INSTRUCTION MANUAL

TE 360 and TE 361

INTEGRATING DIGITAL MULTIMETERS

TEKELEC AIRTRONIC

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Frontispiece

SECTION I GENERAL INFORMATION

1-1. INTRODUCTION

1-2. The Model 360 and 361 Digital Multimeter is a low cost, accurate, 3-digit instrument suitable for use in production, general test, field servicing, and educational applications. It may be used in lieu of any analog type multimeter. The Model 360 will measure DC voltage, AC voltage, DC milliamps, AC milliamps, and ohms. The Model 361 measures DC voltage, DC milliamps, and ohms. There are five ranges for each function. The input can be floated 500V above ground, and the input impedance is greater than 100 Mohms on the 0.2 V range, and greater than 1000 Mohms, on the 2.0 V range.

1-3. The Model 360 and 361 will measure DC volts from 200 millivolts full scale to 1000V full scale. The AC voltage range of the Model 360 is also 200 millivolts full scale to 1000V full scale. The current ranges are 200 microamps full scale to 2 amps full scale. The ohms ranges are 200 ohms full scale to 2 megohms full scale. The functions and ranges are selected by pushbutton switches mounted on front of the instrument.

1-4. The measuring technique used in both instruments is dual slope integration. This technique provides high noise rejection capabilities, accuracy, and stability of the instrument. The input amplifier to the instrument is chopper stabilized to provide high stability and low drift characteristics.

1-5. ACCESSORIES

1-6. The optional equipment available for use with the 360 and 361 is listed below.

1-7. A battery pack is optional which allows the instrument to operate from an internal DC source and thus be used as a portable instrument. The battery may be recharged by plugging into a standard wall outlet and the instrument may also be run from an AC line.

1-8. A rack mounting kit is optional which adapts the instrument to a standard rack mounting configuration 134 mm high and 483 mm wide. It provides the capability of mounting one 360 or two instruments side-by-side.

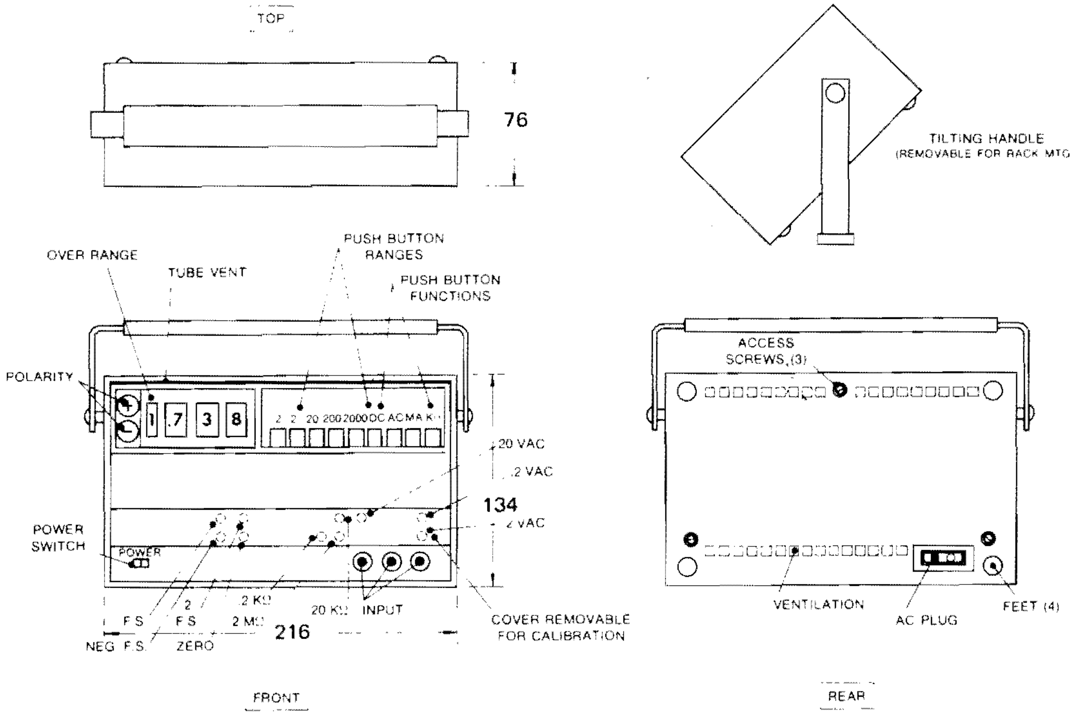


Figure 1-1 Mechanical Outline Drawing

TABLE 1-1
SPECIFICATIONS

DC VOLTS

RANGES	RESOLUTION	IMPEDANCE
.2000V	100 μV	> 100 MΩ
2.000V	1 mV	> 1000 MΩ
20.00V	10 mV	10 MΩ
200.0V	100 mV	10 MΩ
1000.0V	1V	10 MΩ

ACCURACY:

200 mV	±(0.1% Rdg + 0.15% FS)	±(0.1% Rdg + 0.2% FS)
2V, 20V, 200V	±(0.1% Rdg + 0.1% FS) at constant temperature	±(0.1% Rdg + .1% FS) 10°C-40°C for 60 days
1000V	±(0.1% Rdg + 0.1% FS)	±(0.1% Rdg + .2% FS)

VOLTAGE COEFFICIENT: ±0.0005%/V

STEP RESPONSE TIME: 400 ms to within rated accuracy

NORMAL MODE NOISE REJECTION: 30 dB for 60 Hz, increasing 20 dB/ decade

OVERLOAD PROTECTION: 1000 V max on 20,200, 1000V
250V max on 0.2 & 2V range.

AC VOLTS*

RANGES:
.2000V
2.000V
20.00V
200.0V
1000V (750V max input)

ACCURACY:

.2, 2, 20, 200 & 1000V (50 Hz - 10 kHz)
at constant temperature ±(0.5% of Rdg +0.2% FS)
10°C to 40°C for 60 days ±(0.7% of Rdg +0.3% FS)

.2 & 2V (10 kHz to 20 kHz)
at constant temperature ±(1% of Rdg +0.3% FS)
10°C to 40°C for 60 days ±(2% of Rdg +0.4% FS)

.2 & 2V (20 kHz to 100 kHz)
at constant temperature ±(3% of Rdg +0.5% of FS)
10°C to 40°C for 60 days ±(5% of Rdg +0.6% FS)

*Note: AC specifications do not apply to Model 361.

TABLE 1-1
SPECIFICATIONS (CONT.)

STEP RESPONSE TIME: 2 sec

VOLTAGE COEFFICIENT: 0.001%/V

OVERLOAD PROTECTION: 750V AC and/or V DC on the 20,200, 1000V AC ranges 240V AC @ 50 Hz or 115V @ 400Hz on the 0.2 and 2V range.

INPUT IMPEDANCE: 10 MΩ/ /90pF

KΩ SPECIFICATION

RANGE	RESOLUTION	OUTPUT CURRENT
.2000 kΩ	.1Ω	1 mA
2.000 kΩ	1Ω	1 mA
20.00 kΩ	10Ω	10 μA
200.0 kΩ	10Ω	10 μA
2000. kΩ	1 kΩ	1 μA

Max. open circuit voltage: 6V

ACCURACY:

.2, 2, 20, 200 kΩ range
at constant temperature ±(0.2% Rdg +0.1% FS)
10°C to 40°C for 60 days ±(0.3% Rdg +0.2% FS)

2000 kΩ Range
at constant temperature ±(0.2% Rdg +0.2% FS)
10°C to 40°C for 60 days ±(0.5% Rdg +0.2% FS)

STEP RESPONSE TIME: 400 ms to within rated accuracy.

OVERLOAD PROTECTION: ±20V on all kΩ ranges

CURRENT

DC and AC RANGES (50 Hz to 10 kHz):*

RANGE	RESOLUTION	SHUNT RESISTANCE
.2000 mA	100 nA	1000Ω
2.000 mA	1 μA	100Ω
20.00 mA	10 μA	10Ω
200.0 mA	100 μA	1Ω
2000 mA	1 mA	.1Ω

DC CURRENT ACCURACY:

.2, 2, 20, 200 mA Range
at constant temperature ±(0.2% Rdg +0.1% FS)
10°C to 40°C for 60 days ±(0.2% Rdg +0.2% FS)

2A Range
at constant temperature ±(0.3% Rdg±0.2% FS)
10°C to 40°C for 60 days ±(0.5% Rdg +0.3% FS)

*Note: AC specifications do not apply to Model 361.

TABLE 1-1
SPECIFICATIONS (CONT.)

AC CURRENT ACCURACY:*

All Ranges: 50 Hz – 10 kHz
at constant temperature ±(0.5% Rdg +0.2% FS)
10°C to 40°C for 60 days ±(0.7% Rdg ±0.3% FS)

RESPONSE TIME: DC Current – 400 ms within rated accuracy
AC Current – 2 sec within rated accuracy

OVERLOAD PROTECTION:

.2 mA Range . . . 20 mA max
2 mA Range . . . . 100 mA max
20 mA Range . . . 400 mA max
200 mA Range . . 2A max
2A Range . . . . . 5A max

OPERATING CONDITIONS

POWER: 115 VAC ±10% 50-60 Hz optional
230 VAC ±10% 50-60 Hz

TEMPERATURE – OPERATING: 0° to 50°C

WARM UP TIME: Normal room temperature – 5 minutes at 10°C

*Note: AC specifications do not apply to Model 361.

