INSTRUCTION MANUAL

MULTIPLIER

MODEL 230

THIS MANUAL APPLIES SPECIFICALLY TO MODEL 230 SERIAL NO. 177

M130; 12/68

MANUAL CHANGES

Page I-1, line 8:

The current range, stated as "0 to 0.5 mA", should read "0 to 5.0 mA".

Page I-2, specification 10, line 3:

The term "Slowing rate" should read "Slewing rate".

Page V-1, 1st line of text under "(2) Balancing the Operational Amplifier":

The next to last word, "operation", should read "operational".

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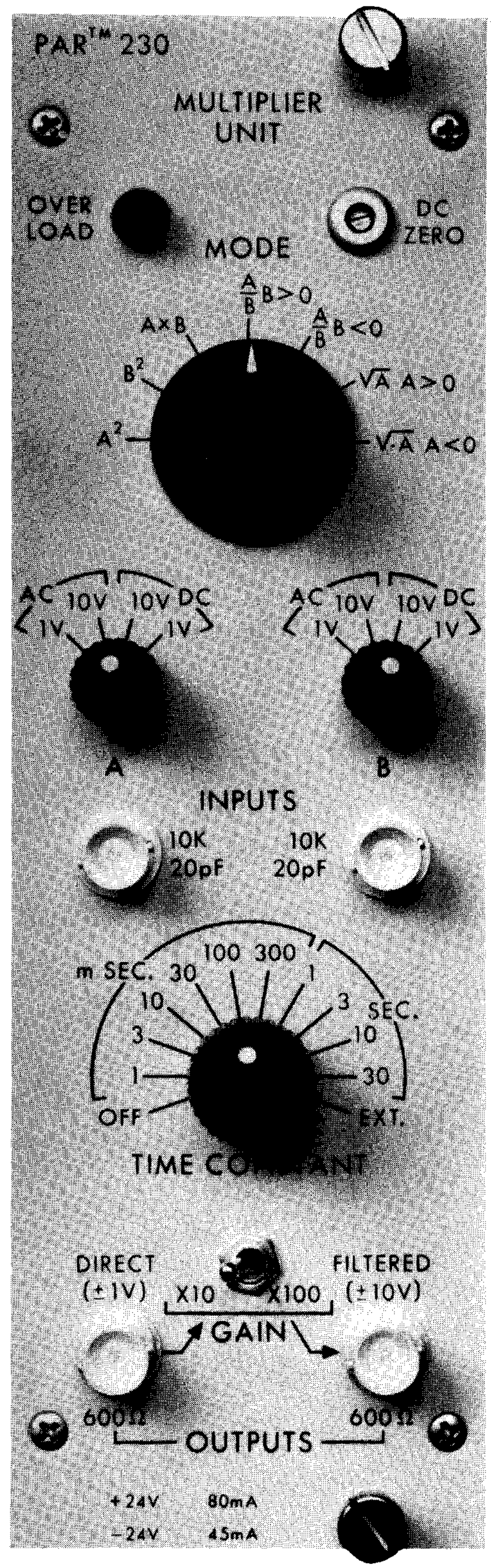
FIGURES

SECTION I
CHARACTERISTICS



1.1 INTRODUCTION

The Princeton Applied Research Model 230 is a NIM compatible wideband multiplier unit. It performs rapid analog computations of the product or ratio of two input voltages, as well as the square and square root of single inputs. The computed function is applied to a low-pass filter, giving an averaged output. Both filtered and unfiltered outputs are available simultaneously.

The front panel features a mode selector switch, sensitivity selectors, choice of ac or dc input coupling, a time constant selector, an overload indicator, and a choice of x10 or x100 gain at the filtered output.

Other features include high linearity and temperature stability, a frequency response from dc to 500 kHz, and a dynamic range of 1000:1. Additionally, the averaging time constant can be increased by connecting capacitors to the rear-panel plug.

Application of the averaging circuit yields the autocorrelation function at $\tau = 0$ of a signal (the mean-square value), the average crosscorrelation between two signals, or smoothing of the output signal.

1.2 SPECIFICATIONS

(1) FUNCTIONS

Front-panel rotary switch allows selection of any one of seven functions: A^2, B^2, A x B, A/B for B positive, A/B for B negative, $\sqrt{A}$ for A positive, and $\sqrt{A}$ for A negative.

(2) INPUT IMPEDANCE

AC Coupling: 10 kilohms (through 3 μF) shunted by less than 20 pF.

DC Coupling: 10 kilohms shunted by less than 20 pF.

(3) SENSITIVITY

1 V or 10 V, ac or dc coupling, both channels. The Model 230 is a unity multiplier in the sense that with one volt applied to both inputs, there is one volt of output. This is the situation on the "1 V" sensitivity range. The "10 V" sensitivity range inserts a 10:1 attenuator in front of either or both multiplier inputs.

(4) OUTPUTS

Direct: Maximum value of output voltage, ±2 V at 600 ohms.

Filtered: Maximum averaged output voltage, ±12 V at 600 ohms; gain of filtered output either 10 times or 100 times that of direct output; front-panel switch allows selection of filtering time constants from 1 ms to 30 s in a 1-3-10 sequence.

(5) FREQUENCY RESPONSE

A x B, A^2, B^2 Modes:
DC Coupling - dc to 500 kHz; ±1 dB.
AC Coupling - 15 Hz to 500 kHz; ±1 dB.

$\sqrt{A}$ and $\sqrt{-A}$ Modes:
100 kHz for $|A| = 1$ volt and proportionally less for $|A|$ less than 1 volt.

A/B Modes:
100 kHz for $|B| = 1$ volt and proportionally less for $|B|$ less than 1 volt.

(6) OVERLOAD

The front-panel overload light indicates overdrive or overload. Overdrive occurs when the signal at either input ("1 V" sensitivity) exceeds 1.5 V with respect to ground. Overload occurs when the direct output exceeds 2.0 V with respect to ground or when the filtered output exceeds 12 V with respect to ground. In addition, the overload indicator will light when the polarity of an input voltage is improper as indicated by the "MODE" switch markings.

(7) DYNAMIC RANGE (ratio of maximum filtered output to combined noise and drift at filtered output)

1000:1 for Gain = x10.

(8) ACCURACY

In multiplication and squaring modes, the output obtained will not deviate from the true value of the computed function by more than 0.5% of full scale output.

(9) POWER REQUIREMENTS (power furnished by bin supply)

+24 V at 80 mA and -24 V at 45 mA.

(10) DIMENSIONS

2.704 inches wide (double-width RIM module), 8 3/4 inches high.

(11) WEIGHT

3.125 pounds.

SECTION II
INITIAL CHECKS

2.1 INTRODUCTION

The following procedure is provided to facilitate initial performance checking of the Model 230. In general, the procedure should be performed after inspecting the instrument for shipping damage (any noted to be reported to the carrier and to Princeton Applied Research) but before using it experimentally. Should any difficulty be encountered in carrying out these checks, contact the factory or one of PAR's authorized representatives, a list of whom appears at the end of the manual.

2.2 EQUIPMENT NEEDED

(1) A low voltage dc source; about 10 volts maximum.

(2) A dc voltmeter, such as a Simpson Model 260.

(3) Provision for +24 V, and -24 V, such as a NIM bin or a PAR Model 201 RIM Assembly Kit in conjunction with a Model 281 ±24 V Power Supply.

2.3 PROCEDURE

(1) Plug the unit into the bin.

(2) Set the A channel sensitivity control to the "10 V DC" position.

(3) Set the voltage source to about five volts.

(4) Connect the voltage source to input "A". (Be careful not to exceed 10 V peak while on the 1 V sensitivity settings or 50 V peak while on the 10 V sensitivity settings, to avoid damaging the input transistors.)

(5) Connect the voltmeter to the "DIRECT" output jack.

(6) Set the "MODE" switch to "A^2". The output voltage should be .01x the square of the input voltage. For example, with an input voltage of five volts, the output voltage should be .25 volts.

(7) Set the A channel sensitivity switch to the "1 V DC" position. The overload lamp should light at a threshold input voltage of about 1.5 V.

(8) Return the sensitivity switch to the "10 V DC" position. Set the "MODE" switch to the "$\sqrt{A}$ A>0" position. The output voltage should be the square root of 0.1xA. For example, with an input voltage of 6.4 volts, the output voltage should be 0.8 V.

(9) Connect the voltmeter to the "FILTERED" output jack. Set the "TIME

CONSTANT" switch to the "10 SEC" position. With the settings as in (8), and the gain selector at the "X10" position, the output voltage should be 8.0 volts. Disconnect the voltage from input "A". The output voltage should not go to zero immediately, but should decay asymptotically over a 50 second interval.

(10) Reconnect the voltage source to the "A" input, and set the "MODE" switch to the "$\sqrt{-A}$ A<0" position. The overload lamp should light for all positive input voltages.

This completes the initial checks. If the instrument performed as indicated, one can be reasonably sure that it is operating properly.

SECTION III
OPERATING INSTRUCTIONS

3.1 INTRODUCTION

The Model 230 is a highly versatile research instrument. To enable the maximum service to be obtained, detailed operating instructions are provided. These follow some preliminary considerations.

3.2 PRELIMINARY CONSIDERATIONS

POWER REQUIREMENTS

This instrument is designed to plug into a NIM bin supplying +24 V at 80 mA, and -24 V at 45 mA.

Alternatively, power can be provided by a PAR Power Supply Model 281 in conjunction with the PAR RIM Assembly Kit Model 201, or equivalent.

TEMPERATURE RANGE

The Model 230 will operate over an environmental temperature range of 10°C (50°F) to 45°C (113°F).

MAXIMUM INPUT-OUTPUT VOLTAGES AND OFFSET

(1) The maximum voltages which can be applied to the A and B inputs without overloading are:

1.4 V dc or 1.4 V peak ac on the 1 V ranges.
14 V dc or 14 V peak ac on the 10 V ranges.

CAUTION: DO NOT EXCEED 10 V PEAK AT THE INPUT JACKS WHILE ON THE 1 V RANGES OR EXCEED 50 V PEAK WHILE ON THE 10 V RANGES, TO AVOID DAMAGING THE INPUT TRANSISTORS.

(2) The maximum voltage obtainable from the "DIRECT" output jack is ±2 V peak.

