INSTRUCTION MANUAL
MODEL 3103
DUAL DC AMPLIFIER
(Chopper-Stabilized)

DONNER SCIENTIFIC COMPANY
Concord, California

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A Division of
Systron-Donner Corporation

August 1960

Lot No.________

CONTENTS

SYSTRON DONNER
CORPORATION

WARRANTY

Systron - Donner instruments are warranted during a period of one year from date of shipment to original purchaser to be free from defects in material and workmanship. This warranty does not apply to vacuum tubes, except as they are warranted by tube manufacturers. The liability of Seller under this warranty is limited to replacing or repairing any instrument or component thereof which is returned by Buyer at his expense during such period and which has not been subjected to misuse, neglect, improper installations, repair, alteration, or accident. Seller shall have the right of final determination as to the existence and cause of a defect. In no event shall Seller be liable for collateral or consequential damages. This warranty is in lieu of any other warranty, express, implied or statutory, and no agreement extending or modifying it will be binding upon Seller unless in writing and signed by a duly authorized officer.

RECEIVING INSPECTION

Every Systron Donner instrument is carefully inspected and is in perfect working order at the time of shipment. Each instrument should be checked as soon as received. If the unit is damaged in any way or fails to operate, a claim should immediately be filed with the transportation company.

REPAIRS

Whenever a Systron-Donner instrument requires service, the nearest Systron-Donner representative should be contacted; all representatives will provide immediate service or arrange factory returns when necessary.

Please specify both model and serial number in all correspondence concerning Systron-Donner instruments. Address all inquiries on operation or applications to your nearest sales representative or Sales Manager, Instruments, Systron-Donner Corporation, 888 Galindo Street, Concord, California.

CONCORD, CALIFORNIA

ADDENDUM

REFERENCE: INSTRUCTION MANUAL MODEL 3103, PAGE 1, GENERAL DESCRIPTION

PARAGRAPH 2, WAS: " ... The amplifiers are designed to withstand prolonged overloads or excessive load currents ..."

CHANGE TO: " ... The amplifiers are designed to withstand momentary overloads or excessive load currents. Prolonged direct shorts or overloads which would cause the amplifier to deliver over 10ma may cause permanent damage and amplifier failure ..."

GENERAL DESCRIPTION

The Donner Dual DC Amplifier, Model 3103, contains two identical amplifier channels constructed on a compact printed circuit chassis. Each dual amplifier is a plug-in unit having a special low-leakage male connector as an integral part of the chassis. Model 3103 designates the chopper-stabilized version of the amplifier. When the stabilizing amplifier section is omitted, the amplifier is designated Model 3104. The stabilizing amplifier section consists of a two-stage mechanical chopper-type a-c amplifier which improves the d-c gain and drift characteristics of the basic amplifier section by a factor of better than 500.

The Model 3103 dual DC amplifiers have been designed for use either with Donner analog computers or in DC amplifier systems. Their high gain, band width, and stability when operated with complex feedback networks make them well-suited for special applications. Stray capacity up to 500 mmfd. may be connected to both the amplifier input and output terminals with negligible effect upon the frequency response below 20 kc. Stability is maintained at low values of feedback resistance, including a short circuit. The amplifiers are designed to withstand prolonged overloads or excessive load currents.

The Model 3103 features a true overload indicating output for external indicator circuitry.

SPECIFICATIONS

(Model 3103, Stabilized)

Note: Unless otherwise noted, all specifications apply to a unity inverter

($R_{in} = R_{fb} = 1$ megohm)

TOTAL DC GAIN —>10 million
Unstabilized section —>20,000
Stabilizer —>500

OUTPUT
Type: A voltage 180° out of phase with the input voltage. Maximum range — ±100 volts at 4 ma maximum load current.

OUTPUT IMPEDANCE — less than 0.01 ohm

D.C. STABILITY (referred to summing junction)
Short-term stability — ±200 μv (random noise)
Off Set for ±10% line voltage change — ±150 μv

PHASE SHIFT

Ø	Frequency A	Frequency B
0.5°	5kc	3kc
1.5°	10kc	5kc
5.0°	40kc	15kc

A: R_{in} & R_{fb} = 100K

B: R_{in} & R_{fb} = 1 megohm

FREQUENCY RESPONSE

	A	B
$f_{resonance}$	100kc	45kc
f_{-3db}	115kc	70kc

A: R_{in} & R_{fb} = 100K
B: R_{in} & R_{fb} = 1 megohm

INTEGRATOR DRIFT
(R = 1 megohm, C = 1 mfd)
Average drift is less than 150 μv/sec.

OVERLOAD RECOVERY TIME - less than 8 sec.

NOISE LEVEL
(60 cps hum referred to summing junction) — 2 mv peak-peak

POWER REQUIREMENTS (two channels)
+300 volts regulated at 25 ma (quiescent)
-310 unregulated at 19 ma (quiescent)
-150V regulated at 0.35 ma
6.3V ±10%, 50-60 cps at 2.0 amps

DIMENSIONS — 3 inches height
1-7/8 inches width
8 inches length

INSTALLATION

MOUNTING

The Dual DC amplifier is the basic component for one series of Donner analog computer components and DC amplifier systems. In the latter application, a Model 3121 amplifier receptacle unit is normally employed for mounting up to five dual amplifiers. The amplifiers are installed in the computer or receptacle unit by unlocking the two wing nuts on the rear apron and inserting the amplifier card into the receptacle connectors. When the rear apron is closed and locked, the amplifiers are held securely in place by the rubber mounting guides on the apron. All signal and power connections to the amplifier are available for measurement at the terminals of the mating female receptacle. Input and output signal connections are available at the front panel receptacles on standard mounting units.

POWER REQUIREMENTS

All filament and DC operating voltages for the dual DC amplifier are normally supplied by the compact regulated power supply contained in the amplifier receptacle unit. Power requirements for one dual amplifier chassis (2 amplifier channels) are given in the Specification section. The +300 volt source is regulated to within ±0.2% for full line and load variations. The −150 volt source is regulated to within ±0.1%. Hum and noise should be restricted to less than 50 millivolts peak-to-peak for best results. All drift and offset characteristics given under "Specifications" were obtained with an unregulated filament supply (6.3 volts ±10%). Regulation of this supply to within 1% will considerably improve amplifier stability.

BALANCE VOLTAGE

An external positive and negative bias voltage source is connected to pins F and D of the amplifier connector to provide the necessary "zero voltage" for balancing the amplifier. In a standard Donner installation this circuitry is provided in the amplifier receptacle unit.

OPERATION

WARM-UP

The Model 3103 amplifiers should be allowed to warm up for at least 15 minutes prior to their use in critical applications. When employed with instruments in which filament and plate power supplies are separately controlled, the plate power need not be energized until the amplifiers are ready for use.

BALANCING

After an initial warmup period, the dual amplifier should be checked for balance. When used with a standard Donner receptacle unit or computer, refer to the appropriate instruction manual for the balance procedure.

Normally, the dual dc amplifier is checked in an inverting circuit having a gain of 1000 (With reference to Figure 1, R_{in} = 1k, R_{fb} = 1 megohms.) With the Model 3104, use R_{in} = 10k, R_{fb} = 1m. The average output voltage reading in either case should be set at zero by adjusting the external balance potentiometer and should not in any case exceed ±0.4 volts, which reflects a typical offset voltage appearing at the summing junction of the amplifier. The minute fluctuations of the meter needle during the balance adjustment are a normal condition.