SECTION II INSPECTION AND CHECKOUT

2-1. INTRODUCTION

2-2. This section outlines procedures for inspection and initial installation. Reshipment instructions are included in case the instrument must be returned.

2-3. UNPACKING AND INSPECTION

2-4. Before accepting the instrument from the shipper, inspect the crated instrument for external damage. Any sign of external damage must be noted by both customer and shipper, and should be called to the attention of an insurance investigator.

2-5. As soon as the equipment is unpacked, inspect the instrument for damage in shipment. Check for scratches or dents and damaged switches or connectors. If damage is noted, do not use the instrument unless instructed by the insuring agency.

2-6. POWER REQUIREMENT

2-7. The Model 360 and 361 is designed to operate from 230 V, $\pm$ 10 % (115 V optional), 50-60 cycles per second power source. It draws approximately 7 watts. Do not connect the instrument to a power source with incorrect voltage or with an inadequate current rating.

2-8. OPERATION CHECK

2-9. The following preliminary operations check may be used to ensure that all components and circuits are in proper operating condition when the instrument is first energized. The procedure provides a quick check for proper functioning, but is not intended to check all specifications.

2-10. Connect the instrument to a proper power source.

2-11. Set the OFF/ON switch to ON. The nixie display should light up.

2-12. Set the function switch to Volts DC and the range switch to 2 volts, and short between the volt input and the common terminals. The readout should be 0.000 or 0.001 or 0.002.

2-13. Set the function switch to ohms. Move the short to between the ohms and the common terminals. Check that the readout is 0.000 or 0.001. or 0.002.

2-14. Remove the short and set the power switch to OFF. Disconnect the instrument from the AC power source.

2-15. Note: These instruments have a very low internal noise current. When the voltage input terminals are open-circuited with the range switch in the

20, 200, or 1000V division, the reading will always drop to 000. When in the 2V position, the low noise current is accumulated as a voltage across the high input impedance and appears as a slowly increasing numerical value on the readout indicator. In any of the ohms ranges with the input open, the instrument will read over full scale since the resistance between the terminals is that of the air gap itself.

2-16. RESHIPMENT

2-17. When a damaged instrument is to be return- to the factory for repair or service, contact your nearest **Tekelec-Airtronic** Representative for written permission to ship, for shipping instructions and for a shipping form. Such action will ensure expedient repair and return of the instrument.

SECTION III OPERATION

3-1. OPERATING INSTRUCTIONS

3-2. The following paragraphs and the diagrams which accompany them describe the control functions and operating procedures for the Model 360 and 361 multimeter

3-3. FRONT PANEL DESCRIPTION

3-4. The function of each control located on the front panel is described in Figure 3 1

3-5. MEASURING DC VOLTAGE

1. Connect the instrument to a proper power source. If instrument is equipped with battery option, this step is not necessary.

2. Set OFF/ON switch to ON (right).

3. Set Function Switch to DC.

4. Set Range Switch to 2000.

5. Connect unknown DC voltage across volts and common terminals.

6. Observe reading: If overrange digit is floating, remove input voltage immediately. If reading is less than overload, reduce range values until proper reading is reached.

RANGE	LIMITS	OVERLOAD PROTECTION
2V	00.0 - 199.9 mV	250V
2V	.000 - 1 999V	250V
20V	0.00 - 19.99V	1000V
200V	00.0 - 199.9V	1000V
1000V	000 - 999V	1000V

3-6 MEASURING AC VOLTAGE (APPLIES ONLY TO MODEL 360)

1. Connect the instrument to a proper power source. If instrument is equipped with battery option, this step is not necessary.

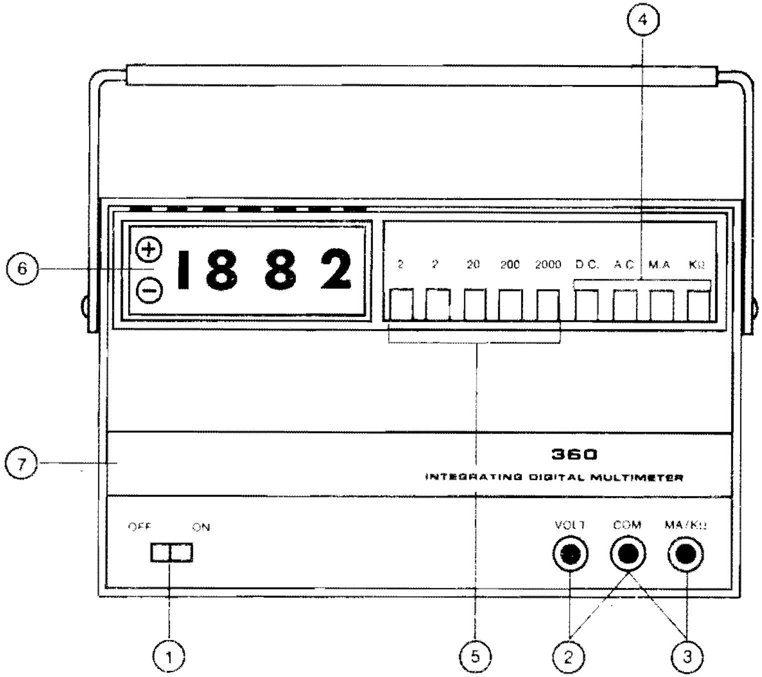
2. Set OFF/ON switch to ON (right).

3. Set Function Switch to AC.

4. Set Range Switch to 2000

5. Connect unknown AC voltage across volts and common terminals.

6. Observe reading: If overrange digit is floating, remove input voltage immediately. If reading is less than overload, reduce range values until proper reading is reached.



1. Power ON/OFF switch applies power to the instrument ON position is to the right.
2. Volts terminal (left) and common terminal (center) are used for DC volts and AC volts measurements.
3. MA/KΩ terminal (right) and common terminal (center) are used for current measurements and ohms measurements.
4. Function switches (white) permit selection of measurement function: DC, AC, mA, KΩ.
5. Range switches (black) permit selection of five ranges for each function: .2, 2, 20, 200, 2000.
6. Readout Panel gives visual presentation of three digits plus overrange, decimal point, and polarity of quantity being measured.
7. Decorative strip removes for access to calibration pots.

Figure 3-1 Front Panel Description

RANGE	LIMITS	OVERLOAD PROTECTION
.2V	00.0 - 199.9 mV	240V up to 50 Hz or 115V up to 400 Hz
2V	.000 - 1.999V	240V up to 50 Hz or 115V up to 400 Hz
20V	0.00 - 19.99V	750V AC or DC
200V	00.0 - 199.9V	750V AC or DC
1000V	000 - 999V	750V AC or DC

RANGE	LIMITS	OVERLOAD PROTECTION
.2 KΩ	00.0 - 199.9 Ω	±20V on all ranges
2 KΩ	.000 - 1.999 KΩ	
20 KΩ	0.00 - 19.99 KΩ	
200 KΩ	00.0 - 199.9 KΩ	
2000 KΩ	000 - 1999 KΩ	

3-7. MEASURING RESISTANCE

1. Connect the instrument to a proper power source. If instrument is equipped with battery option, this step is not necessary.

2. Set OFF/ON switch to ON (right).

3. Set Function Switch to KΩ

4. Set Range Switch to 2000.

5. Connect unknown resistance across MA/KΩ and common terminals.

6. Observe reading: If overrange digit is floating, remove input voltage immediately. If reading is less than overload, reduce range values until proper reading is reached.

3-8. MEASURING DC CURRENT

1. Connect the instrument to a proper power source. If instrument is equipped with battery option, this step is not necessary.

2. Set OFF/ON switch to ON (right).

3. Set Function Switch to MA.

4. Set Range Switch to 2000.

5. Connect unknown current across MA/KΩ and common terminals.

6. Observe reading: If overrange digit is floating, remove input voltage immediately. If reading is less than overload, reduce range values until proper reading is reached.

RANGE	LIMITS	OVERLOAD PROTECTION
.2 mA	00.0 - 199.9 μA	20 mA
2 mA	.000 - 1.999 mA	100 mA
20 mA	0.00 - 19.99 mA	400 mA for 1 minute
200 mA	00.0 - 199.9 mA	2A for 1 minute
2000 mA	000 - 1999 mA	3A for 1 minute

RANGE	LIMITS	OVERLOAD PROTECTION
.2 mA	00.0 - 199.9 μA	20 mA
2 mA	.000 - 1.999 mA	100 mA
20 mA	0.00 - 19.99 mA	400 mA for 1 minute
200 mA	00.0 - 199.9 mA	2A max for 1 minute
2000 mA	000 - 1999 mA	3A max for 1 minute

3-9. MEASURING AC CURRENT (APPLIES ONLY TO MODEL 360)

1. Connect the instrument to a proper power source. If instrument is equipped with battery option, this step is not necessary.