(3) The maximum voltage obtainable from the "FILTERED" output jack is ±12 V.

(4) These maximum output voltages limit the maximum ac input voltage to about 1 V rms. 1 V rms at the A input jack while in the A^2 mode yields an offset cosine wave at the "DIRECT" output which has a peak amplitude of +2 V. The "FILTERED" output, with the "GAIN" switch in the "X10" position, yields 10 V dc, representing 10x the average value of the "DIRECT" output voltage. A larger ac input voltage causes the output circuits to saturate.

(5) The ±5 mV (max.) dc input offset voltage may cause a large error in ratio outputs when the A and B input voltages are both small.

3.3 OPERATION

Basic operation of the Model 230 is straightforward. However, the broad functional utility of such a Multiplier is not always obvious. A discussion of some of the applications of the 230 follows a description of the front-panel controls.

FRONT-PANEL CONTROLS (Refer to the photograph on page I-1)

(1) "MODE" Switch

The "MODE" switch selects the function to be performed, as indicated by the setting.

(2) Input Jacks and Associated Selectors

The signals which are to be operated upon are applied to the input jacks in a manner complying with the "MODE" switch setting. The corresponding selector switch selects the type of input coupling and attenuation. In the "1 V" positions no attenuation of the input signal is applied. In the "10 V" positions 10:1 attenuation is applied. In the "AC" positions a dc blocking capacitor is inserted in series with the input.

(3) Output Jacks (Front and Rear Panels)

The "DIRECT" output is a voltage output with values determined by the "MODE" switch setting and the input voltages (or attenuated inputs). The "DIRECT" output voltage is also applied to a low-pass filter-with-gain; and the filter output goes to the "FILTERED" output jack, so that both outputs are available simultaneously. Filter gains of x10 or x100 may be selected with the "GAIN" switch. The output from the filter is also available at the rear-panel "RECORDER" jack for use with a recorder. A 6.98 kilohm resistor in series with a 15 kilohm rheostat (rear-panel adjustable) are in series with this output.

(4) "TIME CONSTANT" Switch

The filter parameters are determined by the setting of the "TIME CONSTANT" switch. With the switch in the "OFF" position no filtering occurs and the filter circuit acts as an ordinary amplifier (bandwidth of approximately 10 kHz) with a gain determined by the setting of the "GAIN" switch. With the switch in the 1 ms to 30 s positions, the filter acts as a low-pass filter with the indicated time-constant and gain. In the "EXT" position, the filter time-constant may be increased by connecting a capacitor to pins 2 and 3 of an octal plug which plugs into the rear-panel socket. Only non-electrolytic capacitors should be used in the time-constant circuit. Mylar, polystyrene, or polycarbonate film types are preferred. The value of the resistor in the time-constant circuit is 2 megohms, so that the externally determined time-constant is $(C + 1.5 \times 10^{-5}) \times 2 \times 10^{6}$ seconds, where C is the value of the capacitor in Farads. The voltage transfer function of the filter is:

$E_o/E_i = G/(1 + jf/f_o)$, where G = filter gain (x10 or x100)
f = frequency in Hz (independent variable)
$f_o = 1/2\pi RC$
RC = Time-constant

(5) "OVERLOAD" Indicator

The "OVERLOAD" indicator lights whenever the voltages exceed the maximum values given in Paragraph 3.2, or when the polarity is not as indicated by the "MODE" switch markings.

(6) "DC ZERO" Screwdriver Adjustment

The "DC ZERO" screwdriver adjustment is used to set the zero of the "DIRECT" output (zero input signal).

APPLICATIONS

(1) PRECISION SQUARE-LAW DETECTOR

It is often desirable to measure the average power dissipated by a resistive load to which a wide-band signal is applied. This may be done by squaring the voltage across the load and averaging for a sufficiently long period. Average power obtained in this way is analogous to computing the autocorrelation for $\tau = 0$. Integrating, rather than averaging, yields the total energy (joules). The PAR Model 215 Operational Amplifier is recommended as an integrator.

(2) FREQUENCY DOUBLER FOR SINUSOIDS

Squaring a sine wave yields an offset sine wave of twice the original frequency: $\sin^2 \phi = 1/2 - 1/2 \cos 2\phi$.

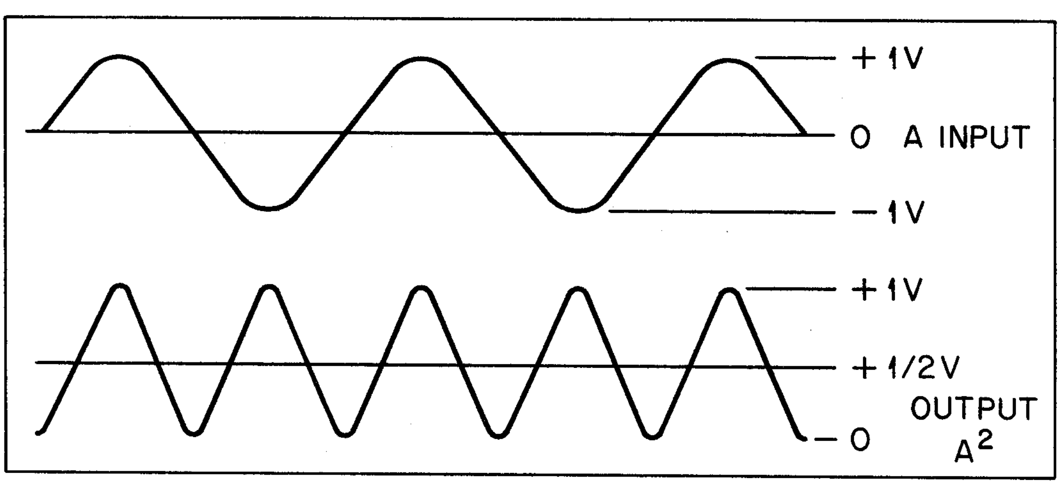


Figure III-1. SQUARING A SINE WAVE

(3) LOW-LEVEL MODULATOR

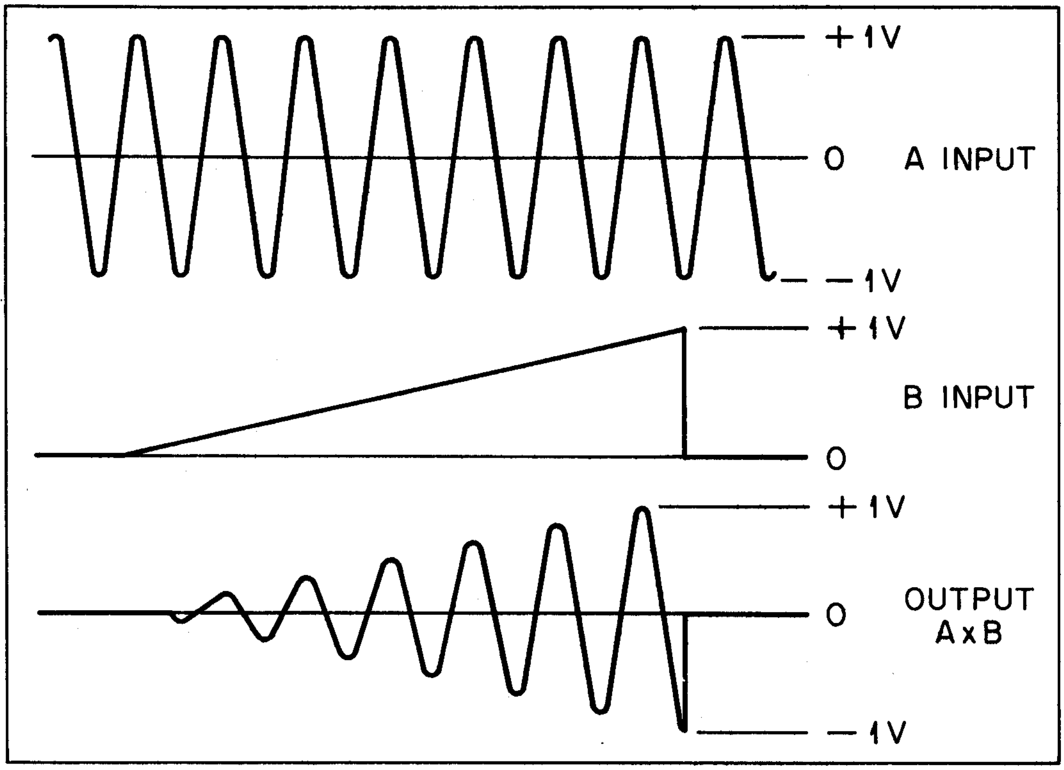


Figure III-2. MODULATING A SINE WAVE
WITH A SAWTOOTH-WAVE

(4) RATIOS

In many experiments ratios are the important factors in evaluating the performance of a device. Additionally, the ratio measurement technique has the advantage of independence of the ratio from the inherent fluctuations and drift and instabilities of a common energy source.

(5) VARIABLE GAIN AMPLIFIER

Operating in the product mode, the 230 may be used as a variable gain amplifier. With the signal applied to one of the inputs and the controlling voltage applied to the other input, the output signal level is a function of the controlling voltage. The required gain may be obtained by taking the output from the "FILTERED" output jack with the "TIME CONSTANT" switch in the "OFF" position.

(6) NOISE FIGURE MEASUREMENTS

An amplifier achieves optimum performance under those conditions where it least decreases the overall signal-to-noise ratio. In

SECTION IV
THEORY AND CIRCUIT DESCRIPTION

4.1 INTRODUCTION

Referring to the Block Diagram, page VII-2, note that the 230 has four main sections: The input circuitry, the computation circuitry, the output circuitry, and the overload circuitry. The input circuitry adjusts the input voltages to meet the computation circuitry requirements. DC blocking capacitors are used when the front-panel switch is in an ac position, and ten-to-one attenuation is employed when the front-panel switch is in a ten volt position. The computation circuitry combines a comparator amplifier and a one volt analog multiplier in the manner required, determined by the switch position, to yield the product, the ratio, the square, or the square root of the input voltages. There are three outputs from the Model 230. One of these is directly from the computation circuitry to the "DIRECT" output jack. The "FILTERED" output and the "RECORDER" output come from the averaging circuitry. The averaging circuitry consists of a gain selector and an operational amplifier connected in a low-pass filter configuration. The time constant of the low-pass filter is adjustable from 1 ms to 30 s. Provisions are available at the back of the unit for connecting additional capacitors if it is desired to further increase the time constant. Current limiting resistors in series with the outputs protect the 230 from short circuits, and diodes at the inputs and outputs prevent externally applied voltages from causing damage. The overload indicator lights whenever the voltage at a multiplier input or the voltage at the averager output is large enough to signify that the dynamic range of the corresponding circuitry is exceeded, or when the polarity of an input voltage is such as to cause a regenerative condition in the operational feedback loop.