OVERLOAD CONDITION

During operation of the Model 3103 amplifier with Donner computers or the Model 3121 receptacle unit, observe the overload indicators to make certain that the amplifiers being used do not overload. If an overload occurs, first verify the external computing circuit connections, component values, and range of input voltages. Next, verify the balance adjustment. If the amplifier appears to be defective, remove the chassis from the receptacle unit. During the warm-up period, all amplifiers may overload but they should return to normal after approximately one minute. Place a feedback resistor between the input and output terminals of any amplifier not being used in a computing circuit to insure that it will not drift into overload.

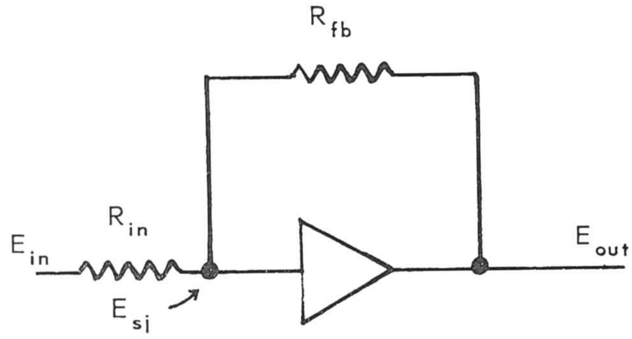


Figure 1. Basic Operational Amplifier Circuit

DC amplifiers are used in analog computers to perform the mathematical operations of addition, subtraction, integration, and multiplication by a constant. These operations are performed by associating precision resistors, capacitors, and potentiometers with the basic DC amplifier. When two precision resistors are connected to the basic amplifier as illustrated in Fig. 1, degenerative feedback is applied around the amplifier, and the value of the closed loop gain is precisely controlled by the ratio of the feedback resistor, R_{fb}, to the input resistor, R_{in}. If the amplifier gain is large relative to this resistor ratio, then the value of the closed loop gain is exclusively determined by the resistor ratio.

The junction between the input resistor and the feedback resistor is called the amplifier summing junction. The summing junction voltage appearing at this point is equal to the amplifier output voltage reduced by the amplifier gain. As the amplifier gain is made very large, the voltage at the amplifier summing junction is reduced towards zero, and the amplifier summing junction can be considered as a virtual ground. Since the DC amplifier exhibits a large, but finite gain, a very small voltage exists at the amplifier summing junction. This voltage is, in fact, necessary to generate the amplifier output voltage.

STABILIZATION

When the voltage applied to the amplifier, illustrated in Fig. 1, is equal to zero, the output voltage should also be zero. However, the amplifier tube characteristics, power supply voltages, and the resistance values do not remain perfectly stable with time. As a consequence, the DC potentials within the amplifier circuitry will vary as a function of tube aging, temperature, the DC supply potentials, and the heater voltages applied to the amplifier vacuum tubes. These effects accumulate within the amplifier and generate an error voltage at the amplifier output terminals. In general, the degenerative feedback through the resistive connection between the amplifier input and output terminals greatly reduces the influence of variations which arise within the amplifier circuitry. The most significant source of drift within the operational amplifier is associated with the amplifier input stage(since this voltage undergoes the largest amount of amplification through succeeding stages) and, in particular, is caused by variations in the heater potential of the input tube. It has been shown that degenerative feedback is incapable of reducing the amplifier drift which is caused by heater current variations in the amplifier input stage.

In order to minimize the critical low frequency components of drift within the amplifier input stage, a drift-free stabilizing amplifier is connected into the circuitry as illustrated in Figure 2. The addition of this stage effectively increases the overall amplifier gain at low frequencies by a factor of approximately 500. Since this stage contributes no drift of its own, the effective overall drift of the amplifier is thereby reduced by approximately an equal amount.

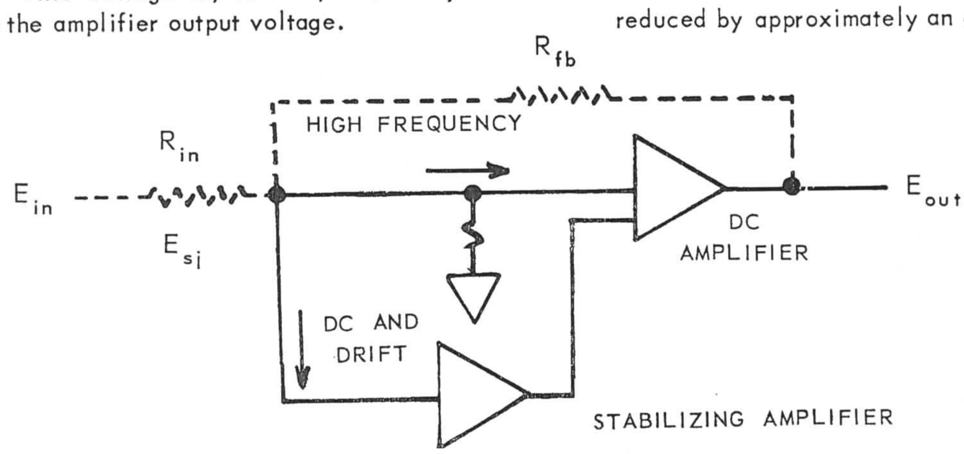


Figure 2. DC Amplifier With Stabilization

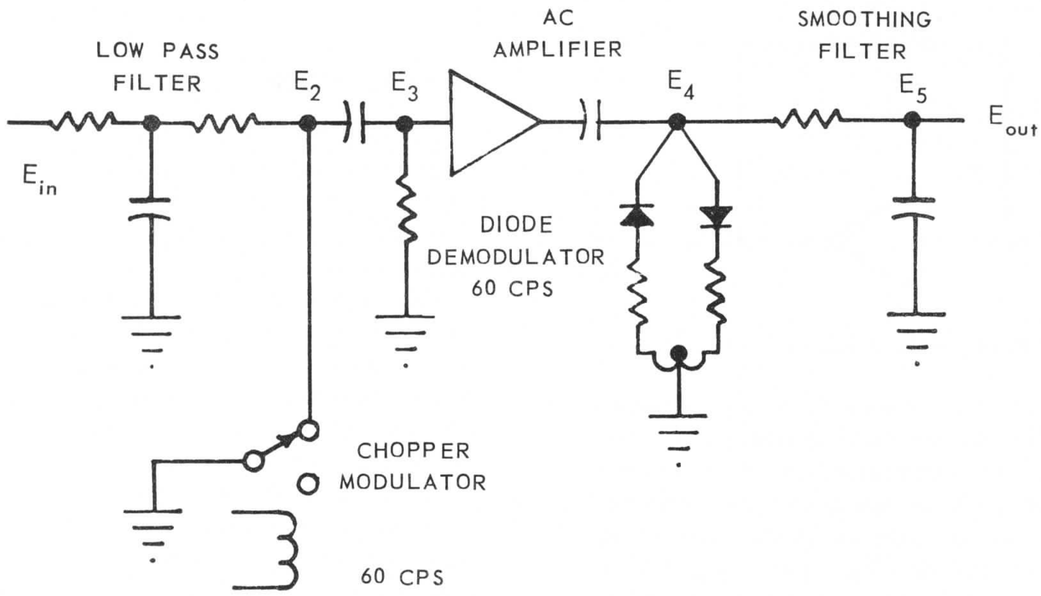


Figure 3. Simplified Diagram of Stabilizer Amplifier (Designated Voltages refer to Figure 4.)