2. Set OFF/ON switch to ON (right).

3. Set Function Switch to MA and AC at the same time.

4. Set Range Switch to 2000.

5. Connect unknown current across MA/KΩ and common terminals.

6. Observe reading: If overrange digit is floating, remove input voltage immediately. If reading is less than overload, reduce range values until proper reading is reached.

SECTION IV THEORY OF OPERATION

4-1. INTRODUCTION

4-2. The Model 360 and 361 is a digital multimeter using dual slope integration for analog to digital conversion.

4-3. The meter is divided into two sections, the analog and digital sections. The analog section receives the input signal, amplifies it, and performs the analog to digital conversion. The A/D converter output is coupled to the meter logic section. The logic section receives the digitized information from the analog section and processes it for the readout which presents a visual display. The operation of the A/D converter is initiated upon command from the logic section.

4-4. A general block diagram is shown as Figure 4-1. A detailed block diagram of the instrument is included as a foldout at the back of the manual. The block diagram shows the following main sections:

- Voltage Attenuator
- AC-DC Converter
- Analog to Digital Converter
- Ohms to DC Converter
- MA to Volts Converter (shunts)
- Digital and Display Section

4-5. VOLTAGE ATTENUATOR

4-6. The attenuator is a resistive voltage driver with attenuation ratios of 1:1, 100:1, and 1000:1. It is capacitively compensated for accurate attenuation of not only DC voltage, but also AC voltages.

4-7. CLAMP

4-8. The clamp's purpose is to protect the input amplifiers from accidentally applied overvoltage. It consists of CR1 and CR2, which become conductive whenever the voltage becomes too positive or too negative.

4-9. AC TO DC CONVERTER (APPLIES ONLY TO MODEL 360)

4-10. This is a precision rectifier circuit which currents an AC voltage into a DC Voltage. In order to achieve high accuracy, the receiver diodes (CR3, CR4) are in the feedback path of an operational amplifier (Q1, Q2, and A1), such that the diode forward voltage drop is reduced by the gain of the operational amplifier, and a very linear and accurate conversion is obtained. Depending on range, two different "gains" are selected. On the .2 volt and 20 volt ranges a gain of 10 and for all other ranges a gain of unity is selected.

4-11. OHMS TO DC CONVERTER

4-12. This circuit is a programmable constant current source, which forces a constant current through the unknown resistor. The DVM then reads the voltage across the unknown resistor. It consists of Q26 and the three precision resistors in its emitter. The reference voltage is taken from the same zener diode (the reverse broken down emitter junction in series with the forward biased collector-diode of Q21) which is used for the DVM. The three constant currents are 6.5V/6.5 Mohms = 1 microamp, 6.5V/650 kohms = 10 microamps, and 6.5V/6.5 kohms = 1 milliamp.

4-13. MA TO VOLTS CONVERTER

4-14. This circuit consists of 5 shunt resistors, whose voltage drop is measured by the DVM. The same shunt resistors are used for AC currents as well as DC currents. The full scale output voltage is .2 volts for each of the full scale input currents. If DC is measured, the DVM measures the DC voltage drop across the shunts directly, whereas if AC voltages are measured, the voltage drop is first passed through the AC to DC converter before it is fed into the DVM.

4-15. INPUT AMPLIFIER

4-16. The input amplifier is a new type developed by Tekelec-Airtronic. It is an amplifier designed to give the stability advantages of Chopper stabilization, but at the same time greatly reduce the complexities usually associated with chopper-stabilized amplifiers. Simplified diagrams of the amplifier are shown in Figure 4-2 and 4-3.

4-17. CHOPPER ACTION

4-18. In the amplifier's normal state between measurements, switch S-1 is closed and switch S-2 is open. This is shown in Figure 4-2. The amplifier, A5, is a high gain integrated operational amplifier. For purposes of discussion, consider that the gain of the amplifier, A5, is infinite, and that it has an offset voltage at the input which is very small, e.g., on the order of hundreds of microvolts.

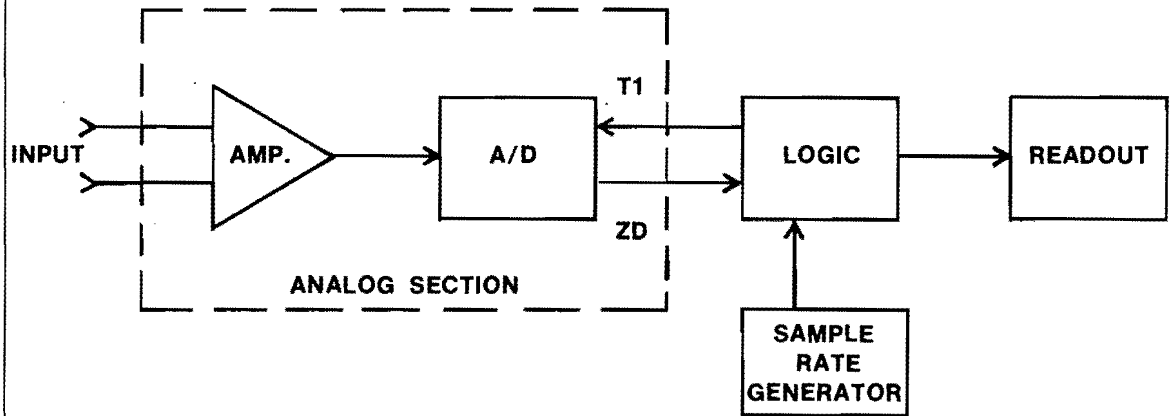


Figure 4-1 General Block Diagram

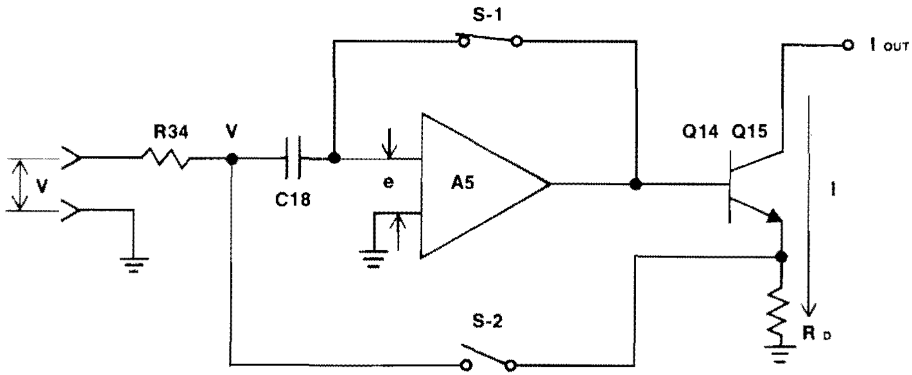


Figure 4-2 Input Amplifier with Chopper in Closed Position

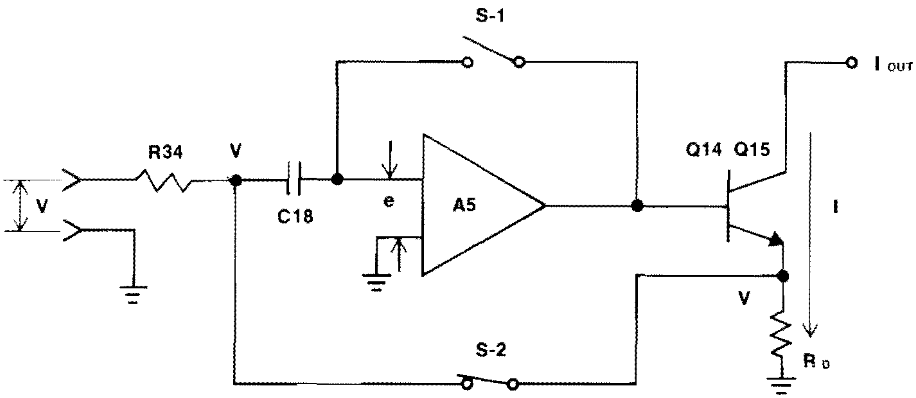


Figure 4-3 Input Amplifier with Chopper in Open Position

4-19. Under the conditions of Figure 4-2, the output of the amplifier will be at the same voltage as the input. This voltage is essentially zero, and the output transistor is held at cutoff. The output current, I, is therefore at zero. The input voltage, V, is present at the input to the blocking capacitor, C18. The operational amplifier input has a very low impedance due to the presence of the feedback through S-1. The capacitor, C18, therefore charges to the input voltage, V.