As previously mentioned, the computation circuitry combines a comparator amplifier and a one volt analog multiplier in the manner required, depending upon the switch position, to yield the product, the ratio, the square, or the square root of the input voltages. Figure IV-1 illustrates these connections.

$\sqrt{-A}$, A<0

Refer to Figure IV-1A. The square root of -A, A<0 is obtained when connected as shown. With a negative voltage at "b", the comparator amplifier produces a positive voltage at "c", which is applied to both inputs of the multiplier unit. The output of the multiplier unit, the negative square of the voltage at "c", is applied to input "a" of the comparator amplifier. The action of the comparator amplifier is to adjust its output voltage so that the voltage fed back to "a" is equal to the voltage at "b". The voltage at "c" is, therefore, equal to the square root of minus the voltage at "b". The square root function is restricted to negative values of the voltage at "b" by the diode. This is necessary because the square root of a negative number is not a real number, and without the diode the large regenerative feedback to the comparator amplifier causes it to latch-up, requiring a large negative voltage at "b"

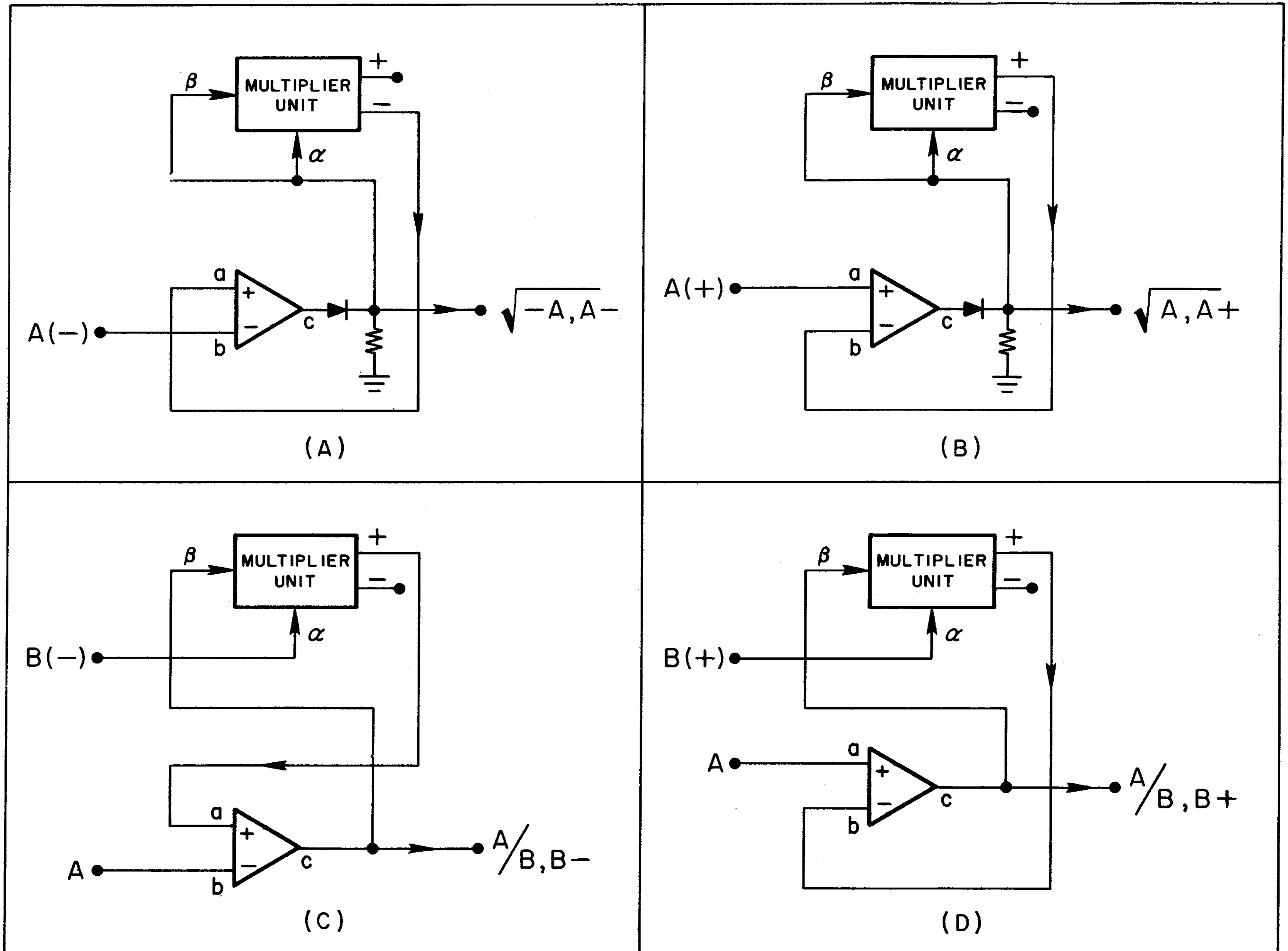


Figure IV-1. COMPUTATION CIRCUIT-CONFIGURATIONS to unlatch it. The overload circuit is activated with "A" positive.

$\sqrt{A}$, A>0

The configuration for the square root of A, A>0, is similar to the configuration for the square root of -A, A<0. The only difference is the necessary changes of polarity at the output of the multiplier unit and the input to the comparator amplifier. See Figure IV-1B.

A/B, B<0

The ratio A/B, B<0, is obtained by connecting as shown in Figure IV-1C. As before, the comparator amplifier, with a voltage at "b", adjusts its output voltage so that the voltage fed back to "a" is equal to the voltage at "b". The voltage at "a", the output of the multiplier, is equal to the product of B and the voltage at "c". The voltage at "c" must, therefore, be equal to A/B. B is restricted to negative values in order to maintain a condition of degenerative feedback in the comparator amplifier feedback loop. Positive values of B cause regenerative feedback, with the resulting large voltage at "c" activating the overload circuitry.

A/B, B>0

A/B, B>0 is obtained in almost the same way as A/B, B<0. The only change in the circuit is a change of polarity at the input to the comparator amplifier, required to maintain a condition of degenerative feedback. See Figure IV-1D.

AB, A^2, and B^2

The comparator amplifier is not used for generating products or squares. For the product function, the A and B input voltages are applied, via the input circuitry, directly to the α and β multiplier unit inputs. For the square function, the A input, or the B input, is applied, via the input circuitry, to both multiplier unit inputs. The product or square from the multiplier unit is taken directly to the output circuitry.

4.2 SCHEMATIC DISCUSSIONS

MULTIPLIER UNIT

The Multiplier unit is a one volt analog multiplier, and is the basis of the Model 230. Referring to the Multiplier Schematic on Page VII-3, note that part of the circuit is encapsulated (dotted line). This circuit performs the actual multiplying by providing a differential output current from terminals 7M and 8M, which is proportional to the product of the differential voltage applied to terminals 1M and 2M and the differential input currents to 5M and 6M. The differential input voltage to 1M and 2M is provided by the emitter-coupled pair Q201 and Q202 which are driven by the β input voltage. The differential input current to 5M and 6M is provided by the emitter-coupled pair Q205 and Q206 which are driven by the α input voltage. The output current, the difference representing the product, in passing to ground through R225-R229 develops voltages at the tops of R227 and R228. These voltages are applied to the input to the Feedback Amplifier (Q207-Q215). The Feedback Amplifier, in sensing a voltage difference at the input, pumps additional current through R227 and R228 to make the difference zero. This feedback current also passes through R233 and R234 to develop output voltages proportional to the currents. The output voltages taken from pins 4 and 5 are therefore complementarily (with respect to ground) proportional to the product of α and β.

COMPARATOR AMPLIFIER

The Comparator Amplifier is a high-gain differential amplifier which is used in conjunction with the Multiplier unit to perform the various computations as described in Paragraph 4.1. Referring to the Comparator Amplifier schematic on page VII-3, note that this is a specialized operational amplifier which has been compensated to meet the overall circuit requirements.

After passing through the compensating circuitry, the input signals go to the bases of the emitter-coupled pair, Q216 and Q217. The differential signals at the collectors of Q216 and Q217 are again amplified by Q219 and Q220. Q221 inverts the output of Q219 to aid Q220 in driving the emitter-follower output transistor Q222. CR212 and CR213 limit the output voltage.

INTEGRATOR AMPLIFIER

The Integrator Amplifier (see schematic on page VII-3) is an averager-connected operational amplifier with switch-selectable gain and averaging time-constant. The gain is selected by switching to R259 (and associated compensating resistor, R269) for a gain of 10, or switching to R260 (and associated compensating resistor, R268) for a gain of 100. The desired time-constant is selected by switching to the appropriate feedback capacitor, C800 through C809. See the Time Constant Switch schematic on page VII-4 for details of the capacitor switching. A non-inverted output is taken from the emitter of Q229. This output and the inverted output from the emitter of Q228 are compared by R278 and R279. The error signal is amplified by Q230 and Q231, and applied as a feedback signal to the base of Q225. This feedback serves to keep the non-inverted output equal to the mirror image of the inverted output.