STABILIZING AMPLIFIER (Model 3103 only)

With reference to the appended amplifier schematic diagram the stabilizer portion of the circuit includes all components associated with tubes V103 and V104. A simplified diagram of the stabilizer amplifier is shown in Fig. 3. Typical voltage waveforms at significant points within this diagram are illustrated in Fig. 4. Circuit symbols designated below refer to the "A" amplifier channel.

A low frequency voltage applied to the amplifier input terminal passes thru the RC filter consisting of R110 and C102, which attenuates frequencies above 3.0 cycles, thus allowing only very low frequency components to pass to the chopper from the input terminals.

The electro-mechanical chopper, Y101, alternately grounds and ungrounds the amplifier input voltage at the point between resistor R111 and capacitor C103 at a rate of 60 cps so that the low frequency components of input voltage are converted into a 60 cps square wave as shown in Fig. 4B. Blocking capacitor C103 removes the dc component of the signal, producing the waveform shown in Fig. 4C. The type 12AX7 and 6112 dual triodes (½ of V104 and ½ of V103) form a typical two-stage capacitively-coupled amplifier. The output of this amplifier is an amplified squarewave voltage in phase with the signal applied to the input grid of V104. This signal is passed thru blocking capacitor C110 to the diode demodulating circuit consisting of rectifiers CR101 and CR102. The diode demodulator operates in synchronism with the chopper modulator in order to generate a rectified voltage (shown at Fig. 4E) which is then applied to the grid (pin 2) of the DC amplifier input stage V101 through the RC filtering network formed by resistor R129 and capacitor C104.

The diode demodulators function in the following manner: The two silicon diodes, CR101 and CR102 are connected in series with the current limiting resistors, R130 and R131 across the center-tapped source of 6.3 volts a-c. During one-half of the 60 cps period, the two diodes will conduct heavily, causing the voltage at the junction between capacitor C110 and resistor R129 to be at the same level at the center tap of the 6.3 a-c filament power source; i.e., at zero potential. During the second half of the 60 cps period the two silicon diodes will be biased in the non-conducting state and the voltage at the junction between them will be unaffected by the demodulator circuitry. The waveform of the voltage at the junction between the diodes is illustrated in Fig. 4D.

The stabilizing amplifier has a gain of 500 or better at zero frequency (d.c.). The low pass RC input filter attenuates input signal frequencies above 3 cps and the stabilizing amplifier is virtually removed from the circuit at frequencies substantially above 5 cps. The stabilizing amplifier, therefore, is the normal path for d-c and drift frequency components, while higher frequencies are applied directly to the input tube (V101 of the DC Amplifier).

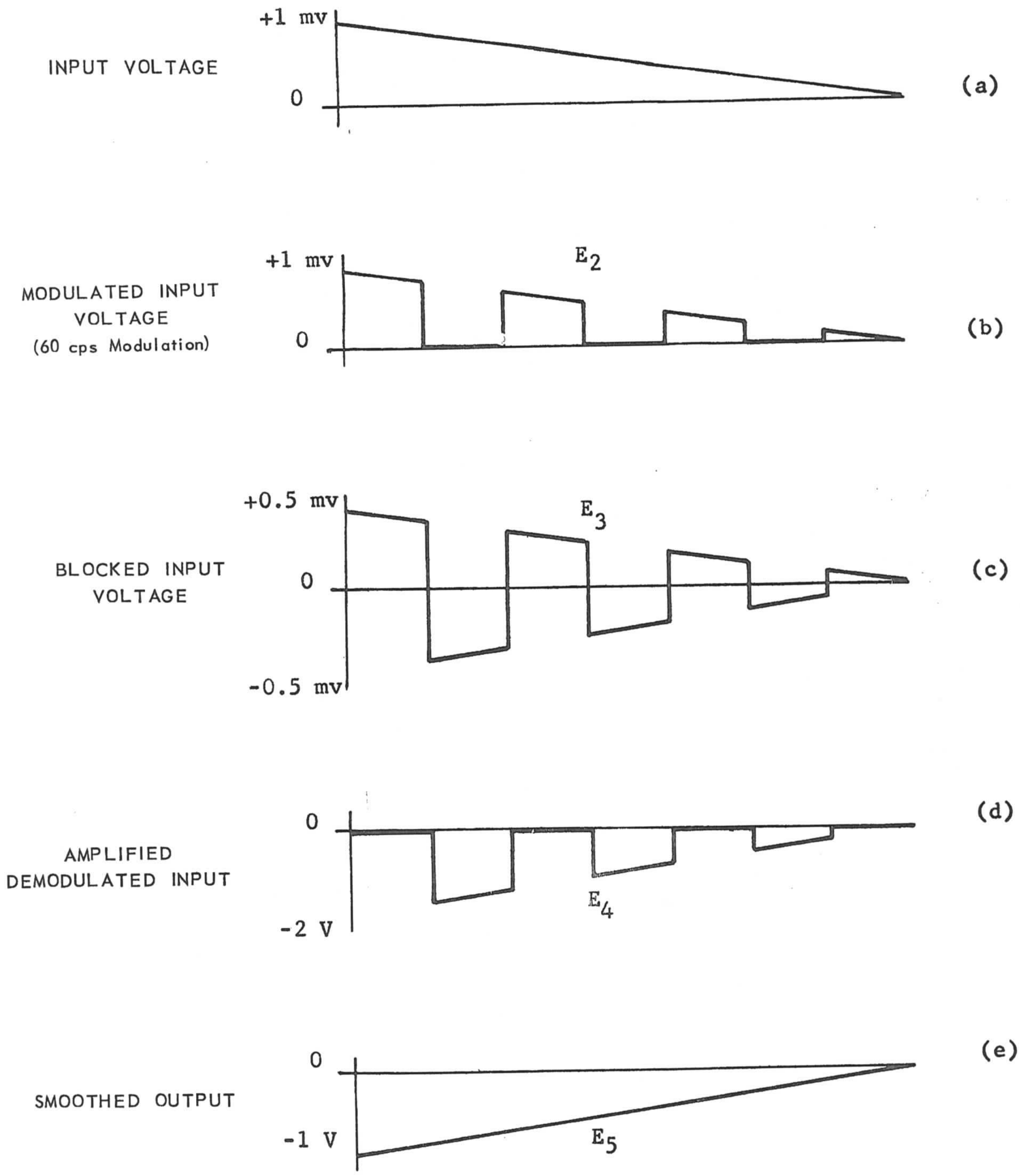


Figure 4. Typical Waveforms in the Stabilizing Amplifier
(Refer to Figure 3)

DC AMPLIFIER

The DC Amplifier section consists of V101, a type 12AX7 tube used as a differential amplifier, and V102, a type 6BR8 tube used as a two-stage regenerative amplifier with cathode follower output. The input signal (or summing junction voltage) is applied to Pin 7 of V101. The stabilizing amplifier output as well as the external balance voltage is applied to the second grid of this tube. Regeneration in the second stage is accomplished through the common cathode coupling resistor R122. The neon tubes I101, I102, and I106 provide a constant voltage drop between the plate of V102A and the grid of V102B, thus biasing the cathode follower output stage correctly to produce a zero volt output in the quiescent condition. The use of this low impedance means of coupling contributes to the high gain of the stage. The overall amplifier is inherently very stable. Capacitors C105 and C107 provide high frequency compensation for improved frequency response.

