAL switch except in the case where the Local Lockout state exists. In this case only the GTL command has an effect. The HP-85 statement for this command is SEND 7;UNL LISTEN05 CMD01 where 05 is the instrument address and 01 is the decimal equivalent of the multiline command. A somewhat more compact statement which performs the same sequence of commands is LOCAL 705.

2. SDC (Selective Device Clear). This command has the same effect on the Phase Meter as the DCL command. The HP-85 statement for this command is CLEAR 705 where 05 is again the instrument address.

3. LLO (Local Lockout). This command inhibits the front panel LOCAL switch of the Phase Meter from returning the instrument to its local state. The HP-85 statement for this command is SEND7; UNL LISTEN 05 CMD17. To remove the Meter from the LLO state the REN line must be set false. The HP-85 accomplishes this with the statement LOCAL 7. The Phase Meter responds by exiting the REMOTE state.

The HP-85 contains an addressable REMOTE 705 statement which addresses a particular instrument to listen before setting the REN line true. This command has the effect of setting both the bus and the Phase Meter in their REMOTE states. For this reason this statement is preferable to the REMOTE 7 statement.

6-6 DEVICE DEPENDENT COMMANDS

The device dependent commands are a sequence of bytes sent to the Phase Meter over the data lines with the ATN line false after the Meter has been addressed to listen. The only four commands to which the Meter responds are an ASCII "S" which causes the Range to toggle between 0-360° and ±180°, an ASCII "O" which removes the internal filter banks, an ASCII "I" which reinstates the internal filter banks and an ASCII "M" followed by a mask byte Y which sets the SRQ Mask for the Serial Poll. All other bytes including terminators are ignored by the Phase Meter. Thus, if an "S" is imbedded anywhere in a string of characters sent to the Meter the Range will toggle; an imbedded "O" will take the filter banks out, and an imbedded "I" will restore them. Similarly, if an "M" is imbedded anywhere in a string of characters, the Phase Meter will interpret the following byte as the Mask for the Service Request.

To send a device dependent command over the bus the controller must perform the following sequence.

1. Set ATN true.
2. Address the Model 6000 to Listen.
3. Set ATN false.
4. Send the command string over the data lines one byte at a time.

The HP-85 handles this sequence in two ways. The first is with the BASIC statement SEND 7; UNL LISTEN05 DATA "STRING" where STRING represents the command byte. The second is with the single more compact statement OUTPUT 705; "STRING". Specifically, the Model 6000 has its Range toggled with the statement

OUTPUT 705;"S"

6-7 DATA OUTPUT COMMAND

The Phase Meter sends its Display Reading over the bus as a sequence of 9 ASCII characters when it is addressed to talk and the ATN line is set false by the controller. The usual handshaking occurs with each character. The format of the sequence is the sign byte, the five digits and the decimal point corresponding to the phase angle reading in degrees, and the terminator comprising a carriage return and a line feed. The EOI line is set true when the line feed is placed on the bus. The controller may request data from the Model 6000 whether or not the Meter is in its REMOTE state. The Model 6000 will not send the Display Reading to the bus more than once during each 0.333sec internal refresh cycle. If data is requested by the bus at a more rapid rate, handshaking will be held off by the Model 6000 until the next update of the Display.

To obtain the Display Reading from the Phase Meter over the bus the controller must perform the following sequence.

1. Set ATN true.
2. Address the Model 6000 to Talk.
3. Set ATN false.
4. Handshake with the Model 6000 to obtain the 9 bytes of data.

The HP-85 handles this sequence with the BASIC statement ENTER 705; N$ where N$ is a string variable resident in the HP-85 which contains the Display Reading with the carriage return line feed terminator removed. The statement DISP N$ would then place the Phase reading on the screen of the HP-85.

If handshaking is terminated before the complete 9 bytes of Display data are placed on the bus by the Model 6000, the unsent bytes will be sent the next time the Phase Meter is addressed to Talk and the ATN line is set false.

6-8 THE REMOTE STATE

The Phase Meter enters its Remote state only when it is addressed to listen by the bus controller while the REN line is true. The existence of the Remote state is indicated by the REMOTE lamp on the front panel. When it is in this state two things happen. First, the front panel keys, with the exception of the LOCAL key, become inoperative. Second, any OFFSET which was set via the front panel key is cleared. Consequently, it is good practice to place the Model 6000 in its Remote state before requesting a Display Reading to ensure that it contains no unknown offset constant.

6-9 SERIAL POLL

The Status byte returned when the Phase Standard responds to a Serial Poll has the following format.

Bit 0 being set indicates that the signal at the reference channel input is less than 20mV RMS. This bit corresponds exactly to the front panel UNDERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 1 being set indicates that the signal at the reference channel input is greater than 312V RMS. This bit corresponds exactly to the front panel OVERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 2 being set indicates that the signal at the signal channel input is less than 20mV RMS. This bit corresponds exactly to the front panel UNDERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 3 being set indicates that the signal at the signal channel input is greater than 312V RMS. This bit corresponds exactly to the front panel OVERRANGE lamp and thus may be set momentarily during an autoranging operation.

Bit 4 being set indicates that the Model 6000 RANGE is set to 0-360°

Bit 5 being set indicates that the Model 6000 OFFSET is ON. If this is the case then the Display Reading sent over the bus will have an unknown constant in it. To remove this constant the Model 6000 should be placed in its Remote State or the OFFSET key on the front panel should be pressed.

Bit 6 being set indicates that the Phase Meter has requested service by activating the SRQ line. This condition results when a bit in the SRQ mask has been set and the corresponding bit in the Status byte occurs.

Bit 7 being set indicates that the internal filter banks have been removed.

Bit 0 through bit 5 and bit 7 are reset when the state of the Model 6000 which causes them ceases to exist except when the SRQ line has been asserted. In this case the bits are reset following the next Serial poll received by the Meter.

Bit 6 is reset following the next Serial poll request received by the Meter.

6-10 SRQ MASK

The SRQ Mask is set by sending MY over the interface to the Phase Meter. In this case Y is a byte whose bits correspond to the bits in the Status byte. Only bit 0 through bit 5 may be masked by placing a 1 in the appropriate bit positions. When the mask is set to recognize a particular bit in the Status byte and this bit is set by the Phase Meter two things occur. Bit 6 in the Status byte is also set and the SRQ line is set true. There is no change in the Status byte until it is cleared by a Serial Poll which also sets the SRQ line false. With the aid of this mask and a controller that responds to a SRQ interrupt, there is no chance of missing a desired bit setting in the Status word.

The following HP-85 statement sets the SRQ mask to recognize bit 4 in the Serial Poll. In the statement 16 is the decimal equivalent of bit 4 which is converted to a string and combined with "M" to obtain the required MY format.

```
OUTPUT 705; "M" & CHR$(16)
```

The SRQ Mask may be reset only by turning the POWER off and then back on or by sending MY over the interface to the Phase Meter where in this case Y is a byte comprising all zeros.

REPLACEMENT PARTS

7-1 INTRODUCTION

This section contains a list of replacement parts for the Model 6000 Phase Meter and the names of typical manufacturers of such parts. Any of these replacement parts may be obtained from CLARKE-HESS. To obtain a part include:

a. The circuit reference number of the part.

b. The printed circuit board number which contains the part.

c. A brief description of the part.

d. The instrument model and serial number.

e. The quantity desired.

Send the order to CLARKE-HESS at the address on the front of the Instruction Manual.

The parts list is broken up into Sub Sections comprising the chassis parts and the individual printed circuit board parts. In each case circuit reference numbers start from one; hence it is important to include the board number as well as the part number when specifying parts.

7-2 LIST OF MANUFACTURERS

The following list contains the key to the abbreviations in the parts list. The list presents both the name and the address of the manufacturer as well as the code numbers (where available) for the manufacturers as listed in the Federal Supply code for Manufacturers Cataloging Handbooks H4-1 (Name to Code). The list order is Abbreviations/Federal Supply Code Number/Company Name/ Company Address.

Abb.	Code	Company Name	Company Address
AB	01121	Allen-Bradley Corp.	Milwaukee, WI
AM	00779	AMP Inc.	Philadelphia, PA
AN	02660	Amphenol Inc.	Broadview, IL
AD	24355	Analog Devices Inc.	Norwood, MA
AP	60024	Apex Microtechnology Corp.	Tucson, AZ
AR	51167	Aries Electronics Inc.	Hopewell, NJ
BE	70903	Belden Mfg. Company	Chicago, IL

Abb	Code	Company Name	Company Address
BK	73138	Beckman Instruments Corp.	Fullerton, CA
BG	22526	Berg Electronics	Camp Hill, PA
BR	-	B & R Electronics	Allendale, NJ
BV	30010	Bicc-Vero Electronics Inc.	Trumbull, CT
BB	13919	Burr Brown	Tucson, AZ
BU	71400	Bussman Mfg. Div of McGraw Co.	St. Louis, MO
BY	21604	Buckeye Stamping Co.	Columbus, OH
CH	34423	Clarke-Hess Comm. Res. Corp.	New York, NY
CM	71744	Chicago Minature Inc.	Chicago, IL
CN	18310	Concord Electronics Corp.	New York, NY
CD	14655	Cornell-Dublier Electric Co.	Newark, NJ
DA	91637	Dale Electronics Inc.	Columbus, NE
EC	50558	Electronic Concepts	Eatontown,NJ
EF	91293	E. F. Johnson Inc.	Waseca, MN
EM	17117	Electronic Molding Corp.	Woonsocket, RI
FA	07263	Fairchild Camera & Inst. Corp. Semiconductor Division	Mountainview, CA
FX	61429	Fox Electronics	Cape Coral, FL
GE	03508	G.E. Semiconductor Prod. Div.	Syracuse, NY
GY	19112	Garry Div Of Brand-Rex Co.	N.Brunswick, NJ
GO	95348	Gordos Arkansas Inc.	Rogers, AR
HP		Hewlett-Packard	Palo Alto, CA
HS	83330	Herman H. Smith Inc.	Brooklyn, NY
IE	05464	IEE Inc.	Van Nuys, CA
IC	74840	Illinois Capacitor Inc.	Lincolnwood, IL
IN	03674	Intel Corp.	Santa Clara, CA
IF	23936	Interfan Inc.	Burlingame, CA