4-20. Assume that with a constant input voltage, V, the switches are suddenly changed to the configuration of Figure 4-3 where S-1 is open and S-2 is closed. Since the emitter of the transistor is at zero when S-2 is closed, and R_D is a much smaller resistor than R34, the voltage at the input of C18 will suddenly begin to decrease. This sudden decrease will be coupled through to the input of A5. This negative input pulse will cause the output of A5 to rise abruptly. The emitter of the output transistor will follow the output of A5 and the voltage on the resistor R_D will rise until the amplifier A5 comes back to its initial' offset, e. During the time that the amplifier is moving the voltage at R_D to V, the input impedance to A5 is very large. The operational amplifier has a very large input impedance since switch S-1 is now open. During the time that the amplifier A5 is moving the voltage on R_D to V, capacitor C18 is unable to charge or discharge due to the extremely high impedance of A1. When amplifier A1 reaches its initial condition, the charge on C18 capacitor has not changed; therefore, the input voltage on the capacitor comes back to V. Assuming that the switch S-2 is a perfect switch and has no voltage drop across it, then the voltage V also appears at R_D. A current therefore flows through R_D which is proportional to the voltage V and is called the output current, I. This output current I flows through the collector of the output transistor assuming that the beta of the transistor is extremely high and essentially zero base current is required.

4-21. The switching stays in the configuration of Figure 4-3 during the conversion time of T1. Since the output current I is no longer needed after T1, the switch is returned to the configuration of Figure 4-2. The closing of switch S-1 causes the output of the amplifier A5 to return to zero, and the voltage on resistor R_D therefore collapses to zero. The output current, of course, then reduces to zero.

4-22. REVERSING POLARITY

4-23. The Model 360 measures both polarities and indicates them on the front panel. The A/D converter operates with only one polarity of input signal current. It is the function, therefore, of the input amplifier to provide the same polarity of signal current to the A/D converter when either polarity of input voltage is present. This is done by the polarity reversing circuit shown in Figure 4-4.

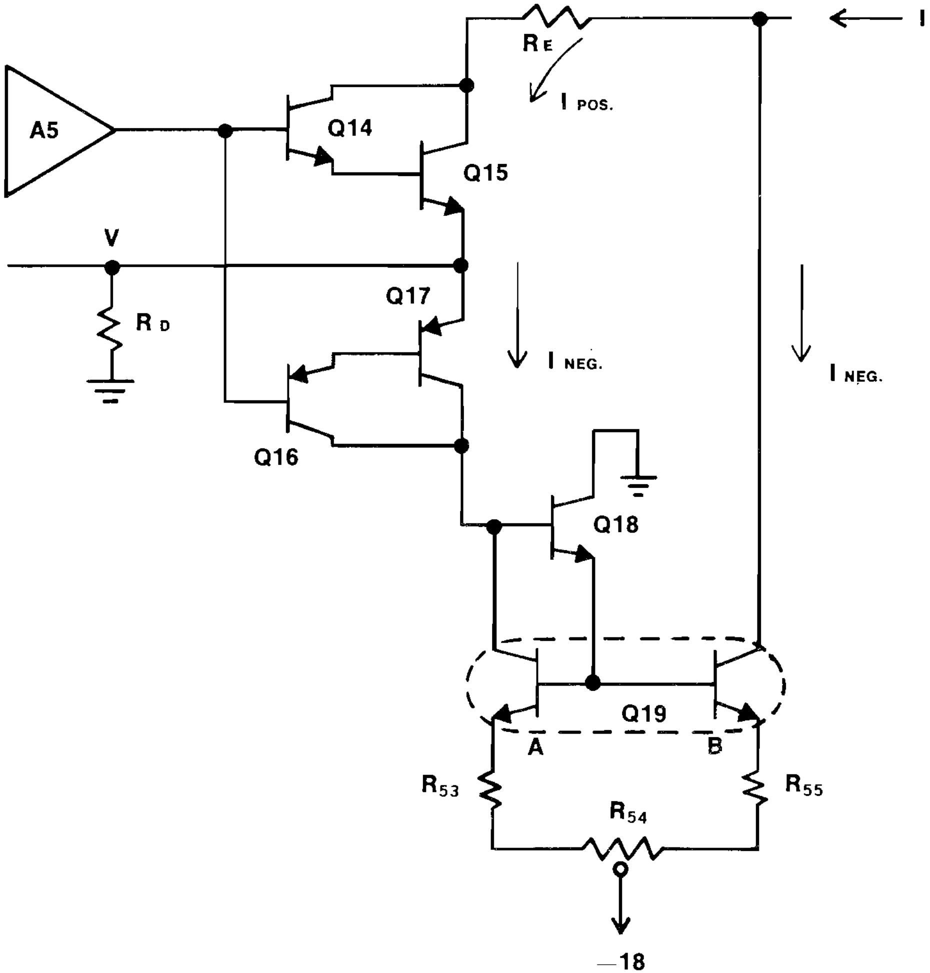


Figure 4-4 Reserving Polarity Circuit

4-24. As described above, the chopping operation of the amplifier presents the voltage, V, at the top of R_D. If this input voltage is positive, then Q14 and Q15 conduct. This Darlington pair of transistors has very high beta. It provides a collector current through RE which is proportional to the voltage V. For positive input voltages this is the signal current provided to the A/D converter. Since the base of Q14 must be above ground to provide conduction, Q16 and Q17 are cutoff. No base current is available for Q18; therefore, Q18, and Q19 are also cutoff. I_+ flows when the input voltage is positive. I_- is zero when the input voltage is positive.

4-25. When the input voltage goes negative, the amplifier A5 establishes V on R_D by causing Q16 and Q17 to conduct. A current therefore flows out the collectors of Q16 and Q17 which is proportional to the input voltage and is here called I_-. This is the exact amount of current which would flow as I_+ if the input voltage were positive. It is necessary to get the current I_- flowing into the A/D converter through the path, I. The negative feedback amplifier Q18 and Q19, is provided for this purpose. Q18 and Q19A form a negative feedback combination which is simply an amplifier with a current gain of 1. Whatever current tries to flow into the base of Q18 causes Q19 to conduct. Q19A therefore conducts, and the conduction of its collector pulls the current I_- down through R53, and R54 and finally to the -18 volt power supply. If the betas of Q18 and Q19A are high, then a negligible amount of current will flow into the base of Q18, and almost all the I_- will flow through Q19A and down through the resistors to the power supply.

4-26. Q19B is present to generate a current exactly equal to that flowing through Q19A. These transistors are a matched pair in the same package. The emitter base voltage drop is therefore identical and as Q18 causes Q19A to conduct, it causes Q19B to also conduct. The emitters of Q19A and Q19B are therefore at the same voltage level. This being the case, and with the potentiometer R54 adjusted so that the resistance between each emitter and -18 volt is identical, the current flowing through each emitter is identical to the other. Since the current flowing through the emitter of Q19A is I_-, then the current flowing through the emitter of Q19B is also I_-. The emitter current of Q19B, of course, flows through its collector and is present at the output terminal which provides current to the A/D converter. The reversing polarity circuit thereby does its function of providing the same polarity and same magnitude of current for a positive voltage as for a negative voltage.

4-27. DUAL SLOPE INTEGRATION

4-28. The dual slope technique performs analog to digital conversion by first integrating an input signal for a certain length of time, thereby establishing a voltage on an integrating capacitor (C22) proportional to the input signal. The capacitor is then discharged back to its initial condition at a constant rate. The