BALANCE CIRCUITRY

The balance voltage applied to Pin 2 of V101 is obtained from an external "zero" or balance potentiometer located on the computer or amplifier receptacle panel. Voltage is applied through a network consisting of R106 to R109 and C104, which has an exceedingly large time constant in order to minimize fluctuations in the balance voltage source. The balance voltage is adjusted to produce zero volts at the amplifier (connected operationally as a high gain "summer") is also zero volts.

OVERLOAD CIRCUITRY

In the Model 3103, an a-c output voltage is obtained from the plate (pin 1) of V103 in the stabilizing amplifier and is available at the chassis connector Pin J (or Pin K) for utilization in an external true-overload circuit. True overload exists when the signal at this point exceeds approximately 20 volts, peak to peak, reflecting an excessive level of voltage at the summing junction of the overall amplifier. When this condition occurs, the voltage fires a thyratron in the external overload indicating circuit. Voltage overload for the Model 3103 is also indicated by external circuitry. A neon lamp is placed across the voltage divider network connected to the amplifier output. When the output voltage exceeds approximately ±100 volts, the lamp fires.

The trouble shooting procedure described below will enable the service man to check the operation of the amplifier and determine systematically the source of trouble. Power is applied for all tests. A sensitive oscilloscope and high impedance millivoltmeter (Kintel Model 202B or Belleville-Hexem EIR meter, Model 110A) are required. In making the tests, use the second amplifier channel on the chassis or one on another chassis known to perform well, to obtain normal indications for comparison. As a rule, component detail numbers given in the text will refer only to the A amplifier channel. Refer to the schematic diagram for the equivalent B channel detail numbers. Always try tube and chopper replacement before making the other tests prescribed.

Symptoms

A. ***Nervous Amplifier*** – output voltage observed during balance adjustment drifts beyond specified balance range, possibly by a factor of 10 or more.

Analysis: Low gain in stabilizing amplifier.

Test: Make gain test as follows: Apply a ±1 millivolt signal to the amplifier input terminal (A), using no amplifier feedback resistor. Measure the output voltage at pin 2 of V101 using a very high impedance (approximately 100 megohms) voltmeter and allowing about one minute for the meter to reach maximum indication. The reading should be at least 0.5 volts, d.c. Reverse the input voltage polarity and repeat the measurement.

Correction: Replace V103 or V104, chopper Y101. Check resistance of R110 to R112 and other components in the stabilizing amplifier. If gain is normal, replace V101 and check associated components. Replace C102 or C103.

B. ***Saturated Amplifier:***

Analysis: Usually fault is in high-speed path or may be combination high-speed and stabilizer section faults.

Test:

(a) Cut out the stabilizer section by shorting to ground at the junction between CR101 and CR102. Now try to balance the amplifier. The adjustment will be extremely sensitive, but if a zero output can be obtained, the DC amplifier section is normal. Refer to Symptom A for hints on locating trouble in the stabilizer section.

(b) If the output is still saturated, check the DC amplifier section gain with no feedback resistor: apply a ±1 millivolt signal to the input (terminal A) and measure the change in output at pin 1 of V101. It should be at least 40 millivolts. Under normal conditions, the output voltage at terminal H will change at least 40 volts for a ±1 mv input.

Correction: Replace tube V101 or V102. Measure their tube pin voltages per Table I.

C. ***Will Not Balance***

Analysis: Stabilizing Amplifier Section.

(a) Equal but opposite offset in the two amplifier channels indicates that one side of the filament voltage source is grounded.

(b) Unbalanced demodulator section.

(c) Noisy chopper.

(d) Excessive 60 cps pickup caused by cathode-to-filament leakage.

Correction: Check CR101, CR102 and associated components. Replace V101 or chopper Y101. Clean printed circuit board to remove dust, etc., between filament and signal lines.

D. ***Excessive Hum (60 cps)***

Analysis: V101 or V102 leaky. If amplifier output is saturated at 60 cps, check for open C104 or R129. See also Symptom C.

E. ***Oscillation at high frequency (60-80KC)***

Analysis: Failure of high-frequency suppression components. Regeneration components out of tolerance.

Test: Observe output on oscilloscope.

Correction: Check values of R118 and R122. Check C105 through C108. Change output tube V102.

F. ***Low Frequency Oscillations (approx. 10 cps)***

Analysis: Poor power regulation supply caused by low line voltage. Faulty chopper Amplifier section. (See Symptom A.)

G. ***Slow Overload Recovery***

Analysis: Second stage in stabilizing amplifier clamping.

Correction: Replace V103. Check R125, CR101, and CR102.

TABLE 1
TUBE PIN VOLTAGES

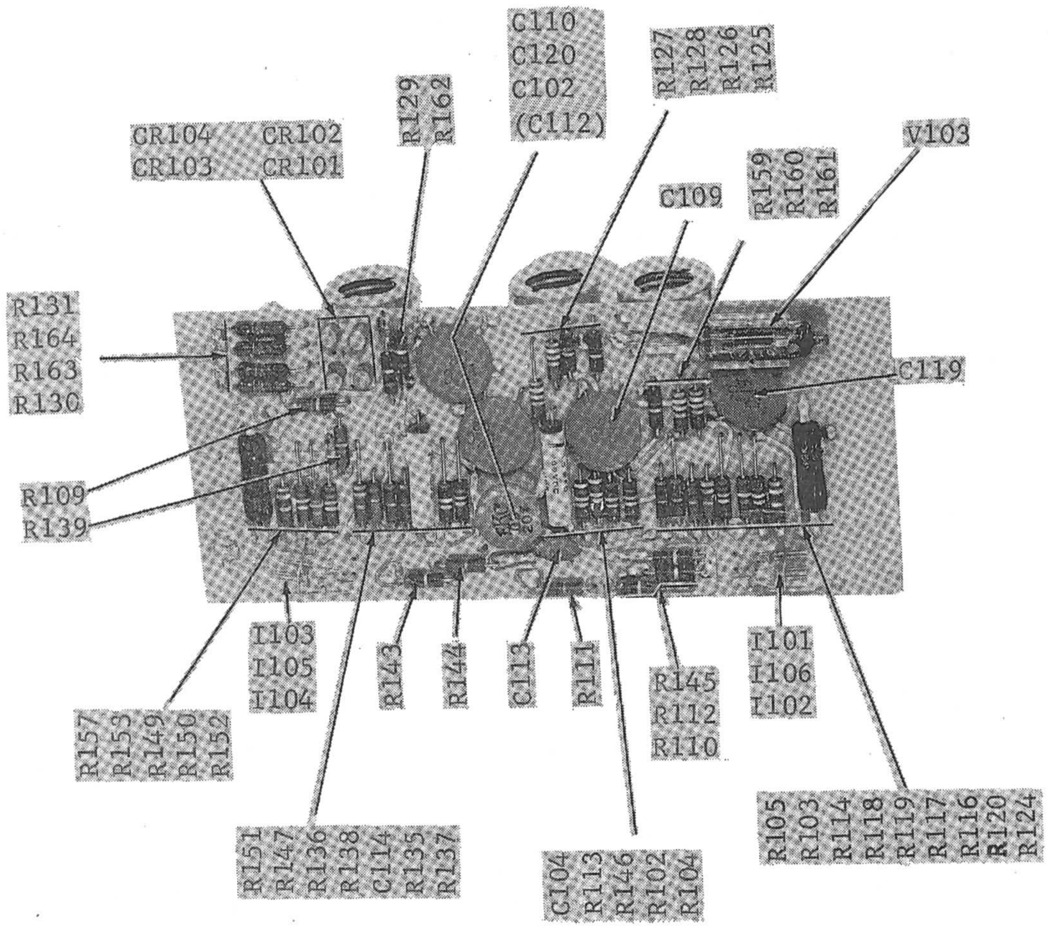
(Measure voltages with a good vacuum tube voltmeter. They should agree within ±10% of the values given below.)