Abb	Code	Company Name	Company Address
IT	32293	Intersil Inc.	Cupertino, CA
KE	31433	Kemet Capacitors Div. Union Carbide Corp.	Greenville, SC
KY	91833	Keystone Electronics Corp.	New York, NY
MA	37942	P.R. Mallory & Co.,Inc.	Indianapolis, IN
ME	71590	Mepco-Centralab	West Palm Beach,FL
MX	27264	Molex Inc. Division of E.I. DuPont	Wellington, CT
MO	04713	Motorola Inc.,Semiconductor Prod.	Phoenix, AZ
MW	32897	Murata-Erie North America Inc.	Kingston, CT
NA	27014	National Semiconductor Corp.	Santa Clara, CA
NT	91967	National Tel-Tronics	Meadville, PA
OK	S4071	OKI Mfg. Co.	Japan
PM	06665	Precision Monolithic	Santa Clara,CA
QT	59205	Quantum Thayer	Houston, TX
RA	02735	RCA Semiconductor Division	Sommerville, NJ
RN	06776	Robinson Nugent Inc.	New Albany, IN
SF	01467	Schaffner EMC Inc.	Union, NJ
SG	18324	Signetics Corporation	Sunnyvale, CA
SP	56289	Sprague Electric Co.	North Adams, MA
SW	82389	Switchcraft Inc.	Chicago, IL
TI	01295	Texas Instruments Transistor Products	Dallas, TX
TK	24227	Tek National Inc.	Rochester, NY
TM	18778	Thompson CSF	Canoga Park, CA
TR	84411	TRW Capacitor Division	Ogallala, NE
UC	05397	Union Carbide Corp., Elect. Div.	New York, NY

7-3 CHASSIS ASSEMBLY (CH60100)

Circuit Ref.	Description	Mfr.	Part Number
MP1	Case (Flexi-Pak Case)	BY	FP-35-4-13NRM
	Rear Panel	CH	CH60021
	Mounting Hardware (Panel):		
	6-32 x 5/16 BHS Screw (2 Each)	CH	CH50049
	3/8" Hex Spacer (4 Each)	KY	1892
	4/40 x 1/4 BHS Screw (4 Each)	CH	CH50043
J3	BNC Connector	AN	31010
	Line Cord Receptacle	SF	FN376-2/22
	Mounting Hardware:		
	4/40 x 3/8 BHS Screw (2 Each)	CH	CH50045
	#4 Internal Washer (2 Each)	CH	CH50062
	#4 Nut (2 Each)	CH	CH50057
F1	1/2 A Fuse	BU	1/2 AGC
	Line Cord	BE	17251B
	Wiring Harness Assembly	CH	CH60066
X1	Power Transformer	CH	CH60034
	Mounting Hardware (Xfmr):		
	6/32 x 1/4 BHS Screw (2 Each)	CH	CH50053
	#6 Internal Washer (2 Each)	CH	CH50063
	#6 Nut (2 Each)	CH	CH50058
	Front Panel	CH	CH50019
	3/4 Hex Spacers (8 Each)	KY	1895
	Red Optical Filter	CH	CH60035
	BNC Connector (2 Each)	AN	31010
SW1	Power On/Off Switch	SW	PS 670602
	Mounting Hardware (Switch):		
	#4 Internal Washer (2 Each)	CH	CH50062
	#4 Nut (2 Each)	CH	CH50057
	Switch Cable Assembly	CH	CH60067
	Input Attenuator Box	CH	CH60028
	Mounting Hardware (Box):		
	Flat Nylon Washer (2 Each)	HS	2678
	Nylon Shoulder Washer (4 Each)	HS	2661
	#4 Nut (2 Each)	CH	CH50057
	#4 Internal Washer (2 Each)	CH	CH50062
	Internal Box Hardware:		
	1" Hex Spacer (6 Each)	HS	9159
	4/40 x 1/4 BHS Screw (6 Each)	CH	CH50043
	#4 Internal Washer (6 Each)	CH	CH50062
	Cover	CH	CH60029
	Mounting Hardware (Cover):		
	4/40 x 1/4 BHS Screw (6 Each)	CH	CH50043
	#4 Internal Washer (6 Each)	CH	CH50062

Circuit Ref.	Descpription	Mfr.	Part Number
	Lengthwise Support Bar	CH	CH60026
	Side Support Bar	CH	CH60027
	Mounting Hardware (Bar):		
	6/32 x 1/4 BHS Screw (4 Each)	CH	CH50053
	#6 Internal Washer (2 Each)	CH	CH50063
	Heat Sink Bracket	CH	CH60025
	Mounting Hardware (Bracket):		
	6/32 x 1/4 BHS Screw	CH	CH50053
	#6 Internal Washer	CH	CH50063

<u>INTERCONNECTING CABLES</u> (CH60100)

	10 Conductor Ribbon Cable (Bus Card)	CH	CH60037
	10 Conductor Ribbon Cable (Input Attenuator) (2 Each)	CH	CH60037
	20 Conductor Ribbon Cable (Display Board)	CH	CH60038

7-4 INPUT BOARD ASSEMBLY (CH 60010)

<u>BOARD, CONNECTORS AND SOCKETS</u> (CH60010)

Circuit Ref.	Description	Mfr.	Part Number
	Input Circuit Board	CH	CH60010A
	Mounting Hardware Board:		
	4/40 x 1/4 RHS Screw (4 Each)	CH	CH50044
	#4 Internal Washer (4 Each)	CH	CH50062
J2	10 Pin Berg Socket	BG	65863-103
	8 Pin Socket (3 Each)	RN	ICN-083-S3T

<u>RESISTORS</u> (CH60010)

Circuit Ref.	Description Ohms	Percent	Power	Mfr.	Part Number
R1	1M	1%	1/4W	DA	RN55D
R2	953,000	1%	1/4W	DA	RN55D
R3	40,200	1%	1/4W	DA	RN55D
R4	1M	1%	1/4W	DA	RN55D
R5	1,620	1%	1/4W	DA	RN55D
R6	499	1%	1/4W	DA	RN55D
R7	1,000	1%	1/4W	DA	RN55D
R8	10,000	1%	1/4W	DA	RN55D
R9	10M	1%	1/4W	DA	RN55D

Circuit Ref.	Description Ohms	Percent	Power	Mfr.	Part Number
R10	80,600	1%	1/4W	DA	RN55D
R11	80,600	1%	1/4W	DA	RN55D
R13	100,000	1%	1/4W	DA	RN55D
R14	2.74M	1%	1/4W	DA	RN55D
R15	2.74M	1%	1/4W	DA	RN55D
R16	4,990	1%	1/4W	DA	RN55D
R17	4,990	1%	1/4W	DA	RN55D
R18	49.9	1%	1/4W	DA	RN55D

CAPACITORS (CH60010)

Circuit Ref.	Description Value	Voltage	Percent	Type	Mfr.	Part Number
C1	10pF	100V	5%	Mica	CD	DM15F100J
C2	1pF	100V	5%	Mica	CD	DM15F010J
C3	8-40pF	25V			EF	275-0112-005
C4	3pF	100V	5%	Mica	CD	DM15F030J
C5	0.3-0.8pF	25V			BR	302504/121NP0
C7	8-40pF	25V			EF	275-0112-005
C8	110pF	100V	5%	Mica	CD	DM15F121J
C9	3-12pF	25V			EF	275-0112-005
C10	0.22uF	50V	10%	Film	EC	ECR224BF
C11	1uF	100V	10%	Film	QT	MPC13 1.0
C12	47uF	35V	10%	Tant	SP	196D476X9035
C13	47uF	35V	10%	Tant	SP	196D476X9035
C14	1,000pF	100V	5%	Mica	CD	DM15F102J
C15	100pF	100V	5%	Mica	CD	DM15101J
C16	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C17	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C18	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C19	10pF	100V	5%	Mica	CD	DM15F100J
C22	10uF	35V	20%	Tant	SP	196D106X9035

INTEGRATED CIRCUITS (CH60010)

Circuit Ref.	Description	Mfr.	Part Number
U1	High Impedance Op Amp	PM	OP42GZ
U2	Low Offset Op Amp	PM	OP07GZ
U3	Broadband Buffer	BB	OPA633KP

TRANSISTORS,DIODES (CH60010)

Circuit Ref.	Description	Mfr.	Part Number
Q1	High Speed PNP Transistor	MO	MPS3640
Q2	High Speed PNP Transistor	MO	MPS3640
Z1	4.7V Zener Diode	MO	1N4732A
Z2	4.7V Zener Diode	MO	1N4732A
RL1	SPST Relay	GO	741-A-10
RL2	SPST Relay	GO	741-A-10
RL3	SPST Relay	GO	741-A-10
RL4	SPST Relay	GO	741-A-10
RL5	SPST Relay	GO	741-A-10
RL6	SPST Relay	GO	741-A-10

7-5 DISPLAY BOARD ASSEMBLY (CH60011)

BOARD, CONNECTORS AND SOCKETS (CH60011)

Circuit Ref.	Description	Mfr.	Part Number
	Display Circuit Board	CH	CH60011
	Mounting Hardware (Board):		
	4/40 x 1/4 RHS Screw (8 Each)	CH	CH50044
	#4 Internal Washer (8 Each)	CH	CH50062
J1	10 Pin Berg Socket	BG	65863-301
	14 Pin Extended Socket (6 Each)	AR	14-8500-310C
	14 Pin Socket	RN	ICN-143-S3T
	24 Pin Socket	RN	ICN-243-S3T

RESISTORS (CH60011)

Circuit Ref.	Description Ohms	Percent	Power	Mfr.	Part Number
R1	1,000	1%	1/4W	DA	RN55D
R2	1,000	1%	1/4W	DA	RN55D
R3	1,000	1%	1/4W	DA	RN55D
R4	191	1%	1/4W	DA	RN55D
R5	191	1%	1/4W	DA	RN55D
R6	191	1%	1/4W	DA	RN55D
R7	191	1%	1/4W	DA	RN55D
R8	10,000	14 Pin Resistor Pack		AB	314-B-10K
R9	191	1%	1/4W	DA	RN55D
R10	191	1%	1/4W	DA	RN55D
R11	191	1%	1/4W	DA	RN55D
R12	191	1%	1/4W	DA	RN55D
R13	73.2	1%	1/4W	DA	RN55D

CAPACITORS (CH60011)

Circuit Ref.	Description Value	Voltage	Percent	Type	Mfr.	Part Number
C1	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C2	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C3	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C4	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C5	10uF	20V	20%	Tant	SP	196D106X0020JA1
C6	10uF	16V	20%	Tant	SP	196D106X0020JA1

TRANSISTORS AND DIODES AND MISCELLANEOUS (CH60011)