OVERLOAD CIRCUIT

Refer to the Overload circuit schematic on page VII-5. The biasing of the emitter-coupled pairs, Q500-Q501 and Q502-Q503, is such that Q500 and Q502 have all of the current of the corresponding pair. When either of the input voltages becomes large enough to overcome this bias condition, the corresponding input transistor is turned off, causing all of the pair current to flow through the other pair transistor. With the positive overload voltage causing Q500 to turn off and Q501 to conduct, Q504 and the light turn on due to the collector current of Q501 passing to the base of Q504. With the negative overload voltage causing Q502 to turn off and Q503 to conduct, the positive collector voltage of Q502 causes Q504 to turn on and the lamp to light.

many instances the thermal noise generated by the signal source resistance is the dominant factor in determining the input signal-to-noise ratio. In this respect, amplifier noise performance can be specified by the amount of noise the amplifier adds to the amplified source thermal noise. Expressed in decibels this is called the "Noise Figure":

$$\text{Noise Figure in dB} = 20 \log_{10} \frac{\text{total rms noise voltage at amplifier output}}{\text{voltage gain x source thermal noise (rms)}}$$

$$= 10 \log_{10} \frac{\text{mean-square of the output noise voltage}}{\text{voltage gain}^2 \times 4KTR\Delta f}$$

where the Source Thermal Noise = $\sqrt{4KTR\Delta f}$ volts rms, and

K = Boltzman's constant, 1.38×10^{-23} joules/K
T = absolute temperature in kelvins
Δf = bandwidth in Hz
R = source resistance in ohms

The Model 230 is well suited to obtain the mean-square of the output noise voltage.

(7) OTHER USES

The Model 230 has such a wide range of applications that it is impossible to go into them in detail here. Some of these applications are: Vector addition, Fourier transforms, high order polynomials, and various other computations. Many of the important applications involve the use of several 230's and other analog instruments such as the PAR Model 215 Operational Amplifier, and assorted switching circuitry.

SECTION V
TROUBLESHOOTING

5.1 INTRODUCTION

The Model 230 Multiplier is a stable, reliable instrument, and as such, should provide long trouble-free service. Occasionally, component deterioration or failure may occur, and the instrument will require repair. The user is strongly advised to send the unit back to the factory for repair, even after the Warranty (Section VI) has expired. The reason for this recommendation becomes apparent when one considers that most of the transistors are carefully matched pairs, and that replacement of one component will generally require the replacement of other components which must be carefully selected for individual compensation, and related adjustments must be made. In addition, the main multiplier unit is of modular construction and cannot be repaired but must be obtained from the factory. Princeton Applied Research Corporation is able to perform such repairs and adjustments smoothly and economically, at a saving of cost and time for the user. Should the user decide to isolate and/or correct the trouble in the field, the following outline will be helpful.

5.2 GENERAL

EQUIPMENT NEEDED

In most instances, the trouble may be isolated with the help of and oscilloscope, voltmeter, and ohmmeter, and perhaps a signal source. However, if the user intends to repair the instrument, the following equipment should be on hand for alignment.

(1) Dc voltmeter, capable of measuring 1 V and 10 V with an accuracy of ±1 mV.

(2) Rms ac high-impedance electronic voltmeter.

(3) General purpose audio oscillator, capable of providing a 2 V pk-pk 100 Hz sine wave.

(4) Oscilloscope with a 200 mV/cm sensitivity.

(5) Two dc voltage supplies capable of being accurately calibrated at ±1 V and one of them capable of being accurately calibrated at +10 V.

(6) Assorted resistors.

(7) Shorting cap and a few short clip-leads.

(8) A test box must be constructed according to the following schematic:

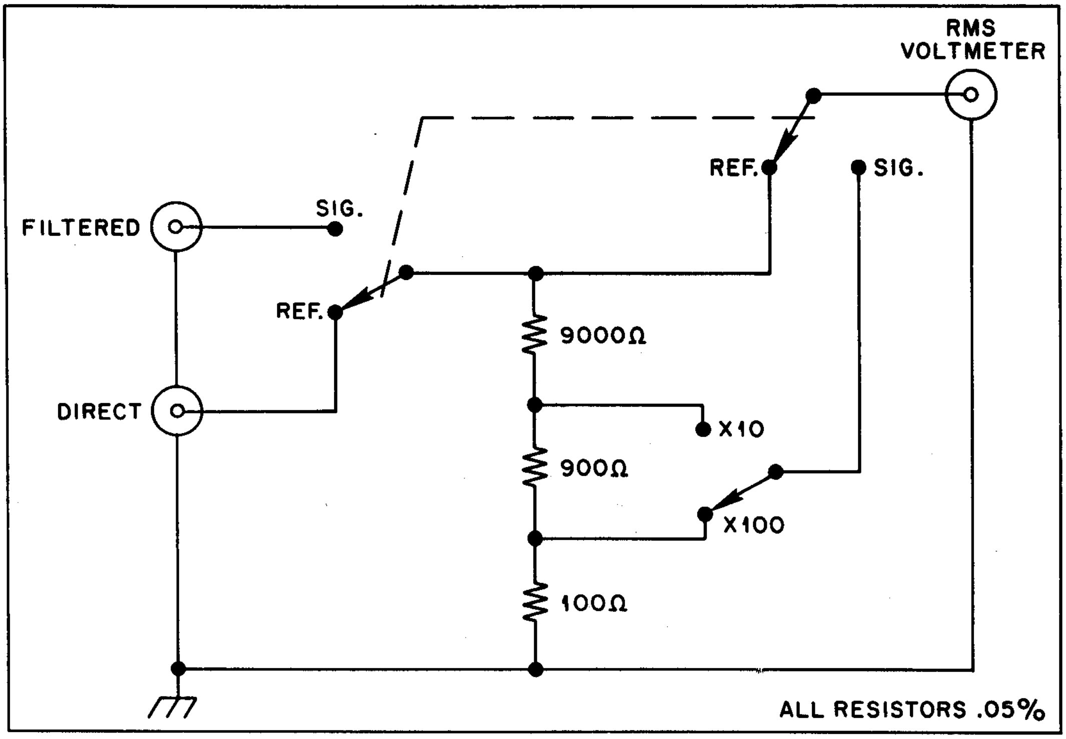


Figure V-1. TEST BOX SCHEMATIC

PROCEDURE

To speed the troubleshooting process, try to determine any external causes of the trouble, and to ascertain the symptoms when the Multiplier is properly connected and tested. Section IV, the Theory and Circuit Description, together with the layout diagram and schematics (Section VII), should provide sufficient information for isolating the trouble. A possible approach is to isolate the trouble to the input circuitry, the computation circuitry, the output circuitry, or the overload circuitry, by functional, voltage, and signal checks. Voltage and resistance checks can then specifically pinpoint the trouble. When doing resistance checks, it is sometimes possible to locate a defective transistor by checking the diode action of the base and collector junctions. While doing voltage checks, it is useful to remember that the base-to-emitter voltage of a forward biased silicon transistor (or diode junction) is roughly 0.6 V, and that the collector voltage of a saturated transistor is less than the base voltage (measured with respect to the emitter).

Once the problem is isolated to a specific circuit or component (or before), the user should contact Princeton Applied Research Corporation for advice on the relative merits of repairing the instrument himself, as opposed to returning it to the factory for repair. In any case, if the instrument is still in WARRANTY (Section VI), it is particularly important that Princeton Applied Research Corporation be contacted prior to attempting a field repair, as failure to do so could invalidate the Warranty.

When troubleshooting and replacement of defective components are completed, it will probably be necessary to adjust some of the bias and other operating points, and possibly change some of the "select-by-test" (SBT) components. Paragraph 5.4, the Alignment Procedure, should be consulted.

5.3 PRINTED CIRCUIT SOLDERING

If any components are removed from a printed-circuit board for inspection or replacement, be especially careful not to damage the print. To remove components "cleanly" requires considerable care. Either one of two methods can be used to remove the solder from a pad. The first entails the use of a bulb-vacuum operated solder remover, and the second the use of a "wick". Both methods give good results. A brief description of each follows.

METHOD #1

Removing solder by means of a solder-remover is a straightforward and relatively simple process. The required equipment includes a bulb-vacuum operated solder remover (UNGAR type SOLDER-OFF #7805 recommended) and a good soldering iron of moderate power (WALL type 14HDG40120 with type W14KS tip). The specific procedure used depends on whether the component to be removed has bent or straight leads. Most of the components have bent leads. Because of this, the solder must be removed from the pad on the side opposite the component, and each lead must be straightened before the component can be removed. In case the "opposite" side of the board is not accessible, the solder must be removed from the component side. To make their removal easier, the leads of these components were left straight by the instrument manufacturer. To remove a component, proceed as follows:

(1) Bent-Lead Components

Heat the pad on the side opposite the component. As soon as the solder flows, use the solder-remover to remove the solder from the pad and hole. Take care not to prolong the heating any longer than necessary. After the solder has been removed, straighten the lead. If enough solder has been removed so that the lead is "free" in the hole, pull the lead through the hole from the component side of the board, using suitable long-nose pliers. If the lead is not free, continue to apply heat while pulling the lead from the hole. Components with leads which cannot be removed one-at-a-time must have all of the leads free in the holes simultaneously by use of the solder remover. If it is not possible to free all of the leads in the holes, the component can be removed by applying heat to one of the leads and "rocking" the component to pull the lead through the hole as far as possible, and successively repeating this for each of the unfree leads until the component is free from the board. After the component has been removed, use the solder remover to completely clear all solder from the holes.

(2) Straight-Lead Components

Heat the lead on the same side as the component. As soon as solder flows, pull the lead through the hole. The above "rocking" procedure may be necessary. When the component has been removed, use the solder remover to completely clear all solder from the holes.

METHOD #2

Wicking entails using a length of stranded wire or shielding braid as a wick to draw up the molten solder from the pad. With this method, exceptionally clean work is easily achieved. Equipment required includes a good soldering iron (that recommended in Method #1 above is excellent), a supply of stranded wire or shielding braid, and some rosin base soldering flux (ALPHA 346-35, or equivalent). As in the first method, the technique varies according to whether the component has bent or straight leads:

(1) Bend-Lead Components

Dip a few inches of stranded wire (shielding braid is ideal) into the rosin-base soldering flux. Then place the wire or braid on top of the joint to be unsoldered, allowing some of the flux to flow over the joint. NOTE: Under no circumstances use an acid-base flux.

As shown in Figure V-2, place a hot soldering iron on top of the stranded wire directly above the joint to be unsoldered. Within a few seconds, most of the solder in the joint will flow quickly up the wick, leaving the joint area free of solder.

Lift the soldering iron and remove the wick before it freezes to the joint. Cut off the "filled" end of the wick (generally about ½ inch should be removed).