Tube	Pin: 1	2	3	4	5	6	7	8	9
V101, V105	115	0.3	1.1	fil	fil	110	0	1.1	
V102, V106	-6	295	0	fil	fil	155	29	2	1
V103	75	-1.1	fil	0	0	fil	-1.1	75	
V104	94	-0.6	0	fil	fil	94	-0.6	0	

PARTS LIST MODEL 3103

(NOTE: All common fixed resistors are described on schematic diagrams.)

Detail Number	Description	Mfr. – Part No.	Donner Stock No.
C102, C112	Capacitor, 0.05 mfd ±20% cerm. disc, 500V	Electra 8U220RA10	C0330
C103, C113	Capacitor, 0.02 mfd 150V cerm disc ±10%	Centralab DDM 203	C0322
C104, C114	Capacitor, 1.0 mfd paper wrap mylar	Electron MI-105	C0314
C105, C108 C115, C118	Capacitor, 50 mmfd ±20% cer disc 500V	Electra 10U500RA10	C0312
C106, C116	Capacitor, 0.01 mfd	Electra 20N103RA6	C0311
C107, C117	Capacitor, 22mfd	Electra 8U220RA10	C0313
C109, C110 C119, C120	Capacitor, 0.02 mfd ±20% cerm disc 500V	Electra 24N203RA6	C0310
CR101, CR102 CR103, CR104	Diode, HB2	Hoffman	CR0044
I101 thru I106	Glow lamp, neon	General Electric NE-81	I0014
R124, R157	Resistor, 39 K, 5W, 5% wirewound	Dalohm RLS-5	R0675
V101, V104 V105	Vacuum Tube, 12AX7	Telefunken	V0071
V102, V106	Vacuum Tube, 6BR8A	Sylvania	V0074
V103	Vacuum Tube, 6112	Raytheon	V0052
Y101	Chopper, Relay, 60 cps	Airpax 175	K0007


C110
C120
C102
(C112)
R127
R128
R126
R125
R129
R162
CR104 CR102
CR103 CR101
V103
C109
R159
R160
R161
R131
R164
R163
R130
C119
R109
R139
I103
I105
I104
R143
R144
C113
R111
R145
R112
R110
I101
I106
I102
R157
R153
R149
R150
R152
R151
R147
R136
R138
C114
R135
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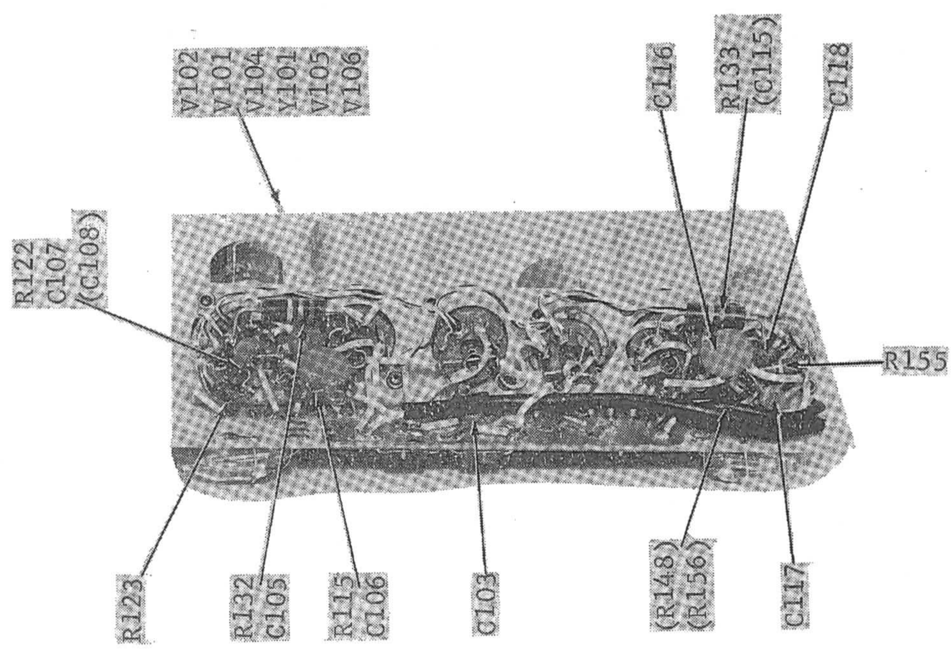
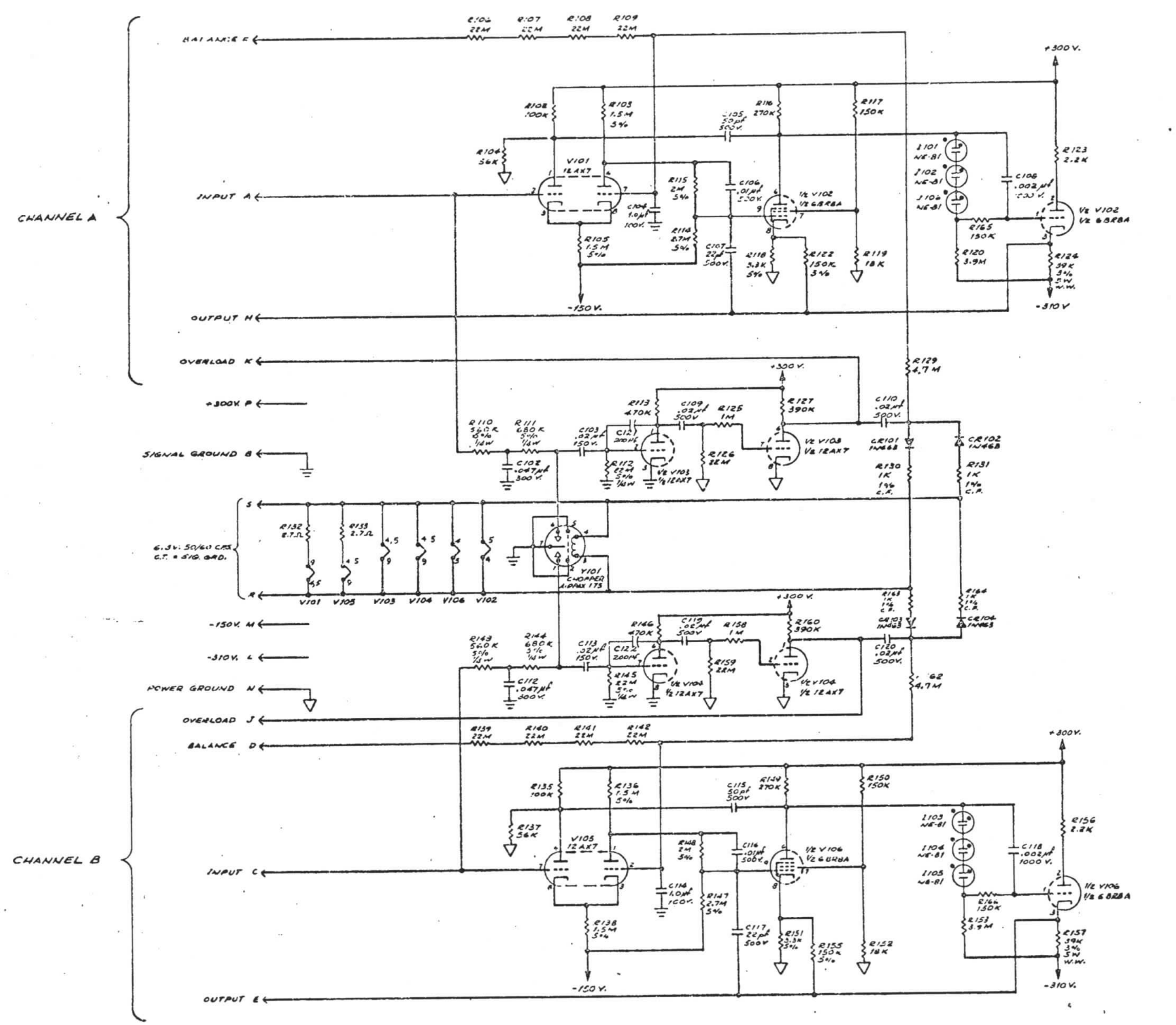
R117
R116
R120
R124