Circuit Ref.	Description	Mfr.	Part Number
Q1	General Purpose Transistor	MO	2N3906
Q2	General Purpose Transistor	MO	2N3906
Q3	General Purpose Transistor	MO	2N3906
Q4	General Purpose Transistor	MO	2N3906
Q5	General Purpose Transistor	MO	2N3906
Q6	General Purpose Transistor	MO	2N3906
Q7	General Purpose Transistor	MO	2N3906
D1,D1A	High Speed Diode	TI	1N914B
LD1	Red Light Emitting Diode	CM	CM4-43B
LD2	Red Light Emitting Diode	CM	CM4-43B
LD3	Red Light Emitting Diode	CM	CM4-43B
LD4	Red Light Emitting Diode	CM	CM4-43B
LD5	Red Light Emitting Diode	CM	CM4-43B
LD6	Red Light Emitting Diode	CM	CM4-43B
LD7	Red Light Emitting Diode	CM	CM4-43B
LD8	Red Light Emitting Diode	CM	CM4-43B

INTEGRATED CIRCUITS (CH60011)

Circuit Ref.	Description	Mfr.	Part Number
U1	Seven Segment Display Module	HP	5082-7653
U2	Seven Segment Display Module	HP	5082-7653
U3	Seven Segment Display Module	HP	5082-7653
U4	Seven Segment Display Module	HP	5082-7653
U5	Seven Segment Display Module	HP	5082-7653
U6	Seven Segment Display Module	HP	5082-7653
U7	I/O Latch	IN	8243
U8	Display Driver	TI	SN75492

7-6 MAIN BOARD ASSEMBLY (CH60012)

BOARD, CONNECTORS AND SOCKETS (CH60012)

Circuit Ref.	Description	Mfr.	Part Number
J1	Main Circuit Board	CH	CH60012A
J2	20 Pin Berg Socket	BG	65863-019
J100	10 Pin Berg Socket	BG	
J200	10Pin Berg Socket	BG	65863-019
	8 Pin Socket (3 Each)	RN	ICN-083-S3T
	14 Pin Socket (13 Each)	RN	ICN-143-S3T
	16 Pin Socket (4 Each)	RN	ICN-163-S3T
	24 Pin Socket (1 Each)	RN	ICN-243-S3T
	40 Pin Socket (2 Each)	RN	ICN-403-S3T
	Mounting Hardware: (Board)		
	4/40 x 1/4 RHS (5 Each)	CH	CH50044
	#4 Internal Washer (5 Each)	CH	CH50062

RESISTORS (CH50112)

Circuit Ref.	Ohms	Description Percent	Power	Mfr.	Part Number
R1	3,320	1%	1/4W	DA	RN55D
R2	10,000	1%	1/4W	DA	RN55D
R3	2250	1%	1/4W	DA	RN55D
R4	49,900	1%	1/4W	DA	RN55D
R5	301,000	1%	1/4W	DA	RN55D
R6	750	1%	1/4W	DA	RN55D
R7	8,870	1%	1/4W	DA	RN55D
R8	357K	1%	1/4W	DA	RN55D
R9	10M	1%	1/4W	DA	RN55D
R10	249	1%	1/4W	DA	RN55D
R11	6,490	1%	1/4W	DA	RN55D
R12	8,870	1%	1/4W	DA	RN55D
R13	20,000	1%	1/4W	DA	RN55D
R14	100	1%	1/4W	DA	RN55D
R15	39,900	1%	1/4W	DA	RN55D
R16	100,000	1%	1/4W	DA	RN55D
R17	10M	1%	1/4W	DA	RN55D
R18	200,000	1%	1/4W	DA	RN55D
R19	100,000	1%	1/4W	DA	RN55D
R20	49,900	1%	1/4W	DA	RN55D
R21	69,800	1%	1/4W	DA	RN55D
R22	100,000	1%	1/4W	DA	RN55D
R23	100,000	1%	1/4W	DA	RN55D
R24	1,780	1%	1/4W	DA	RN55D

Circuit Ref.	Ohms	Description Percent	Power	Mfr.	Part Number
R25	8,870	1%	1/4W	DA	RN55D
R27	1,780	1%	1/4W	DA	RN55D
R28	8,870	1%	1/4W	DA	RN55D
R30	1,780	1%	1/4W	DA	RN55D
R31	20,000	1%	1/4W	DA	RN55D
R33	1,780	1%	1/4W	DA	RN55D
R34	20,000	1%	1/4W	DA	RN55D
R36	10,000	1%	1/4W	DA	RN55D
R37	1M	1%	1/4W	DA	RN55D
R38	162,000	1%	1/4W	DA	RN55D
R39	69,800	1%	1/4W	DA	RN55D
R40	10,000	1%	1/4W	DA	RN55D
R41	499,000	1%	1/4W	DA	RN55D
R42	69,800	1%	1/4W	DA	RN55D
R43	10,000	1%	1/4W	DA	RN55D
R44	100,000	1%	1/4W	DA	RN55D
R45	2,000	1%	1/4W	DA	RN55D
R46	162,000	1%	1/4W	DA	RN55D
R47	10,000	1%	1/4W	DA	RN55D
R48	1M	1%	1/4W	DA	RN55D
R49	1M	1%	1/4W	DA	RN55D
R50	499,000	1%	1/4W	DA	RN55D
R51	1M	1%	1/4W	DA	RN55D
R52	1,000	1%	1/4W	DA	RN55D
R53	1,000	1%	1/4W	DA	RN55D
R101,R201	49,900	1%	1/4W	DA	RN55D
R102,R202	1,000	1%	1/4W	DA	RN55D
R103,R203	10,000	1%	1/4W	DA	RN55D
R104,R204	499	1%	1/4W	DA	RN55D
R105,R205	1,500	1%	1/4W	DA	RN55D
R107,R207	100	1%	1/4W	DA	RN55D
R108,R208	3,010	1%	1/4W	DA	RN55D
R109,R209	100	1%	1/4W	DA	RN55D
R110,R210	100	1%	1/4W	DA	RN55D
R111,R211	10,000	1%	1/4W	DA	RN55D
R112,R212	10,000	1%	1/4W	DA	RN55D
R113,R213	100	1%	1/4W	DA	RN55D
R114,R214	100	1%	1/4W	DA	RN55D
R115,R215	100	1%	1/4W	DA	RN55D
R116,R216	100	1%	1/4W	DA	RN55D
R117,R217	1,000	1%	1/4W	DA	RN55D
R118,R218	301	1%	1/4W	DA	RN55D
R119,R219	1,000	1%	1/4W	DA	RN55D

Circuit Ref.	Ohms	Description Percent	Power	Mfr.	Part Number
R120,R220	301	1%	1/4W	DA	RN55D
R121,R221	66,500	1%	1/4W	DA	RN55D
R122,R222	2,000	1%	1/4W	DA	RN55D
R123,R223	100,000	1%	1/4W	DA	RN55D
U103R,U203R	10,000	RESISTOR PACK (16 PIN)		BK	898-3R10K
R124,R224	4,990	1%	1/4W	DA	RN55D
R125,R225	10,000	1%	1/4W	DA	RN55D
R126,R226	2,210	1%	1/4W	DA	RN55D
R127,R227	10,000	1%	1/4W	DA	RN55D
R128,R228	1,780	1%	1/4W	DA	RN55D
R129,R229	215	1%	1/4W	DA	RN55D
R130,R230	10,000	1%	1/4W	DA	RN55D
R131,R231	10,000	1%	1/4W	DA	RN55D
R132,R232	274,000	1%	1/4W	DA	RN55D
R133,R233	274,000	1%	1/4W	DA	RN55D

CAPACITORS (CH60012)

Circuit Ref.	Value	Description Voltage	Percent	Type	Mfr.	Part Number
C1	10uF	20V	20%	Tant	SP	196D106X0020JA1
C2	22pF	100V	5%	Mica	CD	DM15F220J
C3	10uF	20V	20%	Tant	SP	196D106X0020JA1
C4	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C5	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C6	10uF	20V	20%	Tant	SP	196D106X0020JA1
C7	10uF	20V	20%	Tant	SP	196D106X0020JA1
C8	10uF	20V	20%	Tant	SP	196D106X0020JA1
C9	10uF	20V	20%	Tant	SP	196D106X0020JA1
C10	22pF	100V	5%	Mica	CD	DM15F220J
C11	300pF	100V	5%	Mica	CD	DM15F301J
C12	0.22uF	50V	10%	Film	EC	ECR224BF
C13	0.22uF	50V	10%	Film	EC	ECR224BF
C14	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C15	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C16	33pF	100V	5%	Mica	CD	DM15F330J
C17	33pF	100V	5%	Mica	CD	DM15F330J
C18	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C19	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C20	2.2uF	35V	20%	Tant	MA	TDC105K035EL
C21	33pF	100V	5%	Mica	CD	DM15F330J
C22	33pF	100V	5%	Mica	CD	DM15F330J
C23	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S

Circuit Ref.	Value	Description Voltage	Percent	Type	Mfr.	Part Number
C24	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C25	2.2uF	35V	20%	Tant	MA	TDC105K035EL
C26	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C27	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C28	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C29	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C30	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C31	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C32	0.01uF	50V	10%	Disk	ME	CK50-103
C33	680pF	100V	5%	Mica	CD	DM15F681J
C34	68pF	100V	5%	Mica	CD	DM15F680J
C35	18pF	100V	5%	Mica	CD	DM15F180J
C36	2,200uF	16V	20%	Elect	IC	228RMR016M
C37	2,200uF	35V	20%	Elect	IC	228RMR035M
C38	2,200uF	35V	20%	Elect	IC	228RMR035M
C39	2,200uF	35V	20%	Elect	IC	228RMR035M
C40	2,200uF	35V	20%	Elect	IC	228RMR035M
C41	4,700uF	16V	20%	Elect	IC	478RMR016M
C42	4,700uF	16V	20%	Elect	IC	478RmR016M
C43	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C44	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C45	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C46	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C47	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C48	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C49	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C50	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C51	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C52	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C53	680pF	100V	5%	Mica	CD	DM15F681J
C54	0.022uF	50V	10%	Film	EC	ECR223CF
C55	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C56	300pF	100V	5%	Mica	CD	DM15F220J
C57	100uF	10V	20%	Tant	SP	196D107X0010JA1
C58	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C101,C201	10pF	100V	5%	Mica	CD	DM15F100J
C102,C202	3-12pF	25V		Var	EJ	275-0112-005
C103,C203	18pF	100V	5%	Mica	CD	DM15F180J
C105,C205	360pF	100V	5%	Mica	CD	DM15F361J
C106,C206	3,000pF	250V	2%	Film	EC	ECR302GG
C110,C210	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C111,C211	47uF	20V	20%	Tant	SP	196D476X0020JA1
C112,C212	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S