Inspect the joint. If any solder remains, repeat the procedure as required. Then straighten the lead and, while applying heat to keep

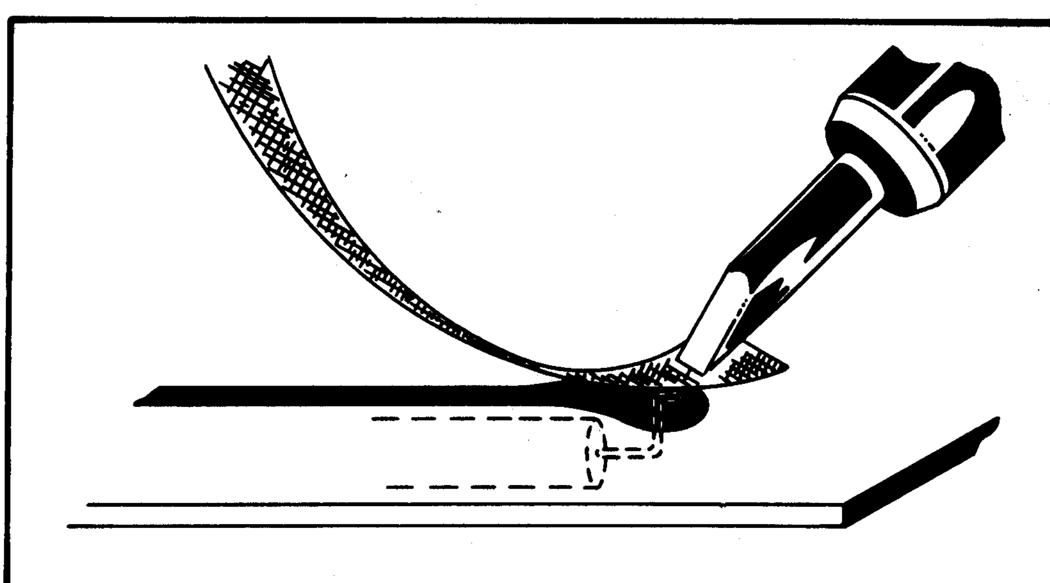


Figure V-2. SOLDER REMOVAL BY WICKING

the solder in the hole molten, pull it through the hole. Components with leads which cannot be removed one-at-a-time, such as transistors and trim-potentiometers, can be removed by applying heat to one of the leads and "rocking" the component to pull the lead through the hole as far as possible, and successively repeating this for each of the leads until the component is free from the board. After the component has been removed, use wicking to completely clear all solder from the holes.

(2) Straight-Lead Components

Heat the lead on the same side as the component. As soon as solder flows, pull the lead through the hole. The above "rocking" procedure may be necessary. When the component has been removed, use wicking to completely clear all solder from the holes.

INSTALLING COMPONENTS

In returning the component or its replacement to the board, make sure the leads are bent on the proper centers and that they don't angle in or out. If they do not pass freely through the centers of the holes, they may catch the edge of the print and lift it. The leads of straight-lead components must be cut before installing the component. In case of bent-lead components, bend and cut the leads after inserting the component. In either case, solder the leads with a hot iron (no larger than 40 watts) and a good grade of rosin core 60/40 solder. Be sure to apply heat no longer than necessary to achieve a good joint (usually a few seconds). Straight-lead components are, of course, soldered from the component side of the board. Bent-lead components are soldered from the opposite side.

5.4 ALIGNMENT PROCEDURE

The Model 230 should be aligned only if necessary after troubleshooting, and then only if the user decides not to send the unit back to the factory for repair and alignment (as discussed in paragraph 5.1). These procedures should be followed in sequence.

5.4A "B" Voltage And Current Zero

(1) Set the "MODE" switch to "A X B".

(2) Set the "A" and "B" input switches to "1 V DC".

(3) Connect a shorting cap to the "B" input BNC and a 2 V pk-pk 100 Hz signal to the "A" input BNC.

(4) Adjust R210 for a minimum signal at the "DIRECT" output ($\leq$500 microvolts peak-to-peak; typically < 200 μV).

(5) Set the "B" input to "1 V AC" and adjust R201 for minimum signal at the "DIRECT" output ($\leq$500 microvolts peak-to-peak; typically < 200 μV).

(6) Repeat (4) through (7) until equal and minimum output signals are

obtained.

5.4B "A" Voltage And Current Zero

(1) Connect the shorting cap to the "A" input BNC and a 2 V pk-pk 100 Hz signal to the "B" input.

(2) Set the "A" and "B" input switches to "1 V DC".

(3) Adjust R232 for a null at the "DIRECT" output jack.

(4) Set the "A" input to "1 V AC" and adjust R220 for a null at the "DIRECT" output jack.

(5) Adjust R15 (front-panel "DC ZERO") to null the second harmonic (visible in waveform).

(6) Repeat (1) through (5) until the minimum null has been reached ($\leq$500 μV pk-pk; typically < 200 μV).

5.4C Differential Voltage Zero

(1) Remove all input signals.

(2) Connect a dc voltmeter (floating) with a 1000 ohm resistor in each lead between terminals #4 and #6 of the printed-circuit board.

(3) Adjust R225 for zero meter indication (< ±500 μV dc). Remove connections.

5.4D Common Mode Voltage Zero

(1) Connect two 10 kilohm 1% resistors in series between P.C. terminals #4 and #6.

(2) Connect the high side of the dc voltmeter to the junction of the two resistors, and the low side to the chassis.

(3) Adjust R246 for zero dc indication (< ±500 μV dc).

(4) Remove the resistors.

5.4E Input Attenuator Compensation

(1) Set "A" and "B" input switches to "1 V DC".

(2) Apply +1 V dc to both input BNC's (same supply).

(3) Select R203 for no change in output as the "MODE" switch is changed from "A^2" to "A X B" (500 μV dc maximum change).

5.4F Multiplier Gain Calibration

(1) Set the "MODE" switch to "A X B".

(2) Set both input switches to "1 V DC".

(3) Record the "DIRECT" output readings for the following functions:

A	B	OUTPUT
+1 V	+1 V	1 V ±5 mV
-1 V	-1 V	1 V ±5 mV
-1 V	+1 V	-1 V ±5 mV
+1 V	-1 V	-1 V ±5 mV

(4) Select R206 for symmetric error of the two worst case readings.

5.4G Comparator Amplifier Voltage And Current Zero

(1) Set the "MODE" switch to "A/B, B > 0", and ground P.C. terminal #40 using a clip-lead.

(2) Set the "A" input switch to "10 V DC" and connect a shorting cap to the "A" BNC.

(3) Adjust R297 for an output as near zero as possible (output should adjust through zero).

(4) Set the "A" input switch to "1 V AC" and adjust R289 for an output as near zero as possible (output should adjust through zero).

(5) Move the ground from P.C. terminal #40 to terminal #39.

(6) Set the "MODE" switch to "A/B, B < 0" and adjust R290 for an output as near zero as possible (output should adjust through zero).

5.4H Integrator Amplifier Calibration And Balance

(1) Set the "MODE" switch to "A X B".

(2) Set the "A" input switch to "10 V DC".

(3) Set the "B" input switch to "1 V DC".

(4) Set the "TIME CONSTANT" switch to "OFF".

(5) Set the "GAIN" switch to "X100".

(6) Connect a 2 V pk-pk 100 Hz signal to the "A" input.

(7) Connect a 1 V dc signal to the "B" input.

(8) Connect the "DIRECT" and "FILTERED" outputs to the Test Box, and connect the test box output to an rms voltmeter. (Test Box construction

described above in paragraph 5.2 EQUIPMENT NEEDED.)

(9) Set the Test Box "X100" and "REF.", and adjust the voltmeter sensitivity for the largest on-scale reading.

(10) Set the Test Box to the "SIG." position, and adjust R261 for exactly the same reading as in (9).

(11) Ground the orange lead going to S4. (S4 is the "GAIN" switch on the front panel).

(12) Connect the dc voltmeter to the "FILTERED" output, and adjust R266 for zero dc output (within ±50 mV).

(13) Reconnect the Test Box and rms voltmeter to the Test Box. Remove the short from S4. Set the "A" input to "1 V DC", and set the "GAIN" switch to "X10".

(14) Set the Test Box to "X10" and "REF.", and note the rms voltmeter reading.

(15) Set the Test Box to "SIG.", and adjust R262 for exactly the same reading as in (14).

(16) Connect the dc voltmeter to the "FILTERED" output.

(17) Ground the orange lead at the "GAIN" switch S4.

(18) Select R269 for zero dc output (±5 mV).

(19) Remove the S4 ground.

5.4I Final Functional Tests

(1) Set the "A" and "B" input switches to "1 V DC".

(2) Using <u>two</u> calibrated 1 V dc supplies, complete the following mode tests:

(3) +1 V to "A" input, and +1 V to "B" input, "MODE" switch in "A/B B > 0; "DIRECT" output should be +1 V ±0.005 V.

(4) +1 V to "A" input, -1 V to "B" input, "MODE" switch to B < 0; "DIRECT" output should be -1 V ±0.005 V.

(5) +1 V to "A" input, "MODE" switch to "$\sqrt{A}$, A > 0"; "DIRECT" output should be +1 V ±0.005 V.

(6) -1 V to "A" input, "MODE" switch to "$\sqrt{A}$, A < 0"; "DIRECT" output should be +1 V ±0.005 V.

(7) Set the "A" and "B" input switches to "10 V DC" and the "MODE" switch

to "A/B, B > 0".

(8) Connect the "A" and "B" inputs to a common positive-voltage calibrated supply.

(9) Record the direct output for the following inputs:

(a) +10.000 V input; output should be +1 V ±0.005 V.

(b) +1.000 V input; output should be +1 V ±0.05 V.

(c) +0.100 V input; output should be +1 V ±0.5 V.

NOTE: Front panel Zero Control may be used to optimize these three readings by adjusting it at 0.100 V input.

SECTION VI
WARRANTY

Princeton Applied Research Corporation warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty are limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned prepaid to our factory for that purpose within ONE year of delivery to original purchaser. Instruments returned to the factory are accepted only when prior authorization has been given by an authorized representative of Princeton Applied Research Corporation.