V102
V101
V104
Y101
V105
V106
C116
R133
(C115)
C118
R122
C107
(C108)
R155
R123
R132
C105
R115
C106
C103
(R148)
(R156)
C117



P.C. BOARD TERMINATIONS

NOTES:

1. ALL RESISTORS ARE 10%, 1/2W UNLESS OTHERWISE SPECIFIED.
2. ALL CAPACITORS ARE IN µf UNLESS OTHERWISE SPECIFIED.
3. SIGNAL GROUND
4. POWER GROUND
5. EXTERNAL DOT INDICATES POSITIVE TERMINAL OF NE-81

REDESIGNED F. REDRAWN	1442	A	
		B	

DONNER SCIENTIFIC COMPANY

SCHEMATIC
DUAL OPERATIONAL AMPLIFIER

DWG NO. 9325 — ISSUE B

DRAWN BY BRADLEY 9-12-61

3103 — 3933

DONNER SCIENTIFIC COMPANY
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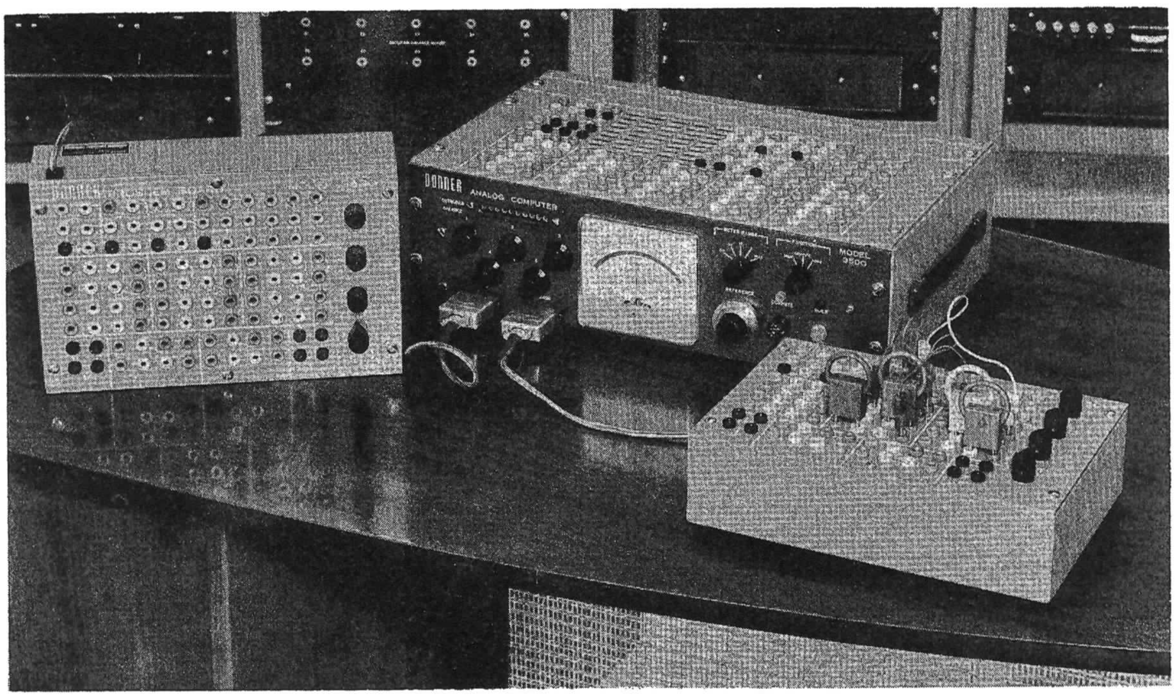
Concord, California

Supplementary Instruction Manual
For Model 3500 Analog Computer

AUXILIARY PROBLEM BOARD SET

MODEL 3530



Model 3530 Problem Board Set used with Model 3500 Analog Computer

GENERAL DESCRIPTION

The Model 3530 Problem Board Set is an accessory for the Model 3500 portable analog computer which effectively converts the instrument into two, independent computers and permits the use of spare problem boards. It is intended primarily as an educational aid, but will greatly enhance the versatility of the computer in general applications. Each unit of the problem board set commands five amplifiers within the Model 3500, three of which may be used as integrators. On each unit are problem board jacks corresponding to the terminals on the Model 3500 fixed problem board, three initial condition coefficient potentiometers, bias voltage terminals, and a function switch duplicating the Model 3500 function switch, all of which are utilized in the same manner as the corresponding controls on the Model 3500 computer. When the cable connectors of the Model 3530 set are inserted into the corresponding front panel receptacles, J407 and J408, of the Model 3500, all necessary connections are made from the function switches and terminals on the units to the amplifiers in the computer.

Each problem board unit of the set measures 4½ inches high by 8 inches wide by 12 inches long, and has a 38-inch cable. Shipping weight for the set of two is 18 pounds.

OPERATION

PRELIMINARY

Place the Model 3500 computer function switch at "hold" during all operations with the Model 3530. Remove all patchcords and components from the Model 3500 fixed problem board and insert the cable connectors of the Model 3530 units into J407 and J408 on the Model 3500 front panel. Each unit will control the following amplifiers in the Model 3500, as indicated by the problem board legend.