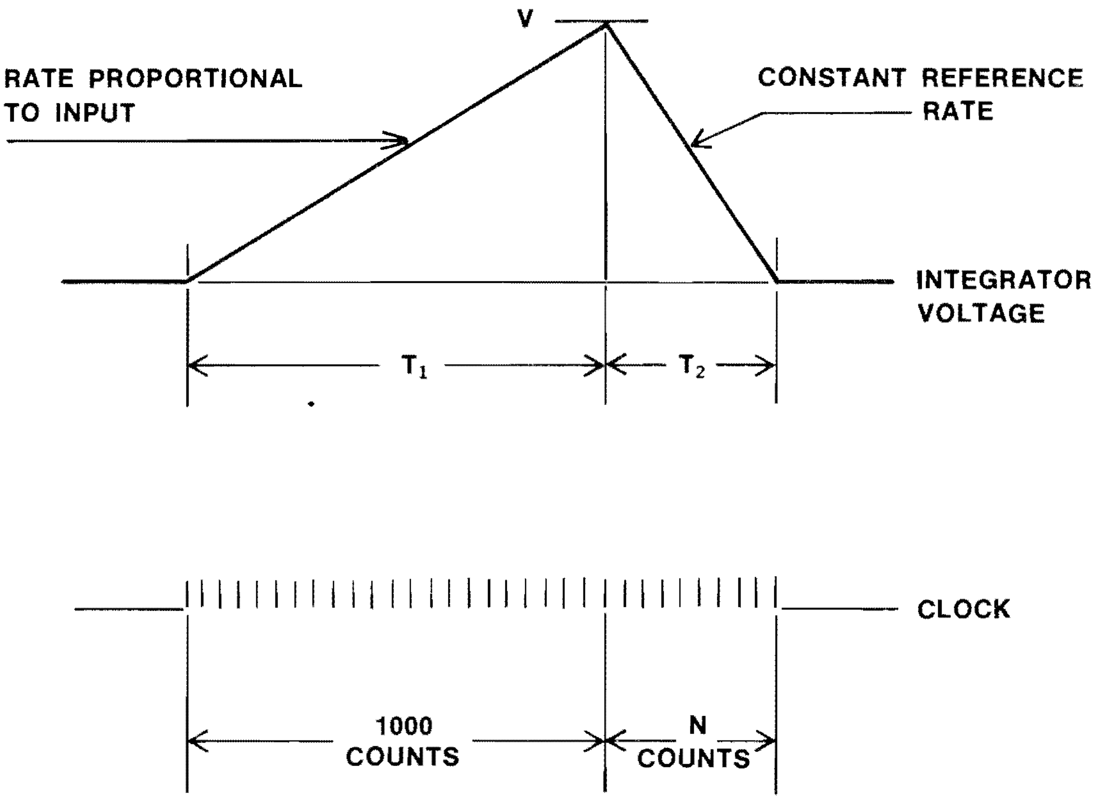


Figure 4-5 Dual Slope Waveforms

time taken to discharge the capacitor back to initial condition is also proportional to the input signal. The important waveforms are shown in Figure 4-5. Here the time taken to integrate at a rate proportional to the input voltage is called T_1. The time taken to discharge the integrating capacitor back to zero is called T_2. A clock in the logic section allows integration of the input voltage for 1000 counts. A counter in the logic section performs the necessary counting. When 1000 counts has been reached, the input voltage passed to the A/D converter is switched off, and a reference current generator is switched into the integrator capacitor. This reference current discharges the capacitor at a constant rate. The counter in the logic section continues to run until the capacitor has reached zero. The counting is then terminated and the number of counts, N, is proportional to the amplitude of the input voltage. The clock rate, amplifier gain, and amplitude of reference current are chosen in such a way that the counter number can be displayed directly.

4-29. For a given accuracy, the dual slope technique provides quality instrumentation at less expense than any other known technique. Many problems inherent in other analog to digital conversion techniques are automatically eliminated when using dual slope. For example, as shown in Figure 4-5, the base line reference level of the integrator voltage does not have to be stable. The integration may begin from a different level at each measurement. A circuit is required to detect when the voltage has returned to its initial level. This is a comparator circuit, and a comparator circuit of some type is common to all A/D conversion methods. In the dual slope technique, however, the zero drift of the comparator is not as critical as is the case in other techniques. Also, the only reactive passive circuit element of importance is the integrating capacitor. Non-linearities and instabilities of the integrating capacitor are not important because the capacitor is not only charged to a certain voltage, but discharged from that voltage back to the initial condition, thereby cancelling long term drift effects. The dual slope technique does not require an accurate drift-free clock. If the clock frequency were to decrease such that T_1 time were increased, then the amplitude of the integration, V, would be larger and it would take longer to discharge during the T_2 time. The number of counts, N, would thereby remain the same, and the effect of the clock frequency change could be cancelled out.

4-30. A/D CONVERTER

4-31. A diagram of the A/D converter is shown in Figure 4-6. The integrating capacitor is C22. It receives current from two sources, the signal current source and the reference current source. As explained above, the signal current source is present during time T1 and the reference current source is present during time T2. The signal and reference current are never acting upon the integrating capacitor at the same time. Gates are shown in Figure 4-6 which have control lines to switch the currents off and on. Normally, the reference current is flowing through its gate into the zero detector. The integrating capacitor C22 has been charged up to a voltage we shall call E_1. This is the normal condition of the A/D converter before measurement begins.

4-32. The zero detector is a comparator circuit which is a very high impedance when the voltage of C22 is below the level of E1. When the voltage of C22 attempts to rise above E1, the zero detector becomes a very low impedance and diverts all the reference current into itself, thereby holding the voltage level at E1. The zero detector circuits present the fault to the logic when the voltage C22 begins to drop below E1. They also present a pulse to the logic circuitry when the voltage on C22 has again risen to E1. This timing is shown in Figure 4-7.

4-33. The logic circuitry determines when a measurement is to begin. At this time, the logic circuitry causes the gate control shown in Figure 4-6 to turn off the reference current gate and turn on the signal current gate. The polarity of the signal current is such as to reduce the voltage of C22. Therefore, the voltage of C22 begins to fall at a linear rate. The logic circuitry also initiates the counting of the clock as shown in Figure 4-1. The discharge of the C22 continues until the clock reaches 1000 counts, and the logic then causes the gate control shown in Figure 4-6 to turn on the reference current and turn off the signal current. The reference current is always of such a polarity as to cause the voltage on C22 to go positive. The voltage then rises at a rate determined by the amplitude of the reference current until the voltage E1 is achieved. At this time the zero detector puts out a pulse to the logic circuitry, and the counting is terminated. The number residing in the counter at this time is the digitized voltage information. The zero detector holds the voltage of C22 at E1 by absorbing the reference current into itself. The state of the A/D converter remains in this condition until the next command for a measurement is given from the logic circuit and the gate control is again switched.

4-34. The zero detector is a differential amplifier consisting of Q22, Q23 and Q25 as shown in Figure 4-8. When the meter is in its standby mode, the reference current wants to make the input voltage of the zero detector positive. Due to the negative gain of the amplifier, its output tries to go negative, but CR15 starts conducting and provides just enough negative feedback to keep the voltage on the integrating capacitor C22 at the threshold voltage of the zero detector amplifier.

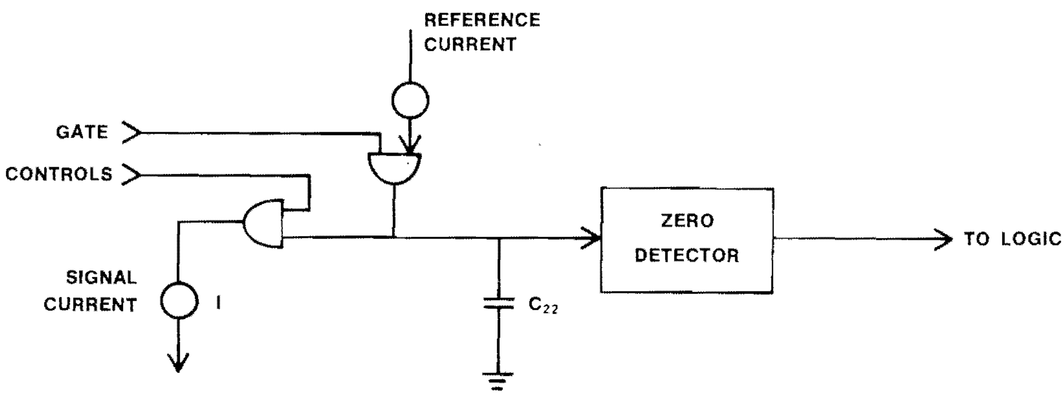


Figure 4-6 A/D Converter Block Diagram

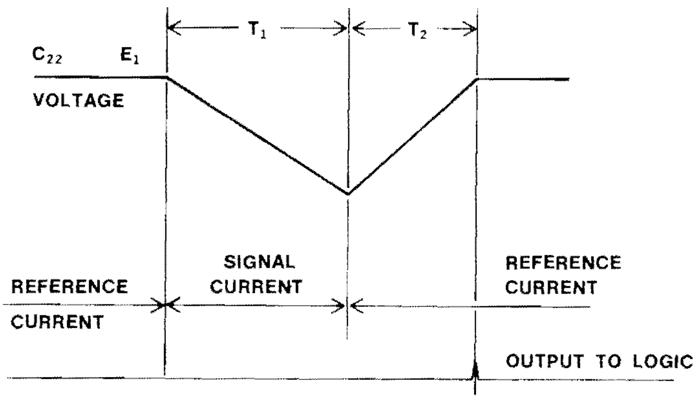


Figure 4-7 Dual Slope Timing Diagram

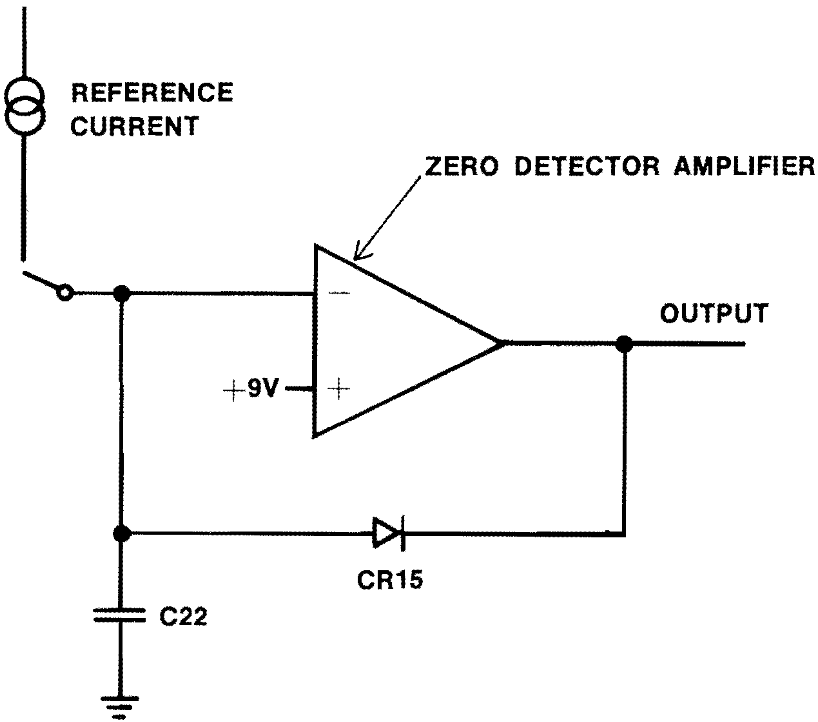


Figure 4-8 Zero Detector Block Diagram

4-35. OVERRANGE DETECTING FLIP FLOP A3

4-36. A3 is a triggered flip flop which counts the carrys from the counter. A3 is inhibited from responding to the counter carry which terminates T1 because of the waveform present on Pin 9. The most significant digit data line, Pin 10 therefore goes positive. If a third counter carry pulse occurs, A3 is triggered back to its reset condition. Most significant data output line Pin 10 goes back to its ground, and the overrange light lights up.