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Princeton Applied Research Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

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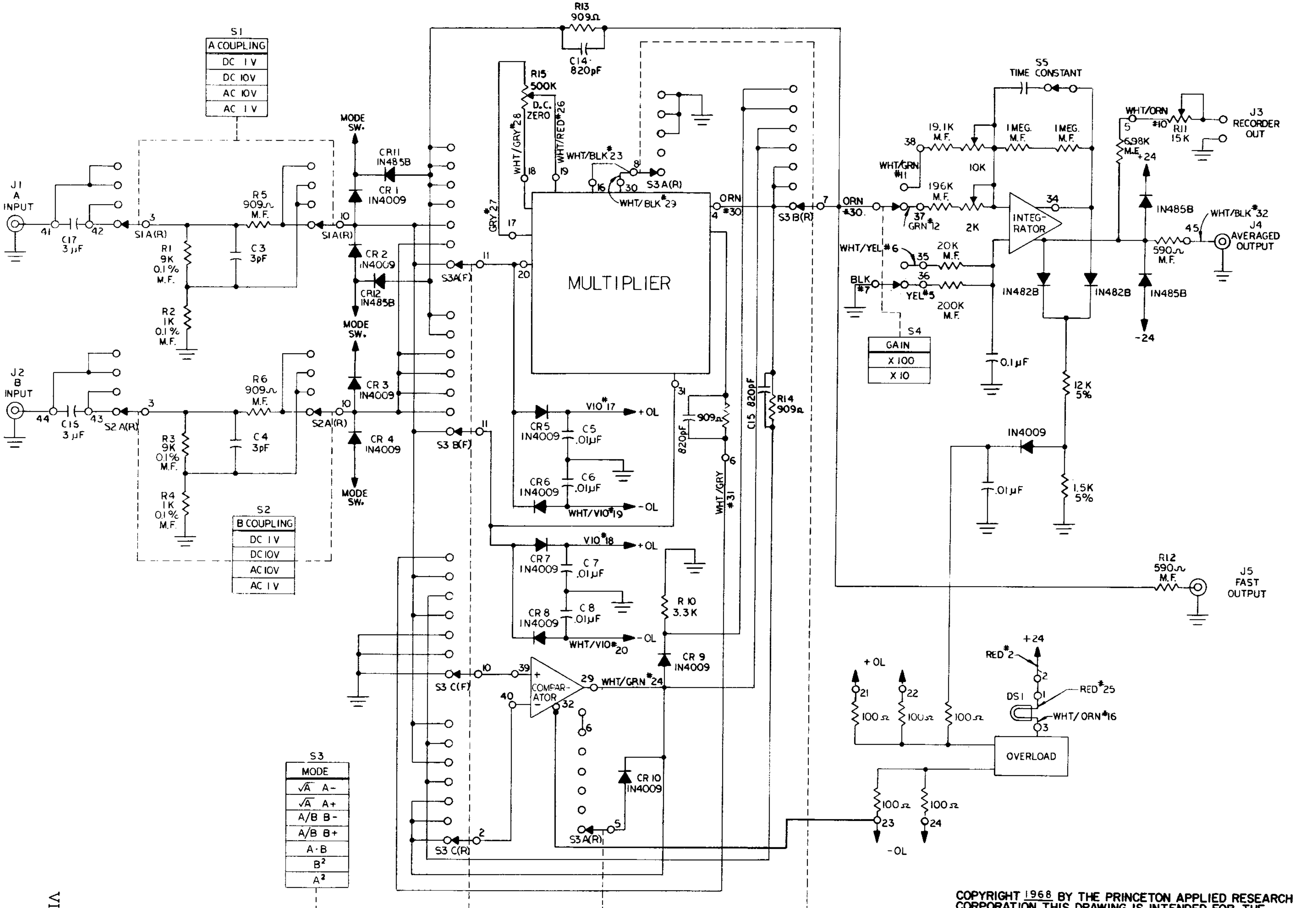
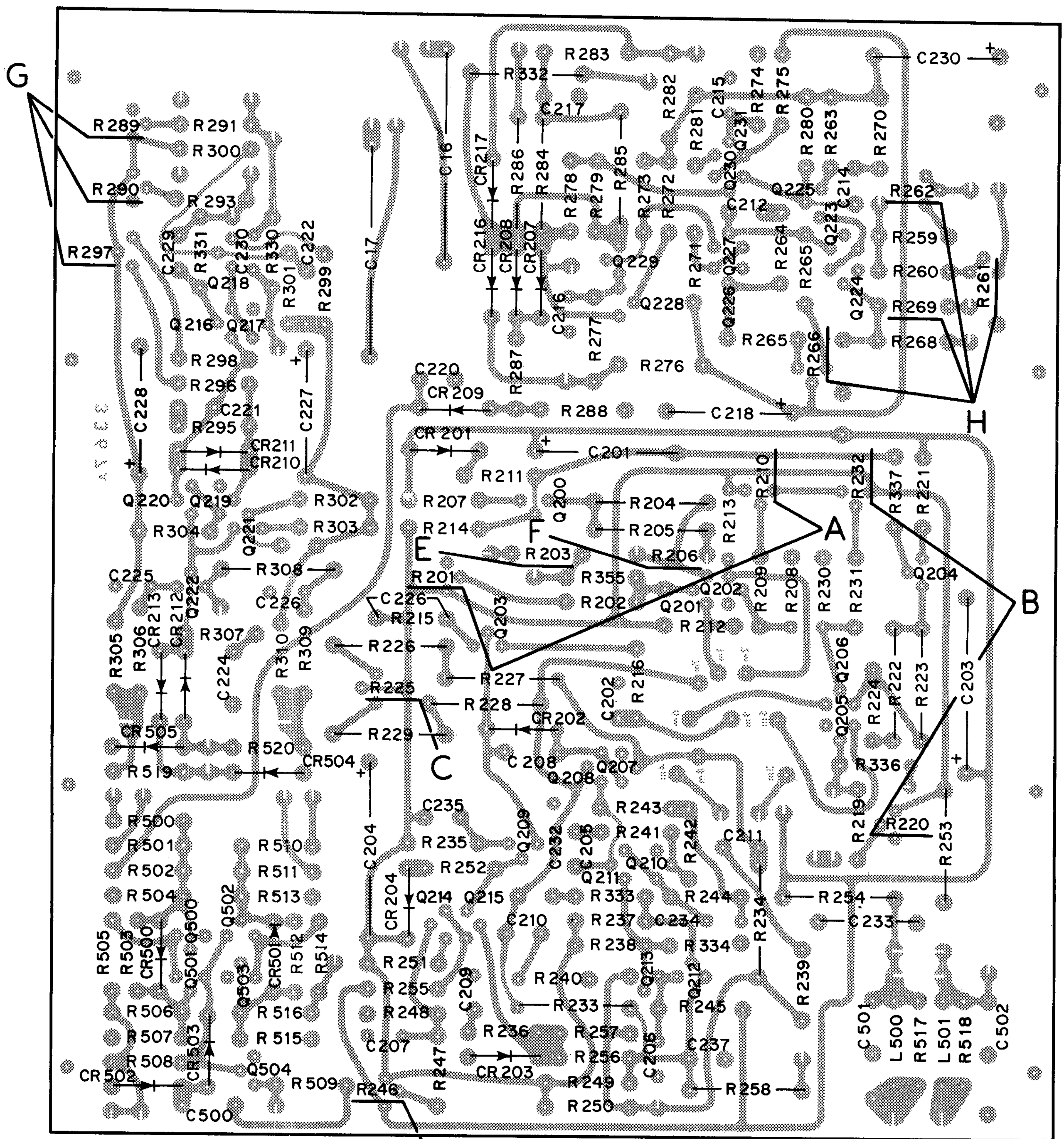
SECTION VII
SCHEMATICS