Amplifiers controlled by
Unit connected to

	J407	*J408*	*Amplifier Function*
Ampl.	#1	#4	integrating or summing
	#2	#5	integrating or summing
	#3	#8	integrating or summing
	#6	#9	summing only
	#7	#10	summing only

PATCHING OPERATIONS

The patching operations for the Model 3530 are identical to those explained in Section 4, page 14, of the Model 3500 instruction manual, with the following single exception. Observe that each amplifier terminal group in the upper row of the Model 3530 problem board panel has three pairs of jumper terminals indicated thus: 

To utilize the amplifier corresponding to each set of terminals as an integrator, connect together the two terminals of each pair as well as the corresponding IC terminals adjacent to the like-numbered potentiometer. For zero initial conditions, ground the IC terminal as illustrated on page 15 of the Model 3500 manual.

Each amplifier has four columns of terminals associated with it. When an amplifier is connected as an integrator, insert the plug-in input components between the first and second columns from the left. To use the same amplifier terminals for summing operations (that is, when the jumpered terminals are disconnected), connect a patchcord between the second and third columns.

The two summing amplifier terminal groups in the lower row are utilized exactly as explained in the Model 3500 manual.

The terminals immediately adjacent to the input and output side of the amplifier symbol  on the Model 3530 units parallel the corresponding terminals on the Model 3500 fixed problem board; therefore, these terminals on the Model 3500 may be used to supplement those on the problem board units when required.

VOLTAGE MEASUREMENTS

All voltage measurements for problems set up on the Model 3500 problem board units are made with the meter on the Model 3500. Connect it either for direct measurements or null operation as described in the Model 3500 manual. When a measurement is to be made at the amplifier output terminal, as for initial condition adjustment, the reading may be taken at the terminal on the Model 3500 fixed problem board as well as at the corresponding terminal on the Model 3530 plug-in board. Measurements on the Model 3530 problem board unit may be facilitated by using the trunk lines to terminals on the Model 3500 labeled "1" or "2". The corresponding trunk-line terminal on each Model 3530 unit is the sole violet-colored one.

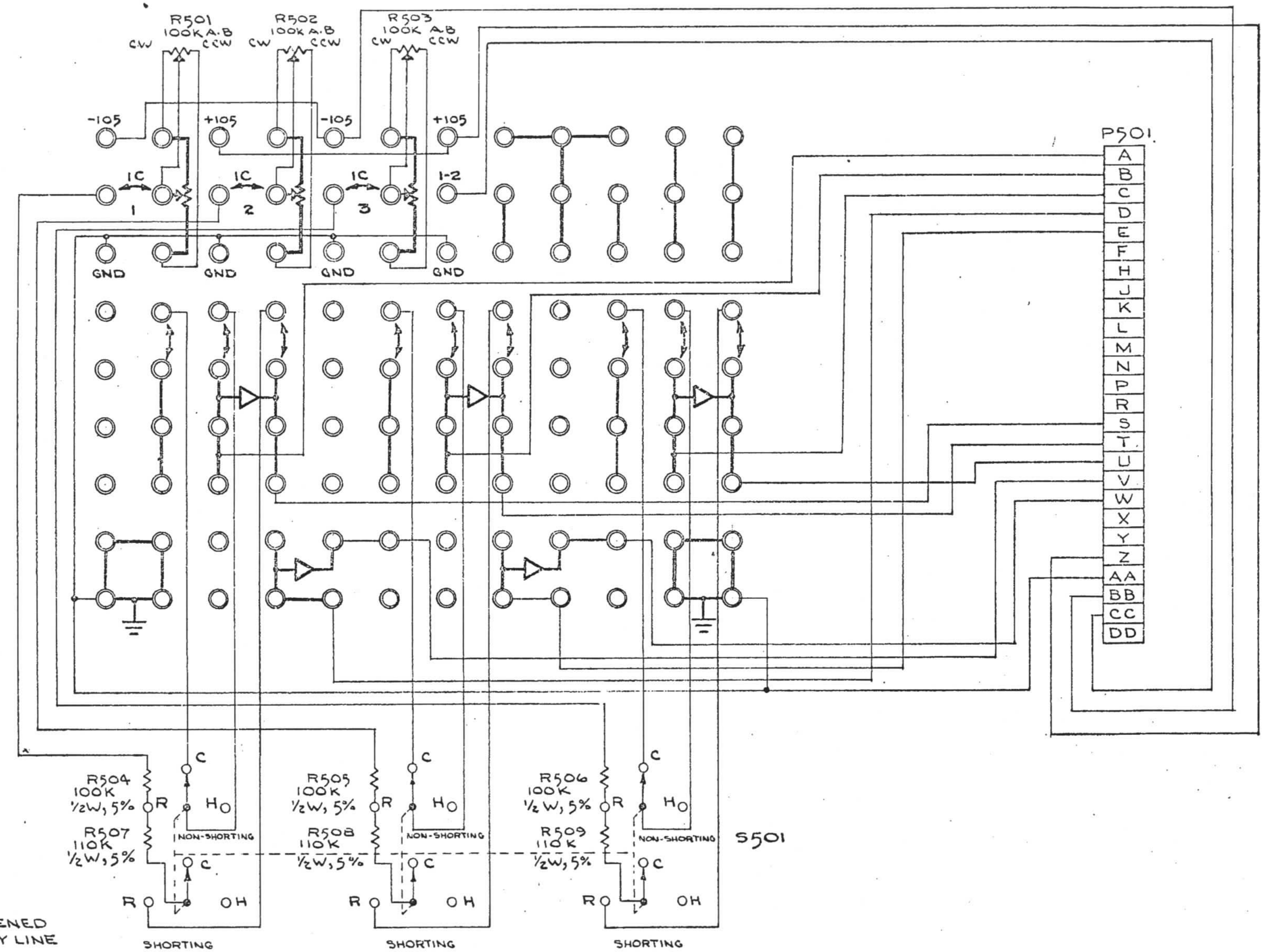
Refer to the Model 3500 instruction manual for all other operating procedures, including amplifier balance.

The Model 3530 Problem Board set cannot be used with the Model 3520 Multiple Control Unit.

MAINTENANCE

The Model 3530 problem board set requires no adjustment nor routine maintenance. Malfunction within these units would be confined to defective switch contacts, potentiometers, and cable connections. Refer to Dwg. 6282 for circuit connection information.

INITIAL CONDITION POTS.



NOTE:
1. NOMENCLATURE SILKSCREENED ON PANEL SHOWN IN HEAVY LINE FOR REF. ONLY.

FINISH		
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CHECKED J.M.C.	4-6-60	
PROJ. ENG.	5/19/60	SURFACE FINISH —
APPROVED	5/19/60	SCALE N.A.
		NEXT ASSEM. 6283
MODEL 3530	TITLE SCHEMATIC - PROBLEM BOARD	DWG. NO. 6282 ISSUE A

DONNER SCIENTIFIC COMPANY

DET. NO.	ITEM	MATERIAL	QUAN/ASSY

REVISIONS	ECO NO.	ISSUE	DATE	APR.