4-37. OVERRANGE FLASHING CIRCUITRY

4-38. When the reading of the meter exceeds 1999, it is necessary for the most significant digit to flash very noticeably and indicate that an overrange condition has occurred. This flashing is accomplished by flip flop A3 overrange illuminating circuitry Q3 and DS1 and the flashing circuitry C9, R20, CR5. If an overload condition exists, the positive pulse on A3 pin 10 (see the waveforms of Figure 4-9) is stretched out and keeps the overrange light on for approximately 40 ms, and then the light goes out. This is repeated on the next reading cycle approximately 200 ms later, which causes the light to flash.

4-39. SAMPLE RATE GENERATOR

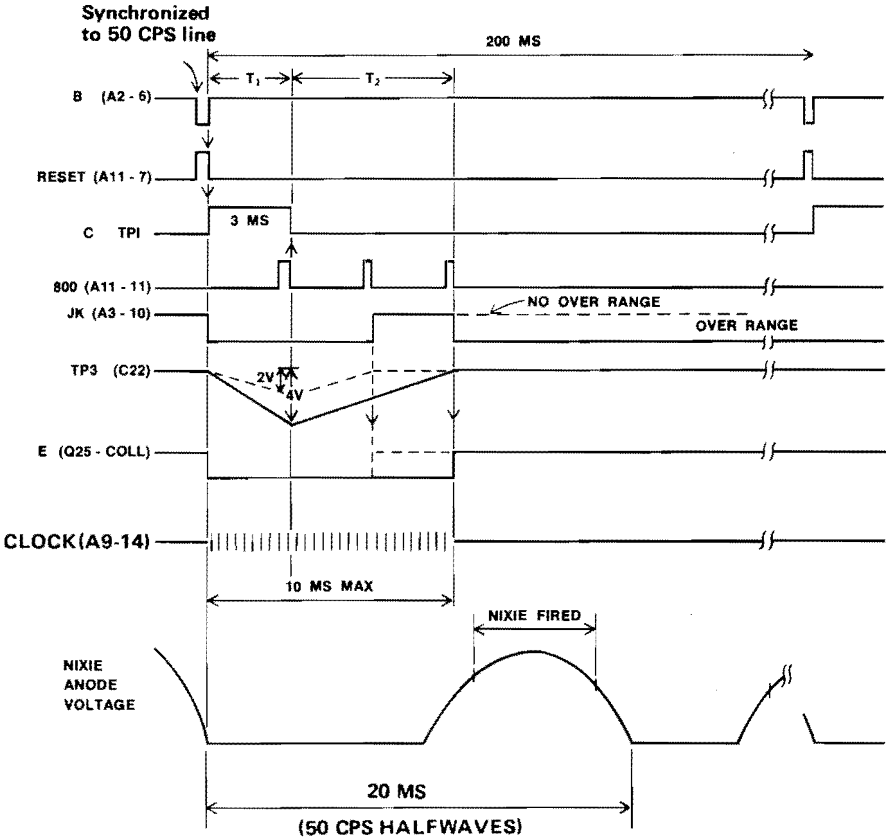
4-40. This circuit is on the power supply board and consists of Q33 and Q34 in a circuit which resembles a silicon controlled rectifier. It is triggered by the zero crossing of the line frequency through Q32 and C30. It retriggers approximately every 200 ms, e.g., every 10 cycles of line frequency.

4-41. LOGIC

4-42. The logic consists of three decade counters (DCU'S), which count the pulses of a gated 300 kc clock. The counters are controlled by a flip-flop (INT-FF-A4). This flip flop is set by the C flip flop (C-FF-A2) and is reset by the zero detector. The C flip flop is set by a start pulse from the sample rate generator and reset by the overspill of the counter. The decoder decodes the binary coded decimal signal and drives the ten cathodes of the nixie tubes.

4-43. TYPICAL TIMING CYCLE

4-44. This is shown in Figure 4-9 for the case of a full-scale input voltage 2 VDC input voltage on the 2 volt range, and the dotted line represents an input voltage of 1.0 volts on the 2 volt range. The analog to digital conversion is made during the time the nixie tubes are not lighted, or when their anode voltage is zero during the grounded portion of the 50 cps half wave.



CONDITIONS: FUNCTION : DC
RANGE : 2
$V_{INPUT\ APPLIED}$: −2.0 VDC
: −1.0 VDC

Figure 4-9 Waveforms

SECTION V MAINTENANCE

5-1. CALIBRATION PROCEDURE

5-2. The following procedure should be followed to calibrate Models 360 and 361, with the exception that Steps 8, 9, & 10 should be eliminated for Model 361. When this procedure has been completed, all functions and ranges (including mA) will be within specification.

5-3. Turn power switch on and allow instrument to warm-up for 15 minutes.

5-4. Unclip the calibration cover on the front of the instrument (this is the aluminum horizontal name-plate. With a small screwdriver, adjust the potentiometer as in Table 5-1

5-5. PARTS LOCATIONS

5-6. The layout of the instrument boards and the location of parts are shown in Figure 5-1 and 5-2. A list of materials and their part number is contained in Table 5-3

TABLE 5-1 POTENTIOMETER ADJUSTMENT

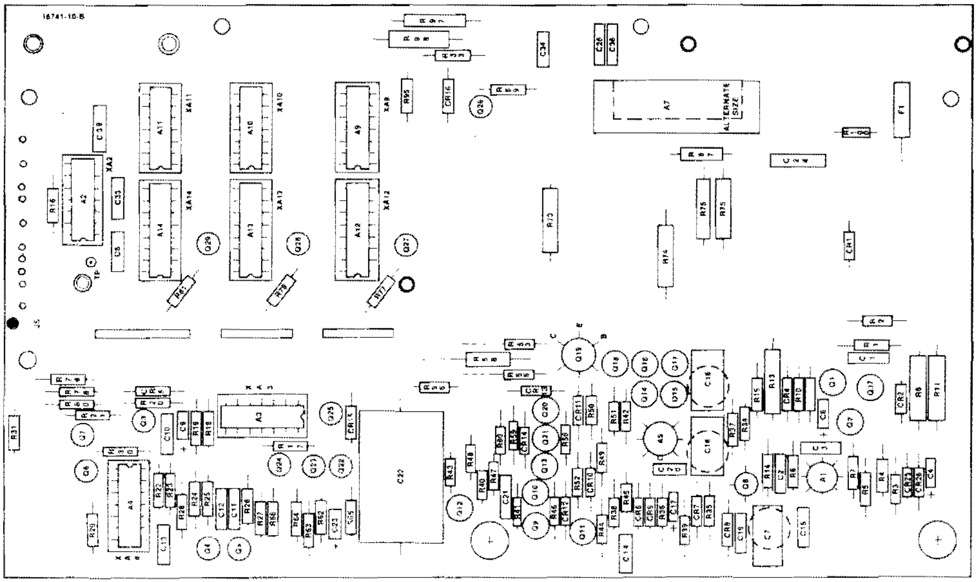
STEP NO.	FUNCTION POSITION	RANGE POSITION	APPLY AT INPUT	REMARKS
1	DC	.2	Short volt - COM	Adjust pot with zero indicated (R32) to uncertain polarity indication.
2	DC	.2	+0.1900V	Adjust F.S. pot (R57) to + 190.0 on the readout.
3	DC	.2	-0.1900V	Adjust neg. F.S. pot (R54) to - 190.0 on the readout. out.
4	DC	2	+1.900V	Adjust 2 F.S. pot (R99) to + 1.900 on the readout.
5	KΩ	.2	190.0Ω Change input leads to mA/KΩ.	Adjust .2KΩ pot (R70) to 190.0 on the readout.
6	KΩ	20	19.00KΩ	Adjust 20KΩ pot (R71) to 19.00 on the readout.
7	KΩ	2000	1900KΩ	Adjust 2MΩ pot (R72) to 1900 on the readout.
8	AC	2	1.900 VAC (RMS) @ 100 Hz. Leads to volts term.	Adjust 2 VAC pot (R12) to 1.900 on the readout.
9	AC	.2	0.1900 VAC (RMS) @ 100 Hz.	Adjust .2 VAC pot (R94) to 190.0 on the readout.
10	AC	20	19.00 VAC (RMS) @ 2 kHz.	Adjust 20 VAC pot (C25) to 19.00 on the readout.