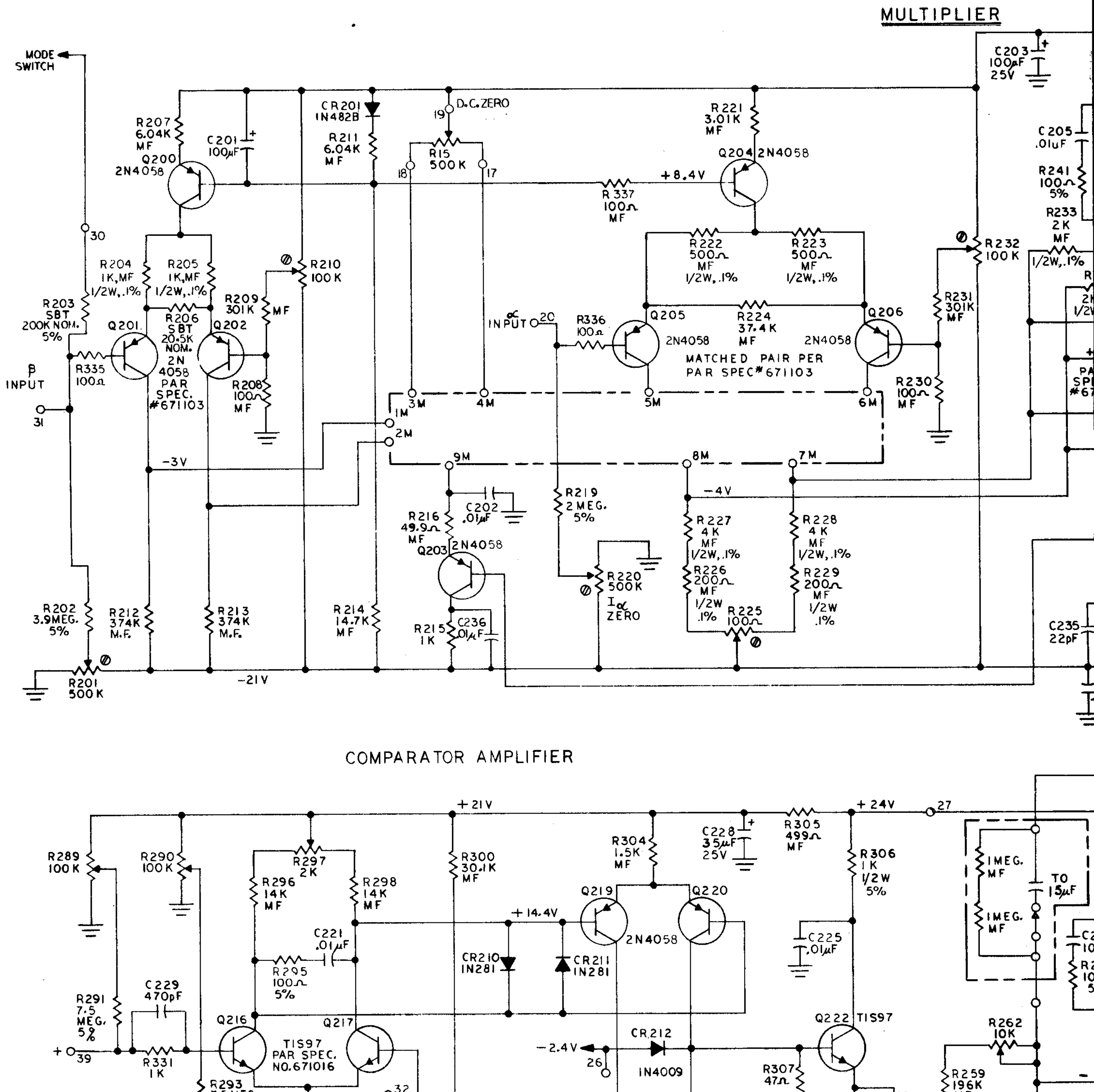


MULTIPLIER UNIT BLOCK DIAGRAM
MODEL 230

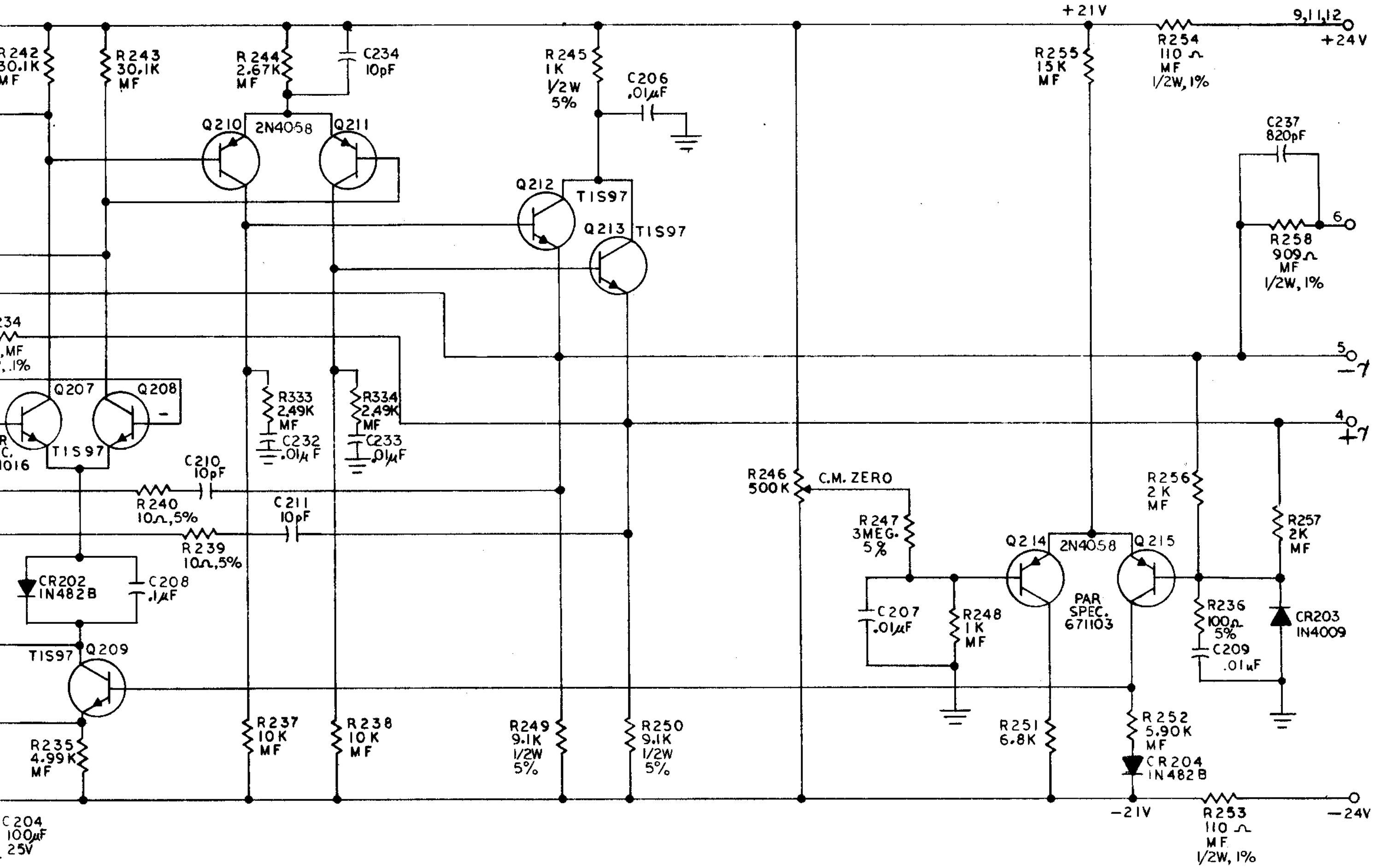
3271	C	SD	B



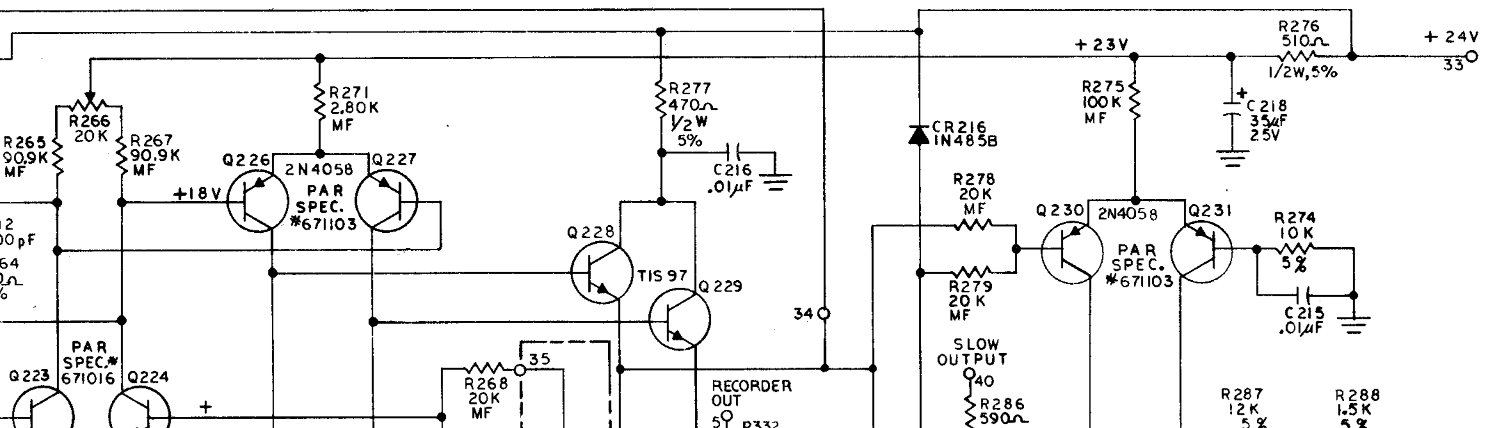
Callouts refer to sub-paragraphs of alignment procedure (paragraph 5.4 starting on page V-5).