Circuit Ref.	Value	Description Voltage	Percent	Type	Mfr.	Part Number
C113,C213	47uF	20V	20%	Tant	SP	196D476X0020JA1
C114,C214	1,800pF	250V	5%	Film	EC	ECR182GJ
C115,C215	150pF	100V	5%	Disk	CD	DM15F151J
C116,C216	0.022uF	75V	2%	Film	EC	ECR223CF
C117,C217	1,800pF	250V	5%	Film	EC	ECR182GJ
C118,C218	150pF	100V	5%	Mica	CD	DM15F151J
C119,C219	0.022uF	75V	2%	Film	EC	ECR223CF
C120,C220	1,800pF	250V	5%	Film	EC	ECR182GJ
C121,C221	150pF	100V	5%	Mica	CD	DM15F151J
C122,C222	0.022uF	75V	2%	Film	EC	ECR223CF
C123,C223	1,800pF	250V	5%	Film	EC	ECR182GJ
C124,C224	150pF	100V	5%	Mica	CD	DM15F151J
C125,C225	0.022uF	75V	2%	Film	EC	ECR223CF
C126,C226	10pF	100V	5%	Mica	CD	DM15F100J
C127,C227	10pF	100V	5%	Mica	CD	DM15F100J
C128,C228	270pF	100V	5%	Mica	CD	DM270101J
C129,C229	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C130,C230	10uF	20V	20%	Tant	SP	196D106X0020JA1
C131,C231	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C132,C232	10uF	20V	20%	Tant	SP	196D106X0020JA1
C133,C233	1uF	35V	20%	Tant	MA	TDC105K035EL
C134,C234	1uF	35V	20%	Tant	MA	TDC105K035EL
C135,C235	510pF	100V	5%	Mica	CD	DM15F511J
C136,C236	82pF	100V	5%	Mica	CD	DM15F820J

POTENTIOMETERS (60012)

Circuit Ref.	Description	Mfr.	Part Number
P1	200 Ohm Twenty Turn Cermet	BK	68WR200
P2	100K Ohm Twenty Turn Cermet	BK	68WR100K
P3	1000 Ohm Twenty Turn Cermet	BK	68WR1000
P4	5000 Ohm Twenty Turn Cermet	BK	68WR5000
P102,P202	500 Ohm Twenty Turn Cermet	BK	68WR500
P103,P203	500 Ohm Twenty Turn Cermet	BK	68WR500
P104,P204	100K Ohm Single Turn Cermet	BK	72PMR100

TRANSISTORS AND DIODES (CH60012)

Circuit Ref.	Description	Mfr.	Part Number
Q101,Q201	General Purpose Transistor	MO	MPS3640
Q102,Q202	General Purpose Transistor	MO	MPS3640
Q103,Q203	General Purpose Transistor	MO	2N3906

Circuit Ref.	Description	Mfr.	Part Number
Q104,Q204	General Purpose Transistor	MO	2N3906
Q105,Q205	General Purpose Transistor	MO	2N3906
Q106,Q206	General Purpose Transistor	MO	2N3906
Q107,Q207	General Purpose Transistor	MO	2N3906
Q108,Q208	General Purpose Transistor	MO	2N3906
Q109,Q209	General Purpose Transistor	MO	2N3906
Q110,Q210	General Purpose Transistor	MO	2N3906
D1	Germanium Diode	MO	1N270
D2	High Speed Diode	MO	1N914B
D3	High Speed Diode	MO	1N914B
D4	High Speed Diode	MO	1N914B
D5	High Speed Diode	MO	1N914B
D6	Power Diode	MO	1N4004
D7	Power Diode	MO	1N4004
D8	Power Diode	MO	1N4004
D9	Power Diode	MO	1N4004
D10	Power Diode	MO	1N4004
D11	Power Diode	MO	1N4004
D12	Power Diode	MO	1N4004
D13	Power Diode	MO	1N4004
D14	Power Diode	MO	1N4004
D15	Power Diode	MO	1N4004
D16	Power Diode	MO	1N4004
D17	Power Diode	MO	1N4004
D18	High Speed Diode	MO	1N914B
D19	High Speed Diode	MO	1N914B
D101,D201	Hot Carrier Diode	HP	5082-2900
D102,D202	Hot Carrier Diode	HP	5082-2900
D103,D203	Germanium Diode	MO	1N270
D104,D204	High Speed Diode	MO	1N914B
D105,D205	High Speed Diode	MO	1N914B
D106,D206	High Speed Diode	MO	1N914B
D107,D207	Germanium Diode	MO	1N270
D108,D208	High Speed Diode	MO	1N914B
D109,D209	High Speed Diode	MO	1N914B

MISCELLANEOUS (CH60012)

Circuit Ref.	Description	Mfr.	Part Number
XL1	Crystal 5.185 MH	FX	5.185MHz
L101,L201	39uH Inductor	DA	IM-2-39-10%
L102,L202	39uH Inductor	DA	IM-2-39-10%

INTEGRATED CIRCUITS (CH60012)

Circuit Ref.	Description	Mfr.	Part Number
U1	Microprocessor	CH	CH60070BCP
U2	I/O Expander	IN	8243
U3	Hex Inverter	RA	CD4069UBE
U4	16 Bit A/D Converter	IT	ICL7104
U5	A/D Amplifier	IT	ICL8068
U6	Low Offset Op Amp	PM	OP07GZ
U7	Low Offset Op Amp	PM	OP07GZ
U8	Low Offset Op Amp	PM	OP07GZ
U9	High Speed Quad Switch	SI	HCT4016E
U10	High Speed Quad Switch	SI	HCT4016E
U11	Dual JK Flip Flop	FA	74F112
U12	Quad 2-Input Multiplexor	FA	74F158
U13	5V Regulator	MO	MC7805CT
U14	15V Regulator	MO	MC7815CT
U15	12V Regulator	MO	MC7812CT
U16	-6V Regulator	MO	MC7906CT
U17	-15V Regulator	MO	MC7915CT
	Mounting Hardware (Regulators):		
	Insulating Strip (5 Each)	TK	SR07-54
	Shoulder Washer (5 Each)	CH	CH50069
	4/40 x 3/8BHS Screw(5 Each)	CH	CH50045
	#4 Internal Washer(5 Each)	CH	CH50062
	#4 Nut (5 Each)	CH	CH50057
U18	Display Driver	TI	SN75492N
U19	Quad Comparator	TI	LM139
U20	Quad 2-Input AND Gate	RA	CD4081B
U101,U201	Wideband Op Amp	HA	HA2542
U102,U202	Quad Comparator	TI	LM139
U104,U204	Dual Comparator	TI	TL514

7-7 BUS CARD ASSEMBLY (CH60116)

BOARD, CONNECTORS AND SOCKETS (CH60116)

Circuit Ref.	Description	Mfr.	Part Number
	Buscard Circuit Board	CH	CH60016
	Mounting Hardware (Board):		
	4-40 x 1/4 RHS Screw (4 Each)	CH	CH50044
	#4 Internal Washer (4 Each)	CH	CH50062
J1	10 Pin Berg Socket	BG	65496-055

Circuit Ref.	Description	Mfr.	Part Number
J2	Amp (Champ) 24 Pin		
	Bus Connector	AM	552224-1
	Connector Hardware	AM	552862-1
	6 Pin Socket (2 Each)	RN	ICN-063-S3T
	14 Pin Socket	RN	ICN-143-S3T
	16 Pin Socket (2 Each)	RN	ICN-163-S3T
	20 Pin Socket (2 Each)	RN	ICN-203-S3T
	40 Pin Socket (2 Each)	EM	10640-01-446

<u>RESISTORS</u> (CH60116)

Circuit	Description			Mfr.	Part Number
Ref.	Ohms	Percent	Power		
R1	10,000	1%	1/4W	DA	RN55D
R2	100,000	1%	1/4W	DA	RN55D
R3	332	1%	1/4W	DA	RN55D
R4	3,320	1%	1/4W	DA	RN55D
R5	332	1%	1/4W	DA	RN55D
R6	10,000	1%	1/4W	DA	RN55D
R7	100,000	1%	1/4W	DA	RN55D
R8	3,320	1%	1/4W	DA	RN55D

<u>CAPACITORS</u> (CH60116)

Circuit	Description				Mfr.	Part Number
Ref.	Value	Voltage	Percent	Type		
C1	10uF	20V	20%	Tant	SP	196D106X0020JA1
C2	0.1uF	16V	20%	Disk	ME	DD310-L608Y58
C3	22uF	25V	20%	Tant	KE	T362B226M025AS
C4	22pF	100V	5%	Mica	CD	DM15-220J
C5	0.1uF	16V	20%	Disk	ME	DD310-L608Y5S
C7	10uF	20V	20%	Tant	SP	196D106X0020JA1

<u>INTEGRATED CIRCUITS</u> (CH60116)

Circuit Ref.	Description	Mfr.	Part Number
U1	Hex Inverter	MO	MC14049BCP
U2	Optical Isolator	TI	TIL 126
U3	Optical Isolator	TI	TIL 126
U4	5V Regulator	FR	MC7805CT
U5	Hex Inverter	MO	MC14049BCP
U6	Microprocessor	CH	CH60071

Circuit Ref.	Description	Mfr.	Part Number
U7	Quad and GATE	MO	MC14081BCP
U8	Bus Controller	TI	TMS9914
U9	Bus Driver	TI	SN75161AN
U10	Bus Driver	TI	SN75160AN

MISCELLANEOUS (CH60116)

Circuit Ref.	Description	Mfr.	Part Number
XL1	Crystal 5.1850MHz	FX	5.1850MHz
SW1	5 Position Dip Switch	AR	1015-25

VIII DIAGRAMS

8-1 INTRODUCTION

This Section contains the schematic diagrams and the component location diagrams for the Model 6000 Phase Meter. Table 8-1-1 provides a listing of these drawings. Table 8-1-2 is a list of the Main Board Connections to the other boards.

Table 8-1-1. Listing of Drawings.