TABLE 5-2
COMMON PROBLEM AREAS AND THEIR POSSIBLE CAUSES

SYMPTOM	POSSIBLE CAUSE
Reads Zero on all Functions	Q4, 5, 9, 10, 11, 12, 24, 33, 34, A2, A4, CR11, & CR12
All Digits Lit Continuously	Q4, 5, 10, 20, 22, 25, 35, 36. A2, A4, CR15
Overrange on all Functions	A5
Overrange on mA and KΩ	F1
Negative Input won't Read Above 500 mV on 2V Range	Q37
Reads 1000 w/Zero Input and Overrange with 1/2 FS Input	A3
Responds Only to Positive Inputs	Q16, 17, 18, 19
Responds Only to Negative Inputs	Q14, 15
Won't Zero on all Functions	Q16, 17, 18, CR6, 7, Q8, 22, 24, Dirty Bd Analog Section
Nonlinear 1/10 FS	A5, C22
Drifts on 2MΩ range	Q26, R75, Dirty Bd or Ohms Input
Will Not Full Scale Calibrate	Q21, CR23, R58, R97, R98
Positive Polarity Light Stays Lit	Q13
Overrange or Varying Indication on 2-2000 mA Ranges	A7 (shunt resistors)
No Response to AC Input	C24, Q1, 2, A1

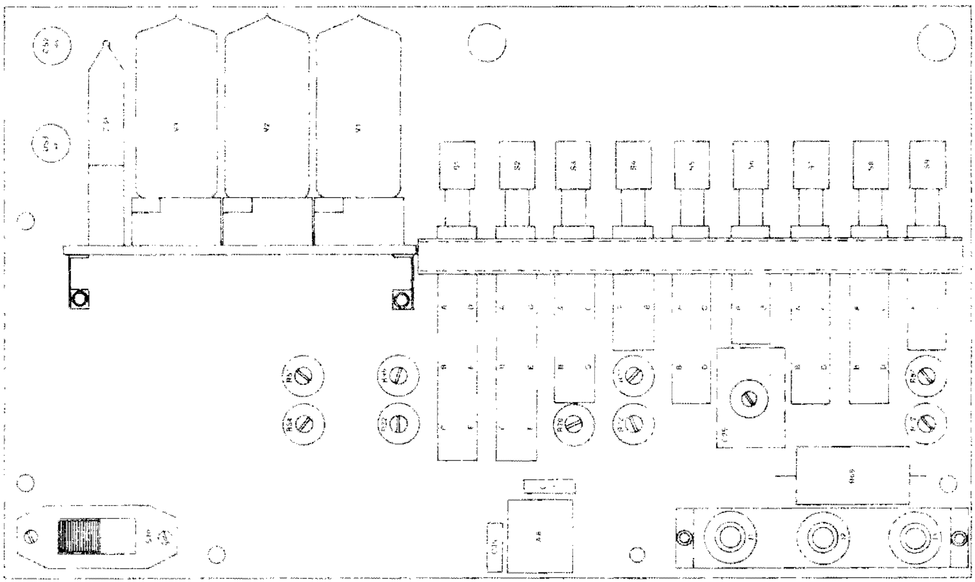
TABLE 5-3
LIST OF MATERIALS

PART NO.	DESCRIPTION	QTY.
16601	Meter Housing, Front	1
16602	Meter Housing, Rear	1
16650	Power Supply Board Assy.	1
16741	Instrument Board Assy.	1
16618	Polaroid	1
16619	Polaroid Frame	1
16620	Ident. Strip	1
16746	Handle	1
16718	Handle Top	1
16870	Handle Stud	2
16827	Transformer T1	1
16946	Overrange Indicator, DS1	1
8AG - 1/4A	Fuse, Power, F2 (little Fuse)	1
#275003	Fuse, Input, F1	1
ZM1000	Readout Tubes V1, V2, V3 (Amprex)	3
16945	Switch Assy.	1
16587-5	Polarity Light (+) DS2	1
16587-6	Polarity Light (-) DS1	1
1509-102	Input Jacks (Red) J1, J3 H. H. Smith	2
1509-103	Input Jacks (Blk.) J2 H. H. Smith	1
16909	Rack Mtg. Kit (Optional)	
#699	Input Cables H. H. Smith	
#17186	Power Cable Belden	
#518	Power Switch S10 H. H. Smith	1
	Battery Pack	