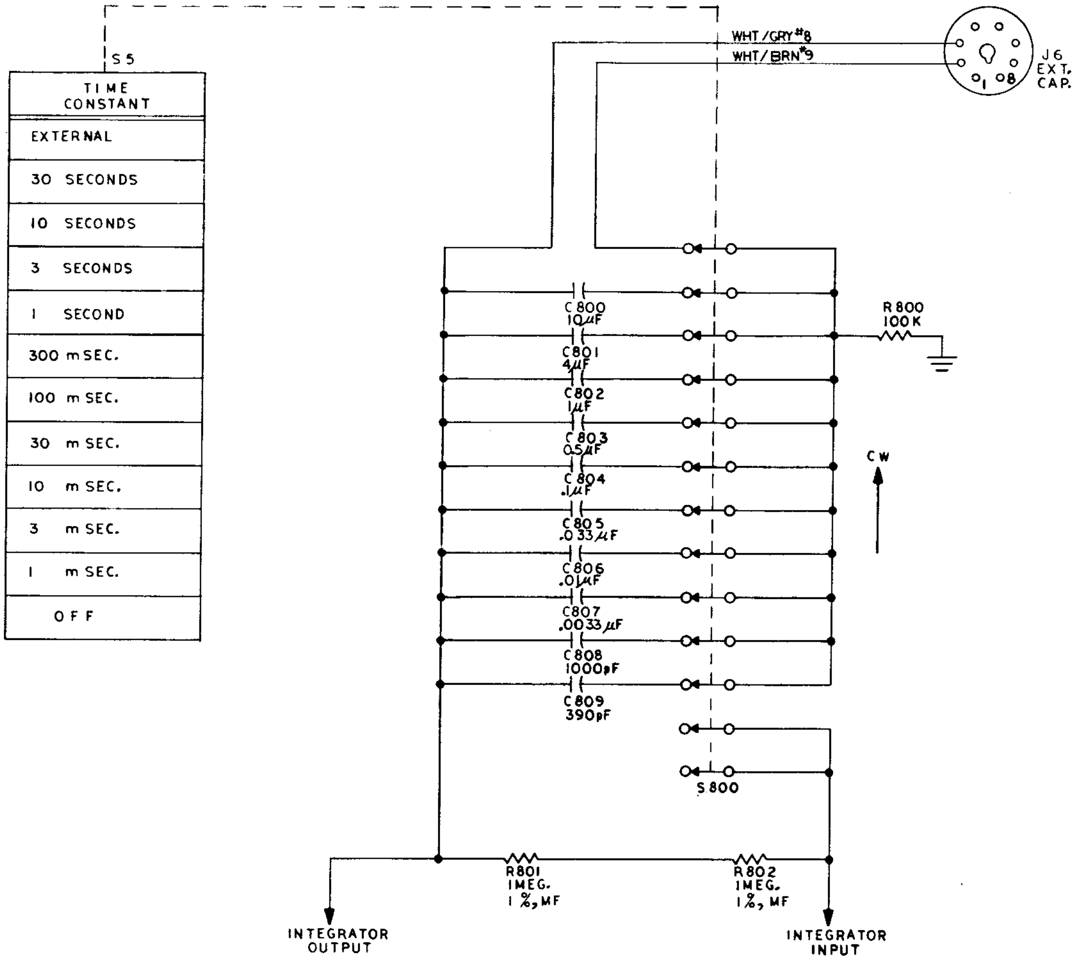


MULTIPLIER
COMPARATOR AMPLIFIER
MODE SWITCH
β INPUT
α INPUT
D.C. ZERO
Iα ZERO
MATCHED PAIR PER PAR SPEC # 671103
TIS97 PAR SPEC. NO.671016
Q200 2N4058
Q201
Q202
Q203 2N4058
Q204 2N4058
Q205 2N4058
Q206 2N4058
Q216
Q217
Q219
Q220
2N4058
Q222 TIS97
CR201 1N482B
CR210 1N281
CR211 1N281
CR212 1N4009
C201 100μF
C202 .01μF
C203 100μF 25V
C205 .01uF
C221 .01μF
C225 .01μF
C228 35μF 25V
C229 470pF
C235 22pF
C236 .01μF
R15 500K
R201 500K
R202 3.9MEG. 5%
R203 SBT 200K NOM. 5%
R204 1K, MF 1/2W, .1%
R205 1K, MF 1/2W, .1%
R206 SBT 20.5K NOM.
R207 6.04K MF
R208 100Ω MF
R209 301K MF
R210 100K
R211 6.04K MF
R212 374K M.F.
R213 374K M.F.
R214 14.7K MF
R215 1K
R216 49.9Ω MF
R219 2MEG. 5%
R220 500K
R221 3.01K MF
R222 500Ω MF 1/2W, .1%
R223 500Ω MF 1/2W, .1%
R224 37.4K MF
R225 100Ω
R226 200Ω MF 1/2W .1%
R227 4K MF 1/2W, .1%
R228 4K MF 1/2W, .1%
R229 200Ω MF 1/2W .1%
R230 100Ω MF
R231 301K MF
R232 100K
R233 2K MF 1/2W, .1%
R241 100Ω 5%
R259 196K
R262 10K
R289 100K
R290 100K
R291 7.5 MEG. 5%
R293
R295 100Ω 5%
R296 14K MF
R297 2K
R298 14K MF
R300 30.1K MF
R304 1.5K MF
R305 499Ω MF
R306 1K 1/2W 5%
R307 47Ω
R331 1K
R335 100Ω
R336 100Ω
R337 100Ω MF
1MEG. MF
1MEG. MF
TO 15μF
+8.4V
-3V
-4V
-21V
+21V
+24V
+14.4V
-2.4V



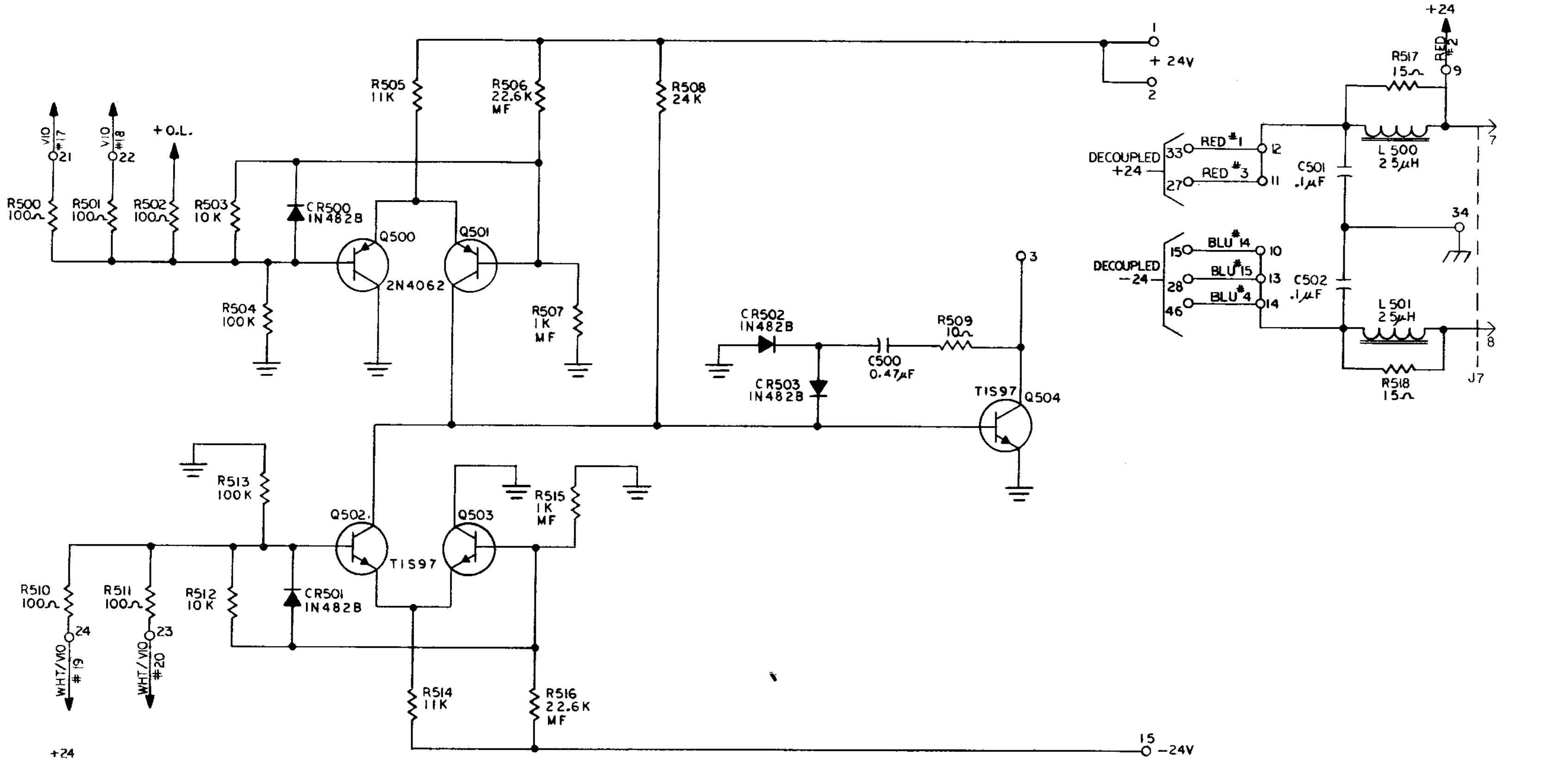
INTEGRATOR AMPLIFIER

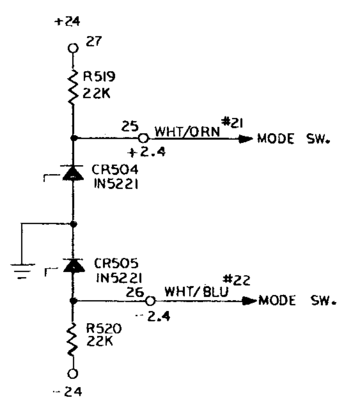




TIME CONSTANT SWITCH MODEL 230

| 3441 | C | SD | A |





OVERLOAD CIRCUIT
MODEL 230

NOTES:

1. ALL MF RESISTORS ARE ±1%, 1/8 WATT.
2. ALL OTHERS ARE ±5%, COMPOSITION, 1/4 WATT.
3.

3340	C	SD	A

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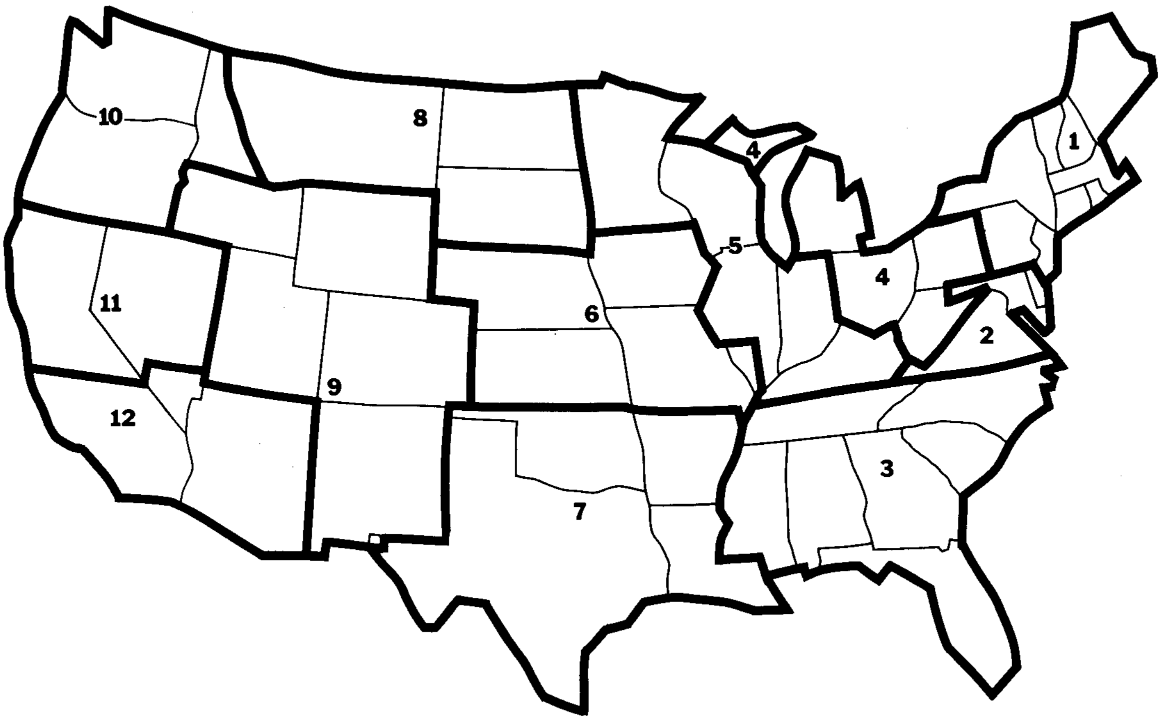

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Frankfurter Ring 81
West Germany
Tel: 0811-359-1001
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PRINCETON APPLIED RESEARCH CORPORATION

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