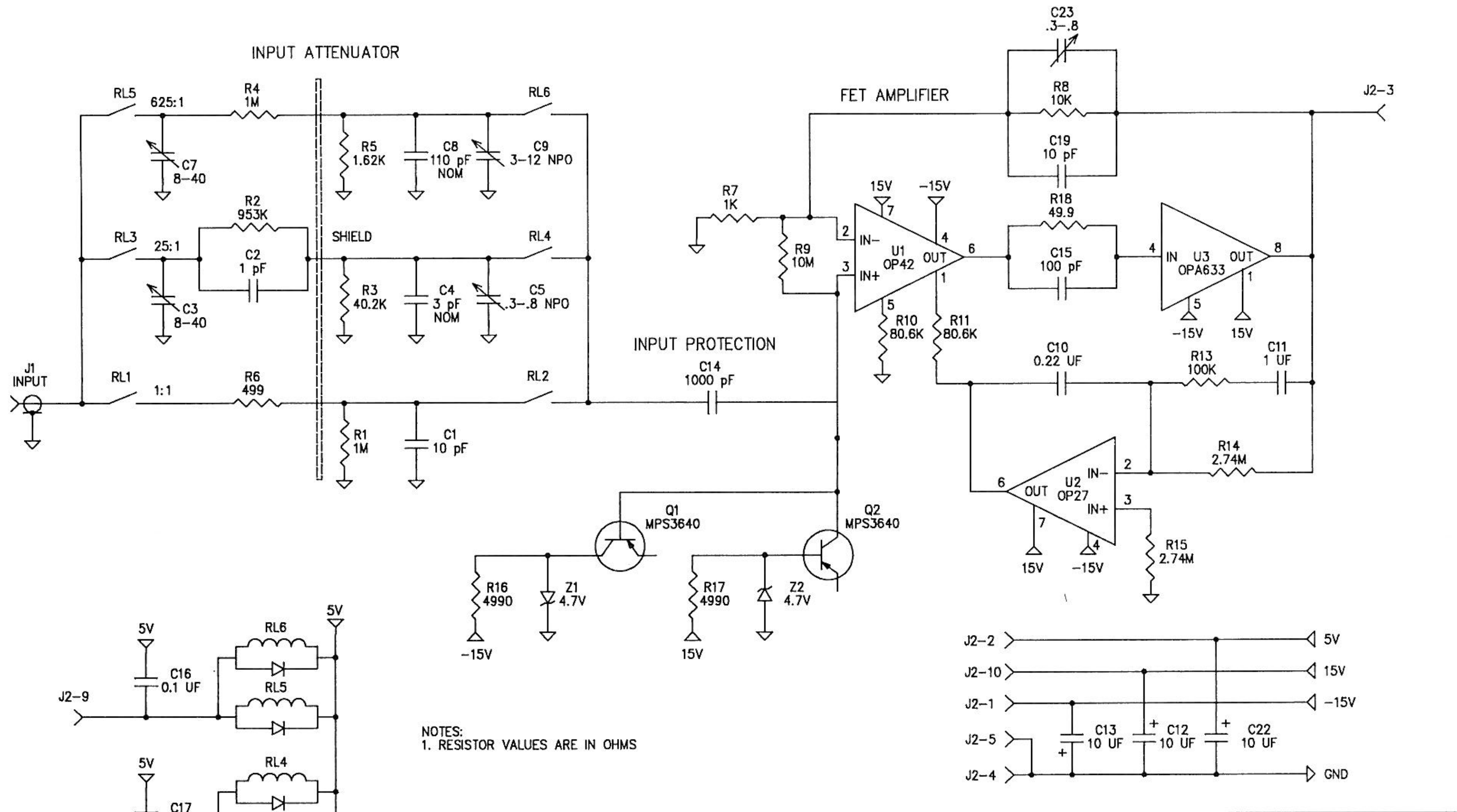
Drawing Number	Description
60000	Input Board Schematic Diagram
60001	Display Board Schematic Diagram
60002*	Power Supply Schematic Diagram
60003*	Signal Channel Schematic Diagram
60004*	Main Board Schematic Diagram
60006	Buscard Schematic Diagram
60010	Input Board Layout
60011	Display Board Layout
60012	Main Board Layout
60016	Buscard Board Layout

* Part of Main Board

Table 8-1-2. Cable Connections - Main Board to Auxillary Boards

Main Board Designation	Auxillary Board and Designation	Cable Part No.
J-1	Display Board J-1	CH60038
J-2	IEEE-488 Bus Interface J1	CH60036
J-100	Signal Input Board J-2	CH60037
J-200	Reference Input Board J-2	CH60037

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED



NOTES:
1. RESISTOR VALUES ARE IN OHMS

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS XX ± XXX ± ANGLES ±

MATERIAL

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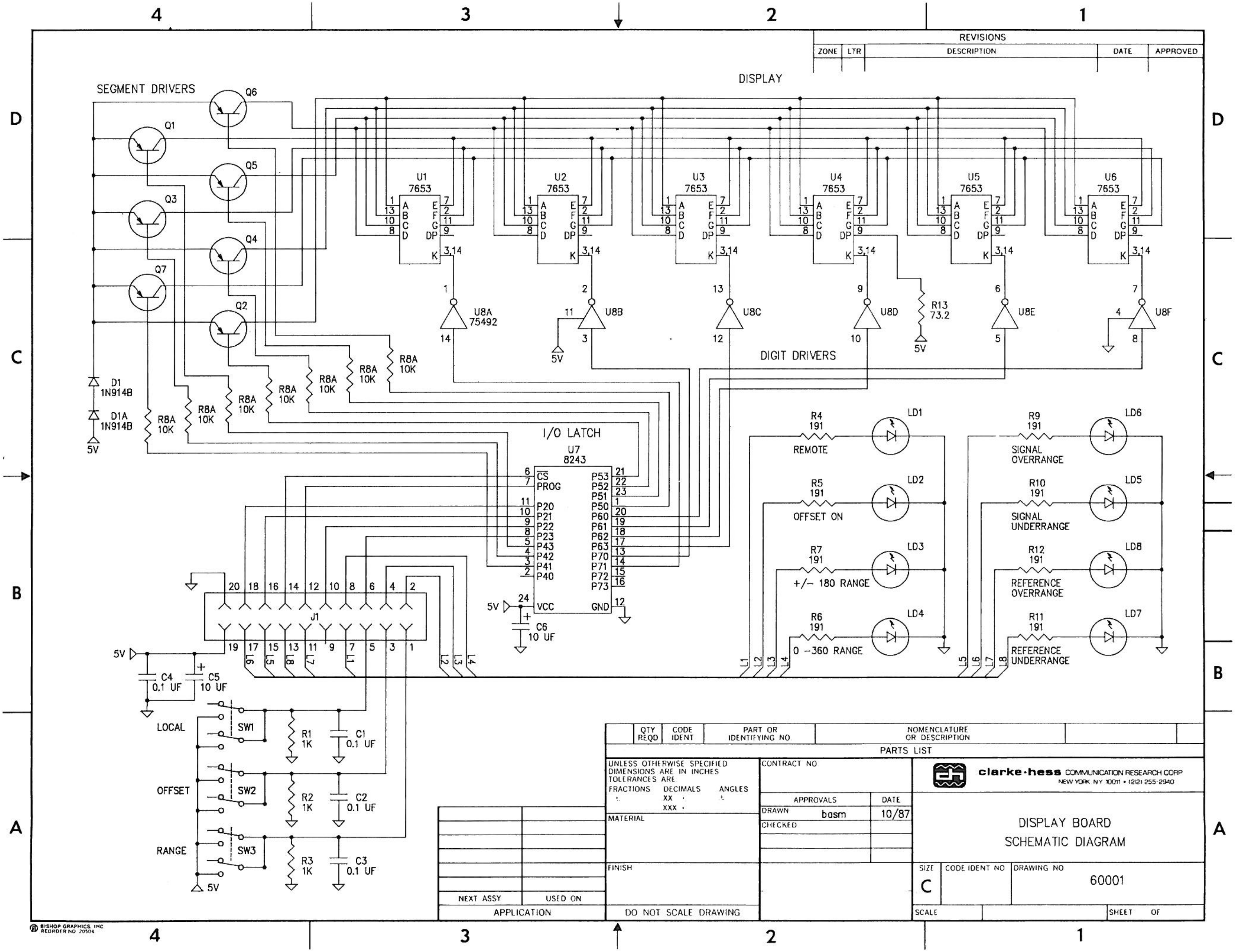
INPUT BOARD
SCHEMATIC DIAGRAM

SIZE	CODE IDENT NO	DRAWING NO
C		60000

SCALE SHEET OF



REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
DISPLAY
SEGMENT DRIVERS
Q1
Q2
Q3
Q4
Q5
Q6
Q7
D1 1N914B
D1A 1N914B
5V
R8A 10K
U1 7653
U2 7653
U3 7653
U4 7653
U5 7653
U6 7653
U8A 75492
U8B
U8C
U8D
U8E
U8F
R13 73.2
DIGIT DRIVERS
I/O LATCH
U7 8243
CS
PROG
P20
P21
P22
P23
P43
P42
P41
P40
VCC
P53
P52
P51
P50
P60
P61
P62
P63
P70
P71
P72
P73
GND
C6 10 UF
J1
C4 0.1 UF
C5 10 UF
LOCAL
SW1
R1 1K
C1 0.1 UF
OFFSET
SW2
R2 1K
C2 0.1 UF
RANGE
SW3
R3 1K
C3 0.1 UF
R4 191
REMOTE
LD1
R5 191
OFFSET ON
LD2
R7 191
+/− 180 RANGE
LD3
R6 191
0 −360 RANGE
LD4
R9 191
SIGNAL OVERRANGE
LD6
R10 191
SIGNAL UNDERRANGE
LD5
R12 191
REFERENCE OVERRANGE
LD8
R11 191
REFERENCE UNDERRANGE
LD7
QTY REQD
CODE IDENT
PART OR IDENTIFYING NO
NOMENCLATURE OR DESCRIPTION
PARTS LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS
DECIMALS
XX
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CONTRACT NO
APPROVALS
DATE
DRAWN
basm
10/87
CHECKED
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DISPLAY BOARD
SCHEMATIC DIAGRAM
SIZE
C
CODE IDENT NO
DRAWING NO
60001
SCALE
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OF
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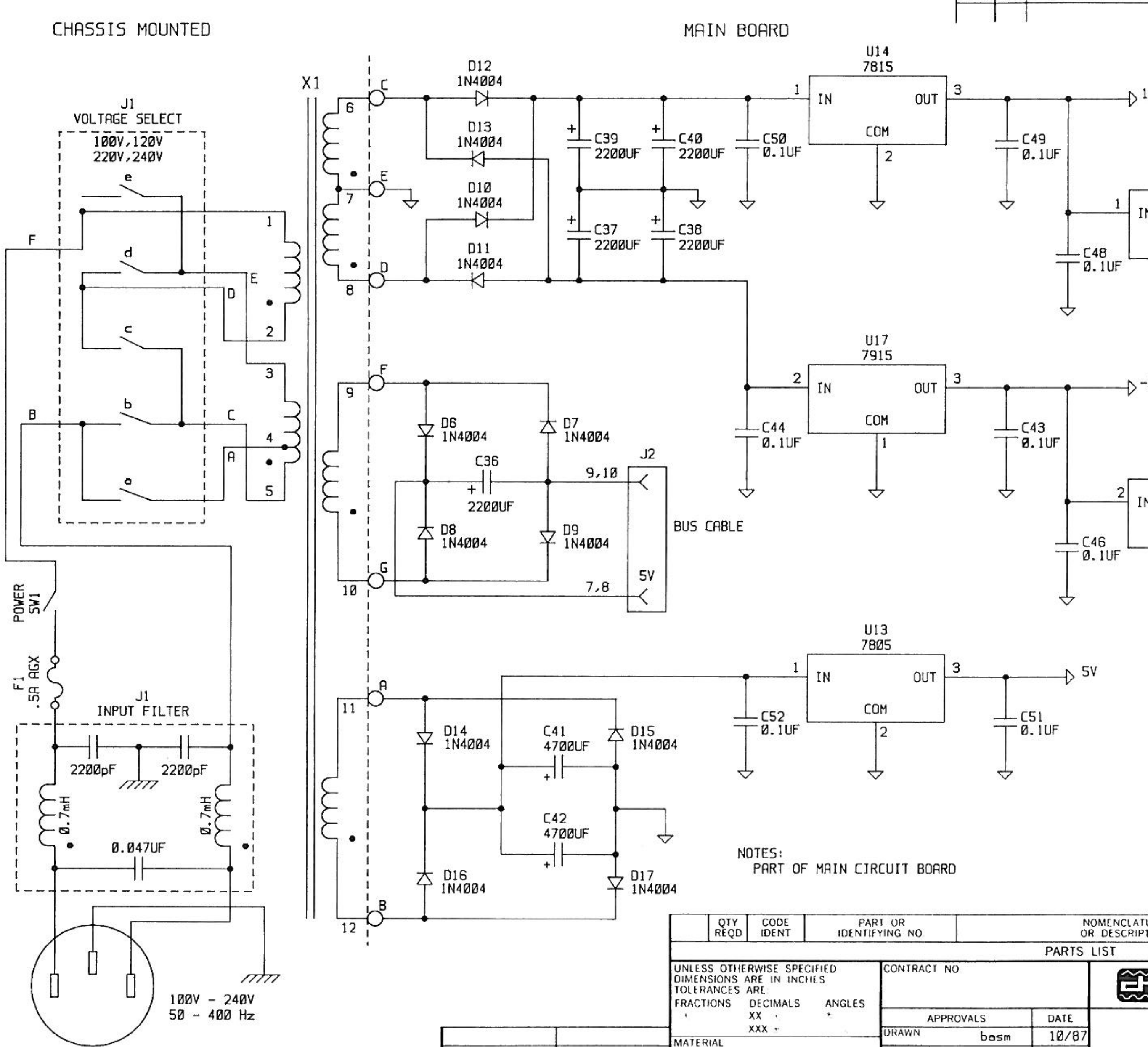