SIDE A

Figure 5-1 Location of Parts



SIDE B

Figure 5-1. Location of Parts

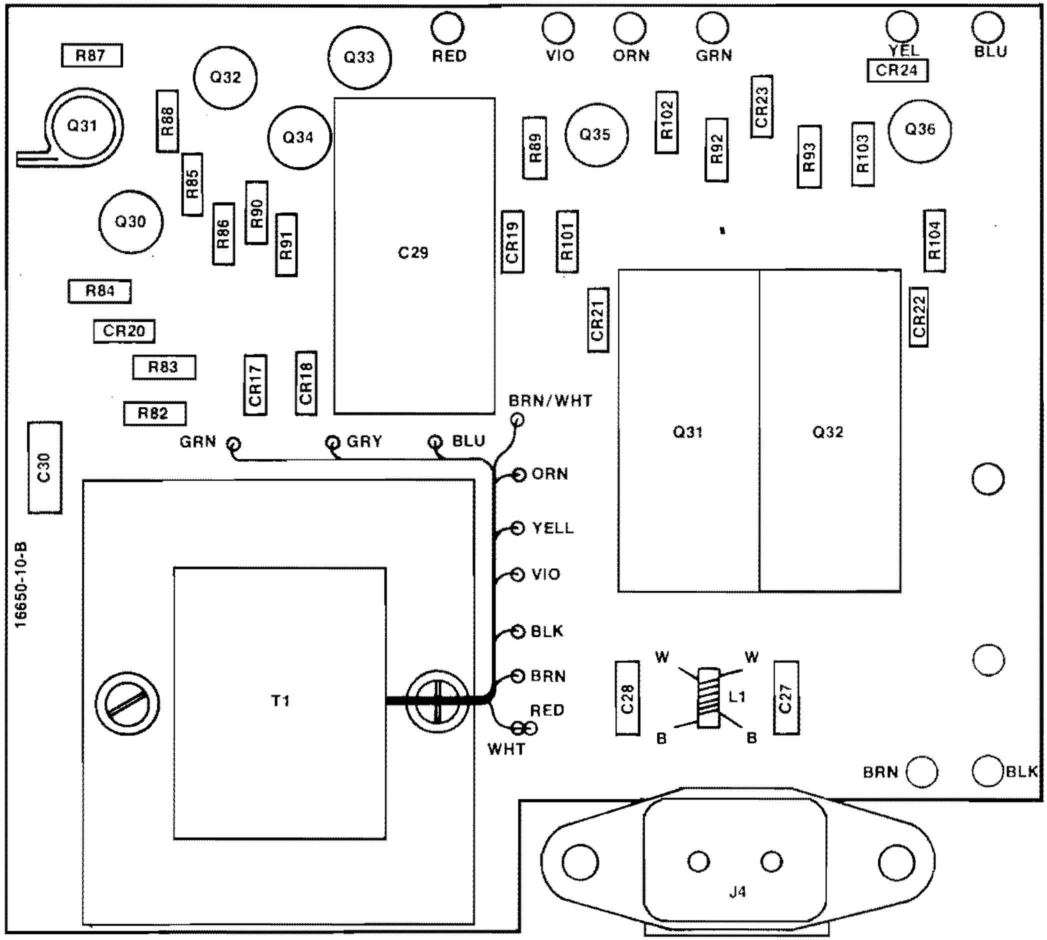


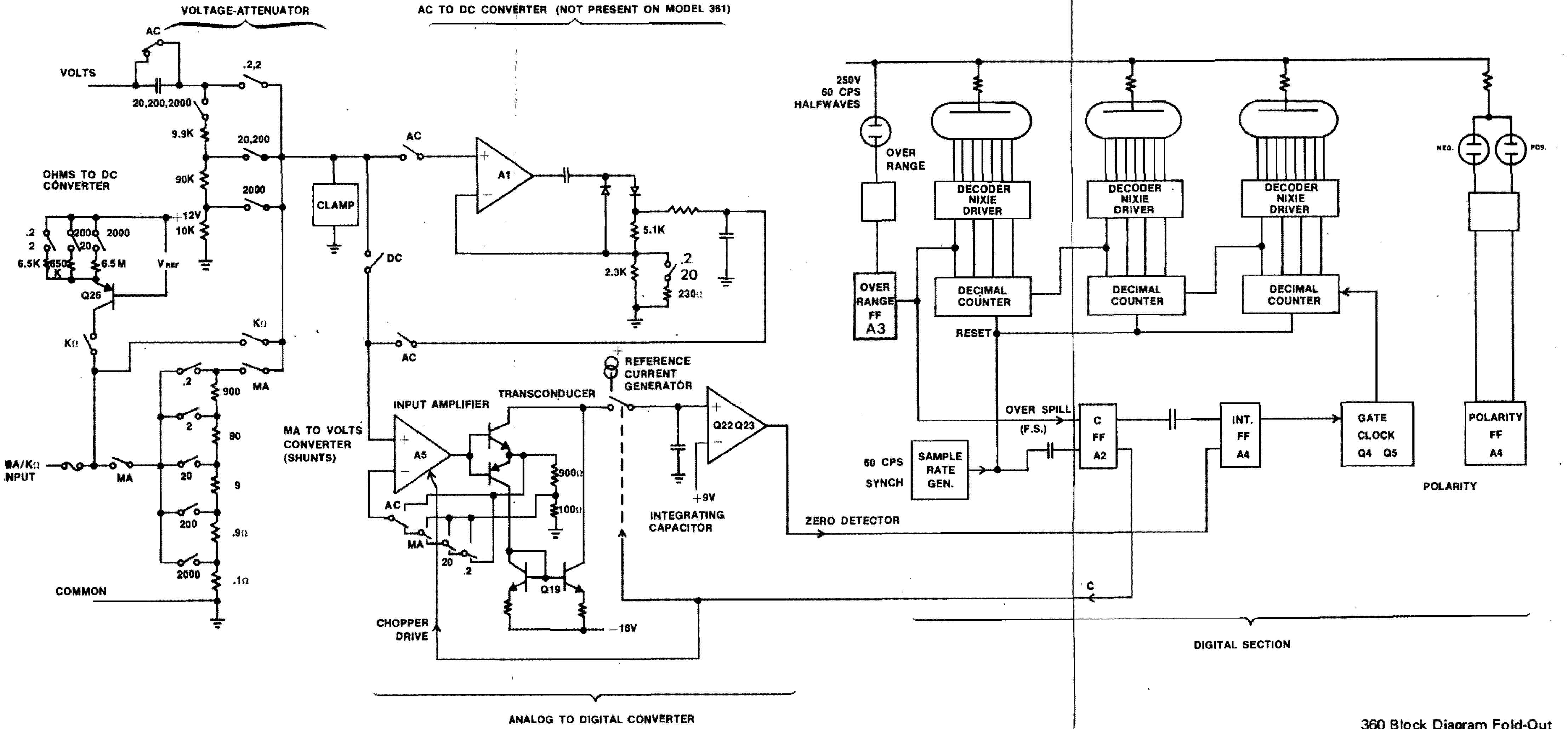
Figure 5-2 Layout of Power Supply Board

FOLLOWING

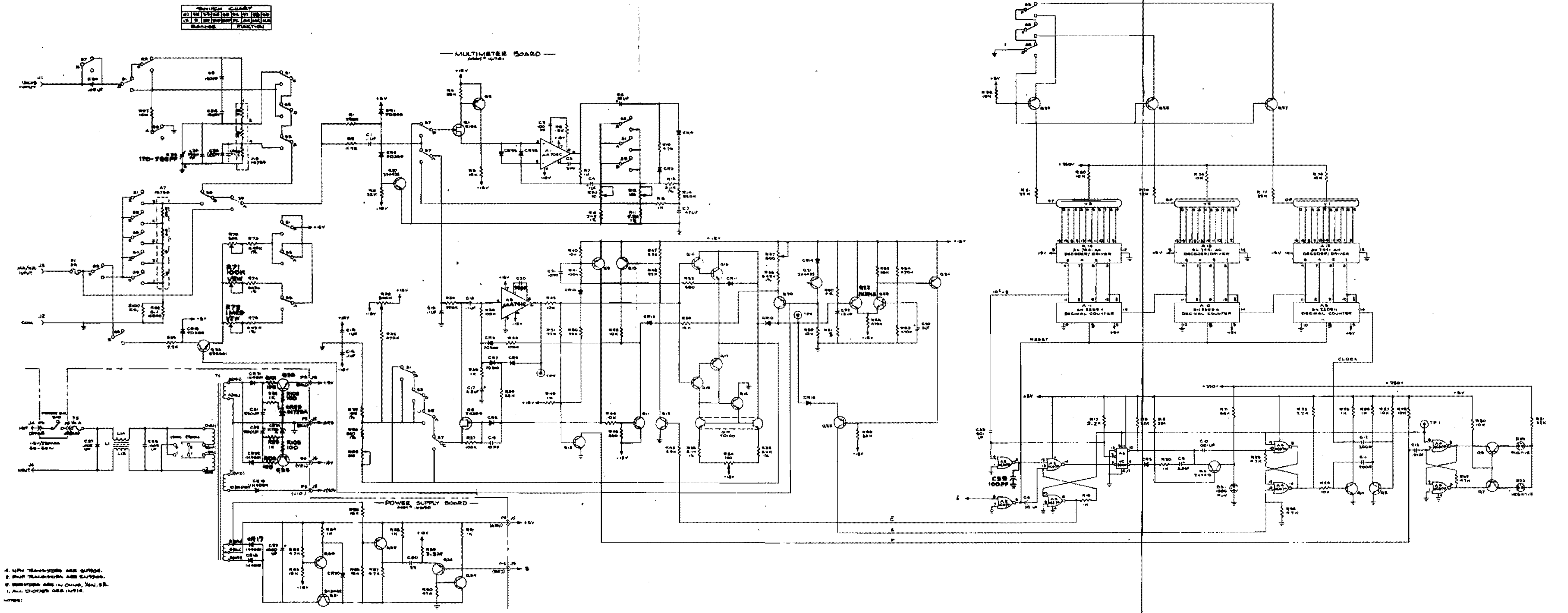
360 Block Diagram Fold-Out

360 Schematic Fold-Out

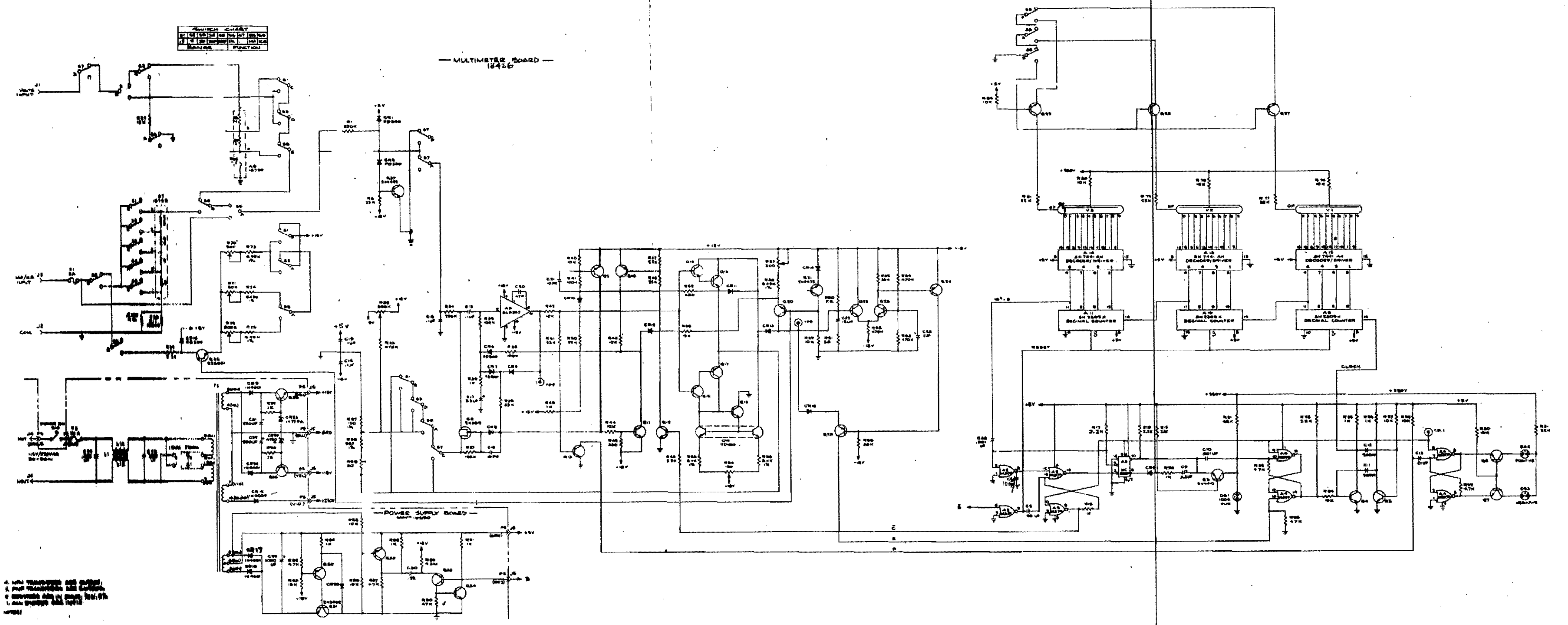
361 Schematic Fold-Out



360 Block Diagram Fold-Out



360 Schematic Fold-Out



361 Schematic Fold-Out

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TE 360 and TE 361

WARNING

THE VOLTAGE BETWEEN THE COMMON TERMINAL AND THE POWER SUPPLY GROUND MUST NOT EXCEED 500 V. PEAK.

FOR APPLICATIONS REQUIRING HIGHER INSULATION, USE MODEL TE 360 B (BATTERY POWERED VOLTMETER).

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