LINE VOLTAGE SELECTOR

100V	a, c, e
120V	b, c, e
220V	a, d
240V	b, d

NOTES:
PART OF MAIN CIRCUIT BOARD

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION

PARTS LIST

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FRACTIONS ± DECIMALS XX ± XXX ± ANGLES ±
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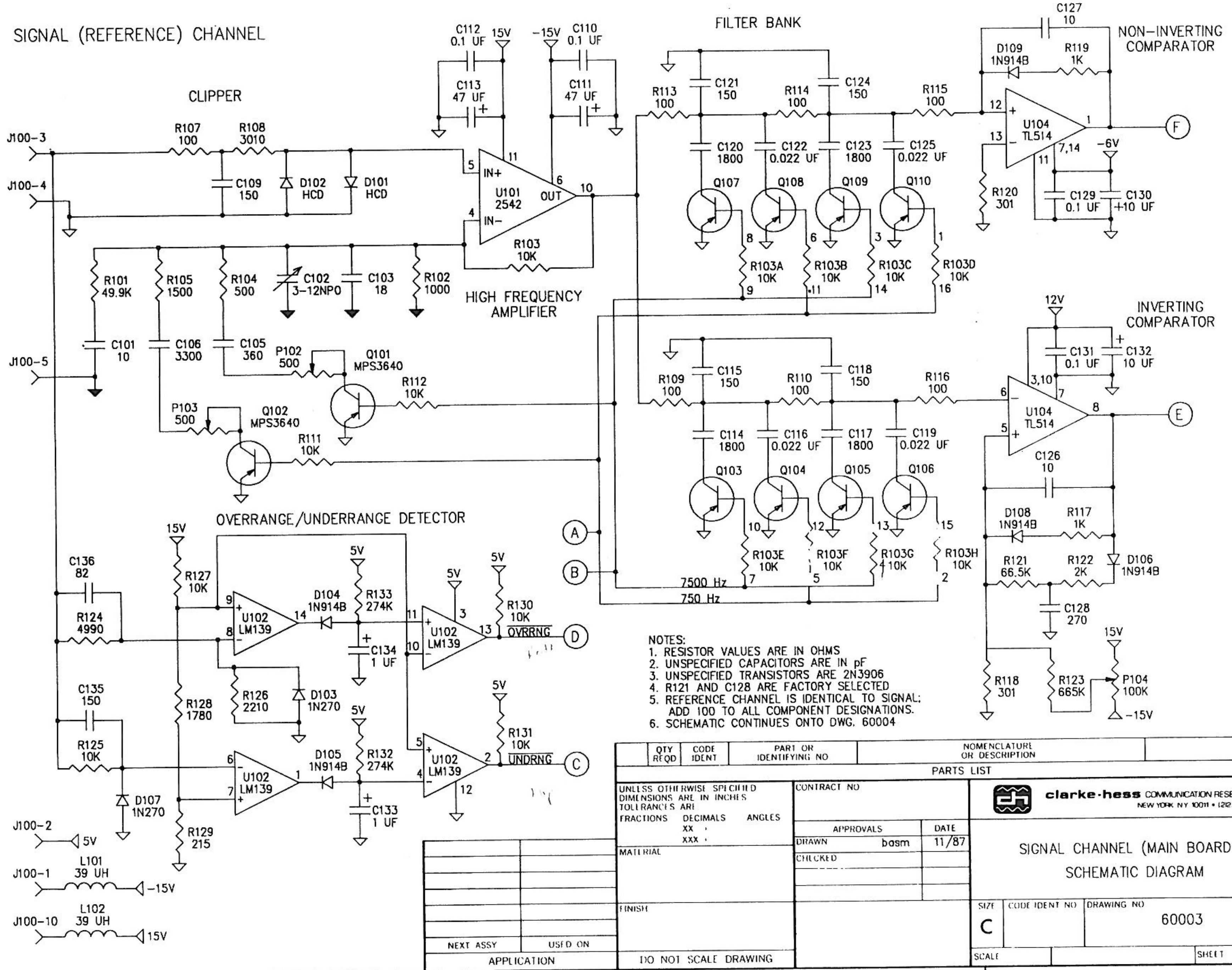
POWER SUPPLY
SCHEMATIC DIAGRAM

SIZE C | CODE IDENT NO | DRAWING NO 60002
SCALE | SHEET OF

SIGNAL (REFERENCE) CHANNEL



NOTES:
1. RESISTOR VALUES ARE IN OHMS
2. UNSPECIFIED CAPACITORS ARE IN pF
3. UNSPECIFIED TRANSISTORS ARE 2N3906
4. R121 AND C128 ARE FACTORY SELECTED
5. REFERENCE CHANNEL IS IDENTICAL TO SIGNAL; ADD 100 TO ALL COMPONENT DESIGNATIONS.
6. SCHEMATIC CONTINUES ONTO DWG. 60004

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS DECIMALS ANGLES
XX ±
XXX ±

MATERIAL

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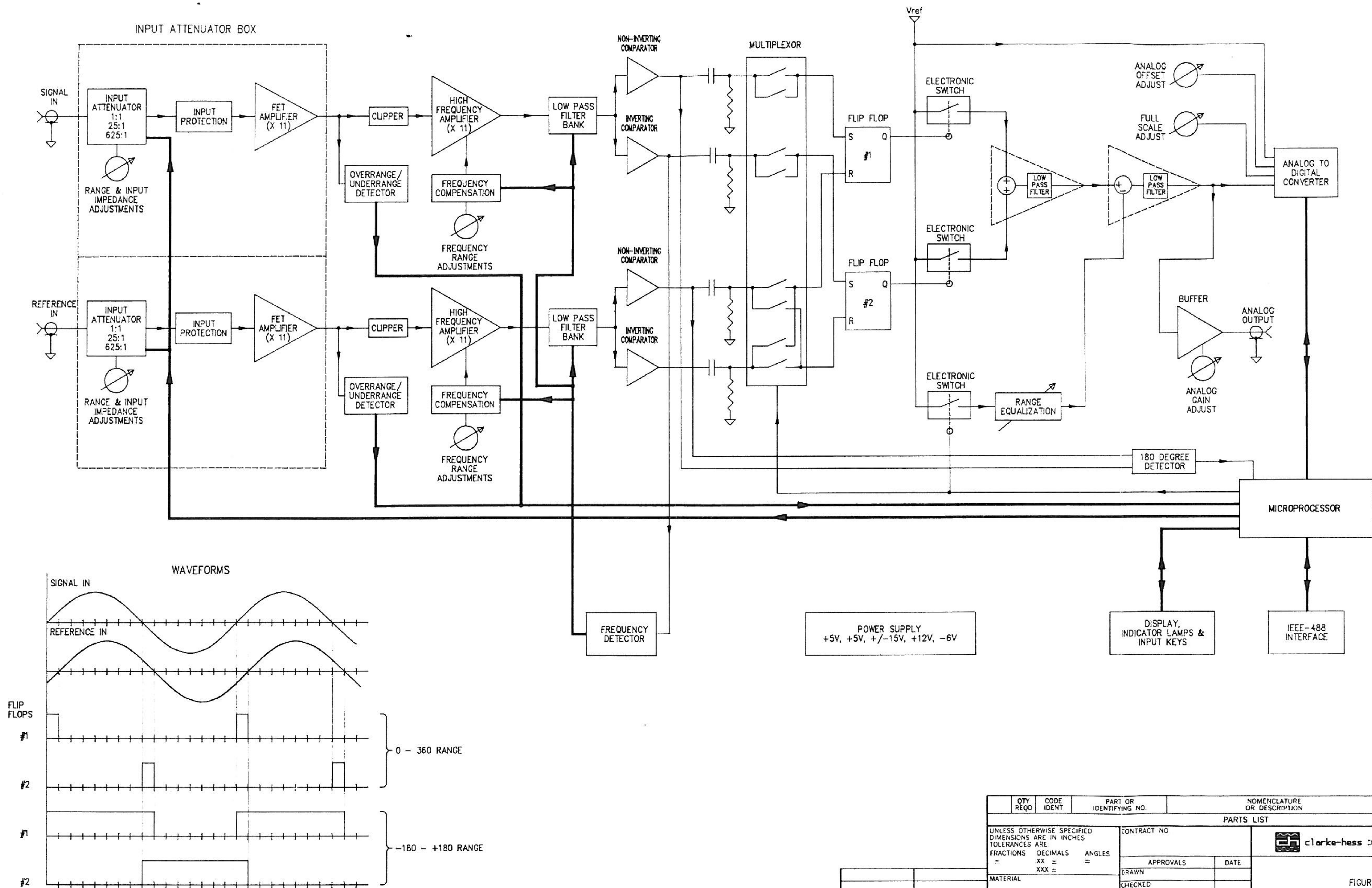
SIGNAL CHANNEL (MAIN BOARD)
SCHEMATIC DIAGRAM

SIZE C | CODE IDENT NO | DRAWING NO 60003

SCALE | SHEET OF

BISHOP GRAPHICS INC REORDER NO 20504



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS ± DECIMALS XX ± XXX ± ANGLES ±

MATERIAL

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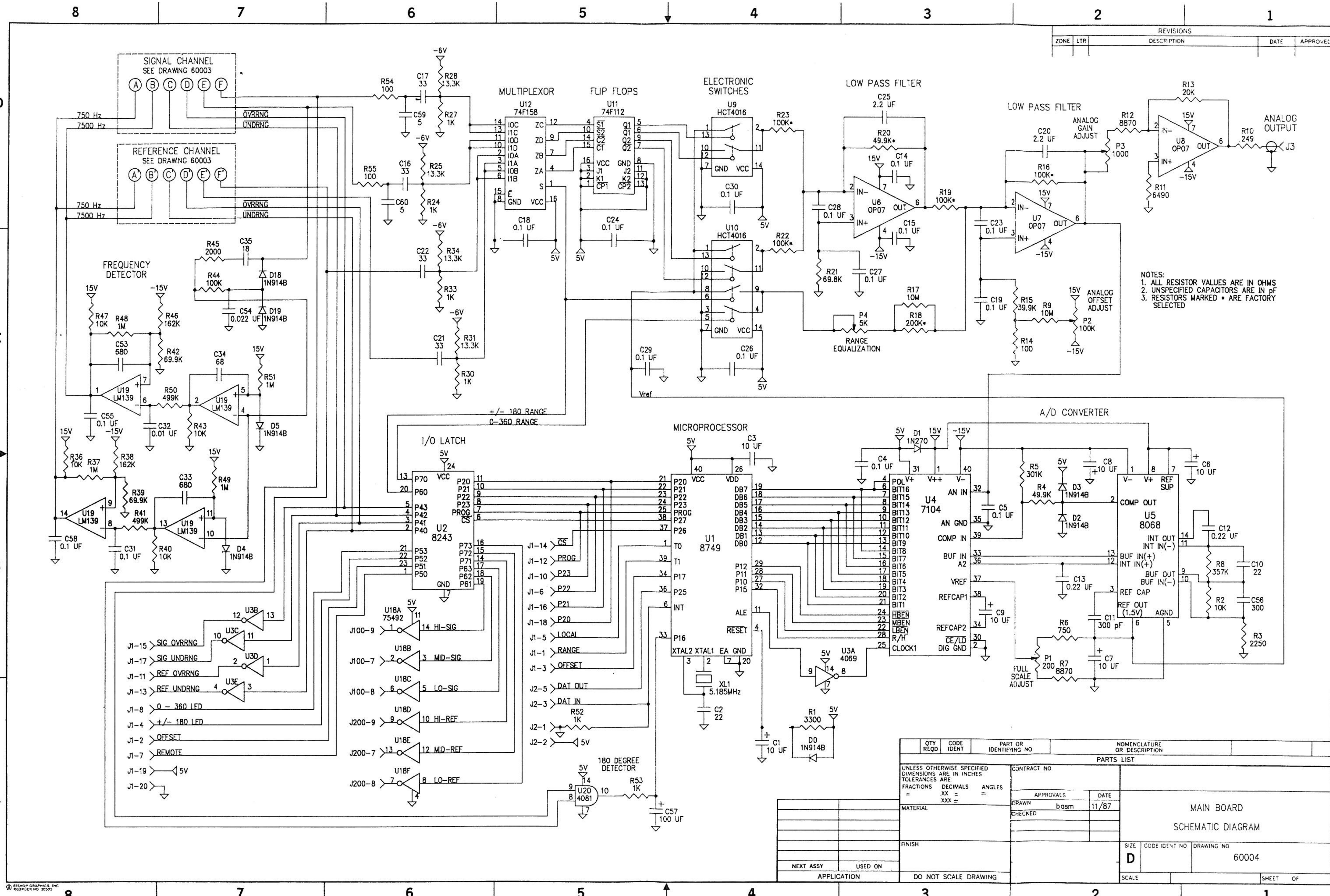
FIGURE 2-2-1

PHASE METER BLOCK DIAGRAM

SIZE D | CODE IDENT NO | DRAWING NO

SCALE | SHEET OF

REVISIONS: ZONE | LTR | DESCRIPTION | DATE | APPROVED



SIGNAL CHANNEL
SEE DRAWING 60003
REFERENCE CHANNEL
SEE DRAWING 60003
750 Hz
7500 Hz
OVRRNG
UNDRNG
FREQUENCY DETECTOR
MULTIPLEXOR
U12 74F158
FLIP FLOPS
U11 74F112
ELECTRONIC SWITCHES
U9 HCT4016
U10 HCT4016
LOW PASS FILTER
U6 OP07
LOW PASS FILTER
U7 OP07
ANALOG GAIN ADJUST
U8 OP07
ANALOG OUTPUT
J3
RANGE EQUALIZATION
ANALOG OFFSET ADJUST
NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS
2. UNSPECIFIED CAPACITORS ARE IN pF
3. RESISTORS MARKED • ARE FACTORY SELECTED
Vref
+/- 180 RANGE
0-360 RANGE
I/O LATCH
U2 8243
MICROPROCESSOR
U1 8749
XL1 5.185MHz
A/D CONVERTER
U4 7104
U5 8068
FULL SCALE ADJUST
180 DEGREE DETECTOR
U20 4081
U3A 4069
U18A 75492
J1-15 SIG OVRRNG
J1-17 SIG UNDRNG
J1-11 REF OVRRNG
J1-13 REF UNDRNG
J1-8 0 - 360 LED
J1-4 +/- 180 LED
J1-2 OFFSET
J1-7 REMOTE
J1-19 5V
J1-20
J100-9 HI-SIG
J100-7 MID-SIG
J100-8 LO-SIG
J200-9 HI-REF
J200-7 MID-REF
J200-8 LO-REF
J1-14 CS
J1-12 PROG
J1-10 P23
J1-6 P22
J1-16 P21
J1-18 P20
J1-5 LOCAL
J1-1 RANGE
J1-3 OFFSET
J2-5 DAT OUT
J2-3 DAT IN
J2-1
J2-2 5V
REVISIONS
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MAIN BOARD
SCHEMATIC DIAGRAM
SIZE D
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DRAWING NO 60004
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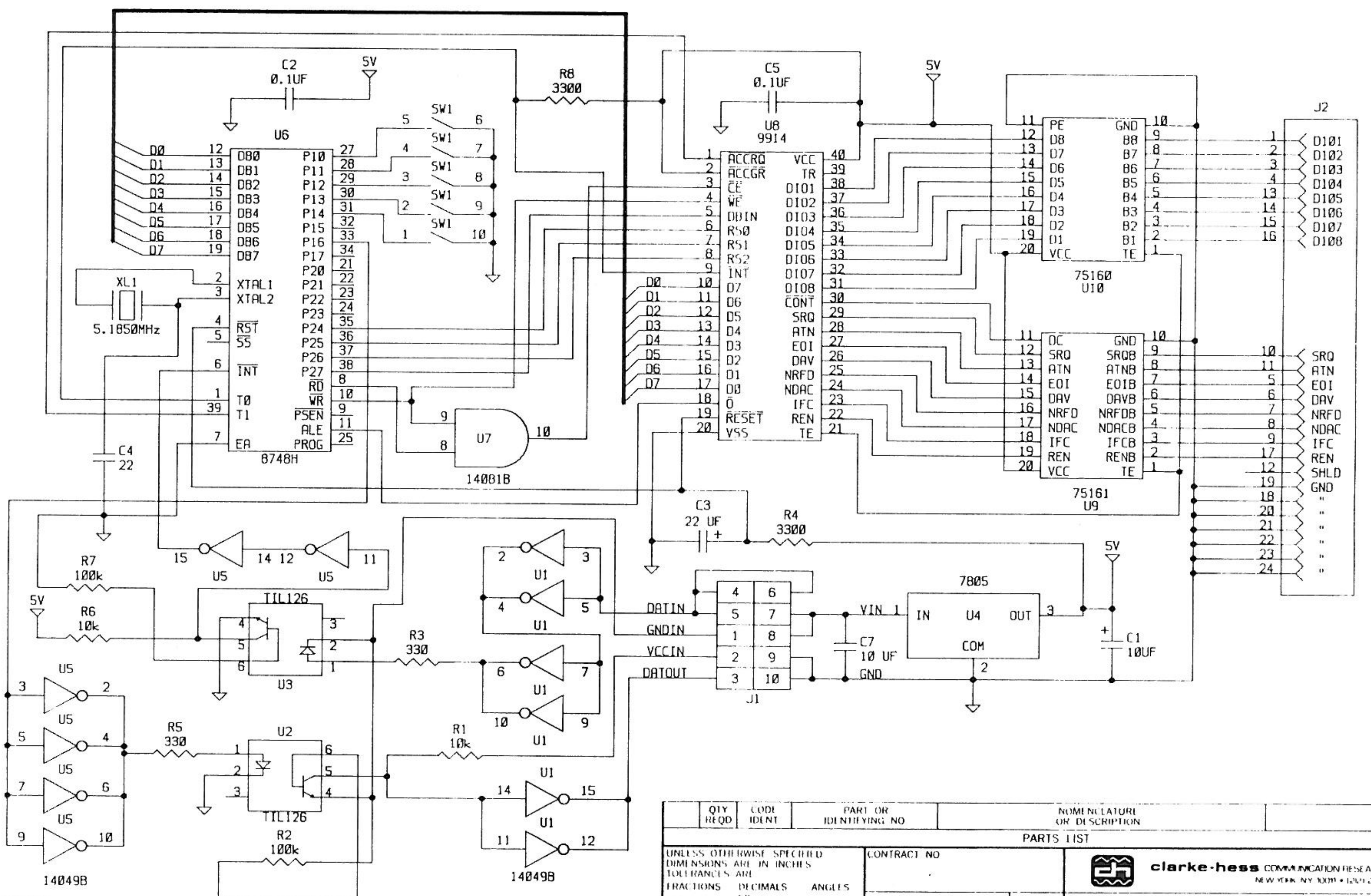
BISHOP GRAPHICS, INC. REORDER NO 20505



NOTES:

1. RESISTOR VALUES ARE IN OHMS.
2. UNSPECIFIED CAPACITOR VALUES IN pF.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION

PARTS LIST

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FRACTIONS DECIMALS ANGLES
XX
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MATERIAL

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IEEE-488 BUS INTERFACE
SCHEMATIC DIAGRAM

SIZE C | CODE IDENT NO | DRAWING NO 60006

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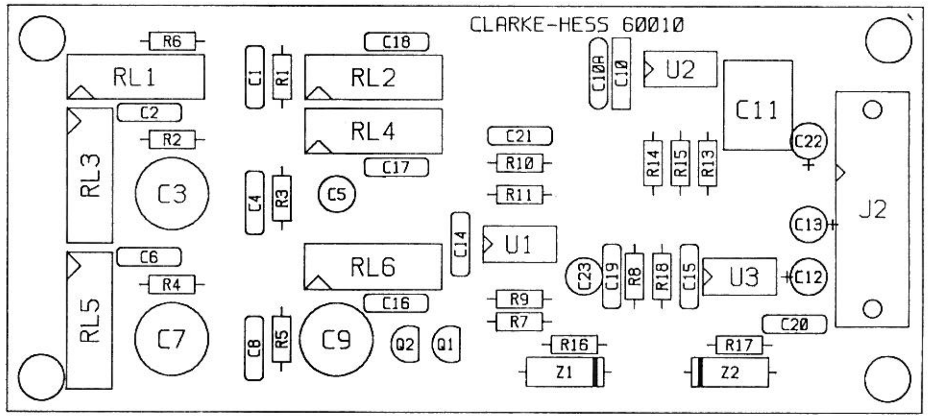
ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED



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PARTS LIST						

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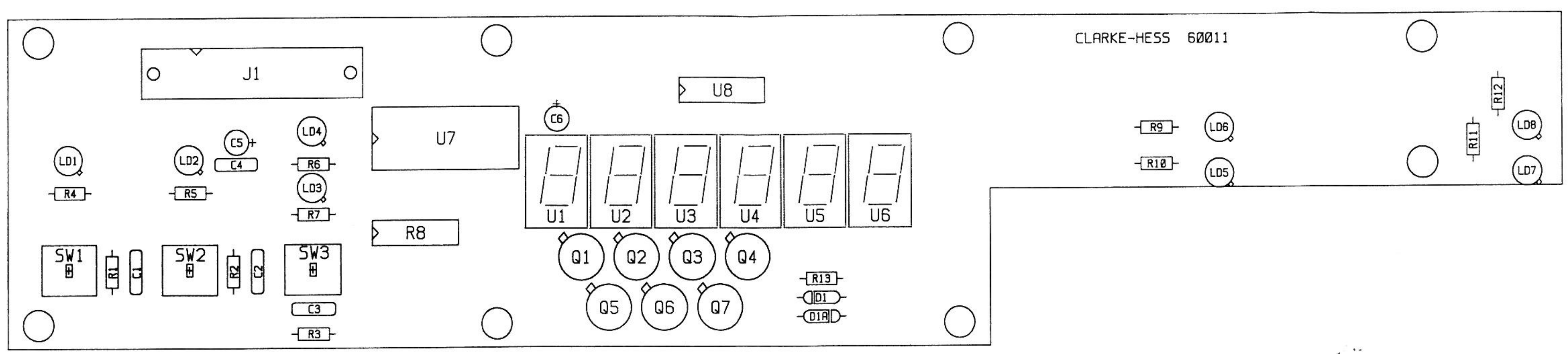
INPUT BOARD LAYOUT

SIZE	CODE IDENT NO	DRAWING NO
C		60010

SCALE SHEET OF

BISHOP GRAPHICS INC REORDER NO 70504

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS ± DECIMALS XX ± XXX ± ANGLES ±

MATERIAL

FINISH

CONTRACT NO

APPROVALS	DATE
DRAWN	
CHECKED	

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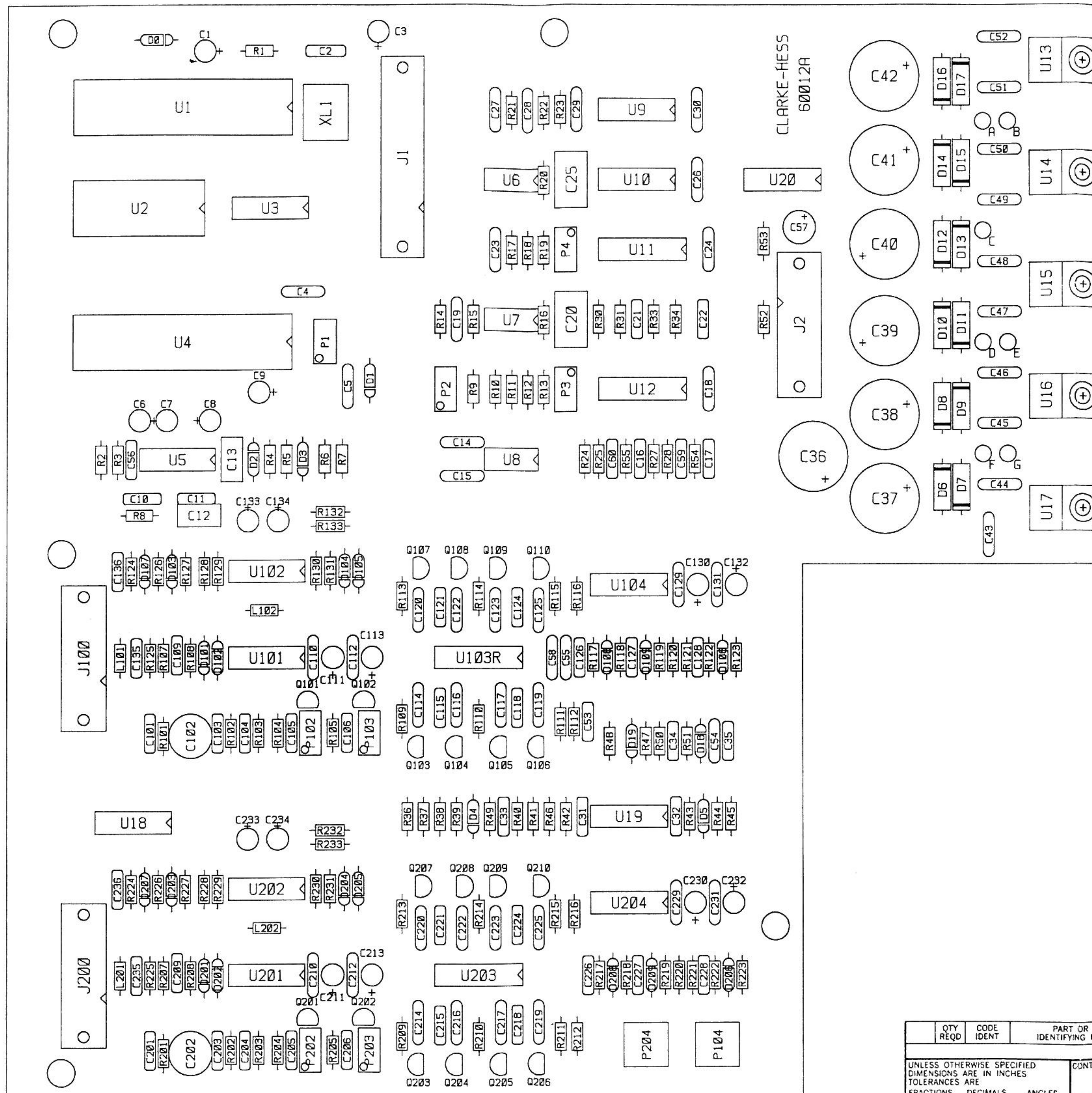
DISPLAY BOARD LAYOUT

SIZE	CODE IDENT NO	DRAWING NO
D		60011

SCALE SHEET OF

NEXT ASSY	USED ON
APPLICATION	

DO NOT SCALE DRAWING



REVISIONS			
ZONE	LTR	DESCRIPTION	DATE	APPROVED

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE
FRACTIONS ± DECIMALS XX ± XXX ± ANGLES ±

MATERIAL

FINISH

DO NOT SCALE DRAWING

CONTRACT NO

APPROVALS | DATE
DRAWN
CHECKED

NEXT ASSY | USED ON
APPLICATION

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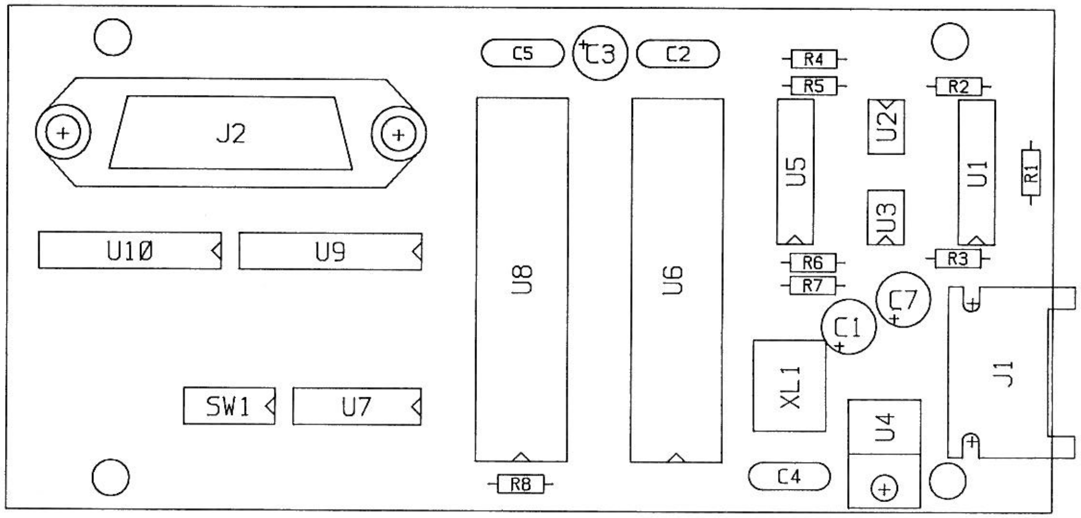
MAIN BOARD LAYOUT

SIZE D | CODE IDENT NO | DRAWING NO 60012

SCALE | SHEET | OF

BISHOP GRAPHICS, INC. REORDER NO. 20505

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION

PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

MATERIAL

FINISH

DO NOT SCALE DRAWING

CONTRACT NO

APPROVALS	DATE
DRAWN	
CHECKED	

NEXT ASSY	USED ON

APPLICATION

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IEEE-488 BUS INTERFACE
BOARD LAYOUT

SIZE C | CODE IDENT NO | DRAWING NO 60016

SCALE | SHEET OF

BISHOP GRAPHICS INC
REORDER NO 20504