INSTRUCTION MANUAL

MODEL 3732

ELECTRONIC MULTIPLIER

(Quarter-Square Type)

Issue No. ______________

Serial No. ______________

July, 1961

SYSTRON DONNER

CORPORATION

CONCORD, CALIFORNIA

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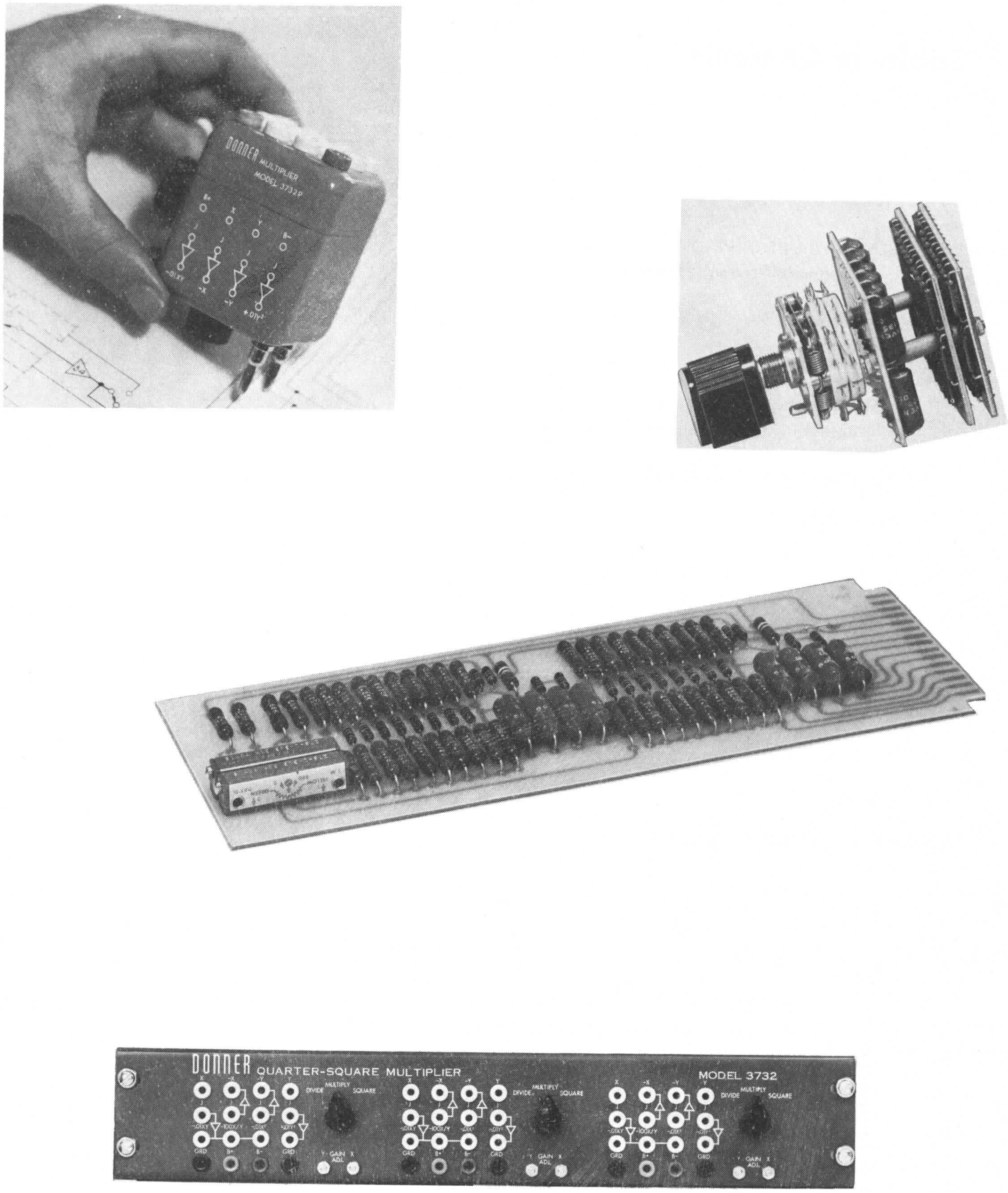


Figure 1 – The Four Basic Versions of the Model 3732 Multiplier

1-General Description

1.1 FUNCTION

The 3732 series electronic multipliers offer a choice of several different packaging versions of a solid-state quarter-square type multiplier circuit. Each unit is essentially a dual channel squaring network which performs the following basic operations when patched into a computer circuit:

a. Four-quadrant multiplication (single-channel): output = $-.01XY$
b. Two-quadrant division: output = $-100X/Y$
c. Squaring (two channels): outputs of $-.01X^2$ and $+.01Y^2$
d. Square-root (two channel): outputs of $+10X^{\frac{1}{2}}$ and $-10Y^{\frac{1}{2}}$
e. Fourth power and fourth root

Many variations of these operations are possible as explained under "Operating Instructions".

The 3732 series normally operates with input and output voltages of ±100 volts full scale, but for solid-state system applications a ±10 volt range instrument may be ordered. Static accuracy in four quadrant multiplication is within 500mv (0.25% of full scale) and within 250mv in the squaring mode. External operational amplifiers are required with the quarter-square multiplier. For multiplication, one amplifier is needed for output scaling and, if two-polarity input signals are not available, two input inverting amplifiers are also necessary. Input and feedback resistors for the associated amplifiers are internally mounted (except in Model 3732A) and resistance values of the input networks are matched in pairs to within 0.01% tolerance. The multiplier normally operates from a ±100 to 105-volt reference supply available in the computer, or it may be factory set to operate from another level. Two screwdriver adjustments are provided for calibration of the squaring networks. No other adjustments are required.

1.2 DIFFERENT VERSIONS

Four basic versions of the Model 3732 multiplier are illustrated in Figure 1.

MODEL 3732P is packaged as a compact plug-in unit with operating mode switch which may be mounted directly on the problem board of a Donner or other type of analog computer having ¾-inch hole spacing. All interconnections are made to terminals on top of the case. Case dimensions are 3" × 2½" × 2".

MODEL 3732R is a three-channel (maximum) rack-mounting panel version. Panel dimensions are 3½" × 19". Total depth is 3½" (2¼" behind the panel).

MODEL 3732B is the internal switch and component assembly of the plug-in multiplier, supplied without case or signal terminals, for panel mounting in custom systems. The two gain adjustment controls are supplied unmounted. Dimensions are 2" × 2" × 3" deep.

MODEL 3732A may also be referred to as a dual squaring network. It is designed as a system module and is laid-out on a 3 by 8-inch printed circuit card which mates with a 15-pin connector. The operating mode switch and precision resistors for the external amplifiers are not included, but the instrument can be connected to perform the same operations as the other versions.

2-Specifications

Multiplication:

INPUT AND OUTPUT RANGE:	±100 volts (±10 volt version available)
INPUT IMPEDANCE:	33K ohms minimum
ACCURACY:	100V range: 500mv (0.25% of full scale) 10V range: 100mv (0.5% of full scale) With both inputs zero, the output is within 20mv of zero. Output drift is less than 5mv in an 8 hour period. With one input zero and the other ranging over ±100 volts, maximum error in output is within 60mv.
BANDWIDTH:	-3db at 20kcs typical
PHASE SHIFT:	Less than 1° at 1kcs.
NOISE LEVEL:	Will add less than 15mv rms to hum level of external amplifier.
REFERENCE REQUIREMENTS:	Requires a positive and negative source (with 0.1% regulation for rated accuracy). Internal adjustment permits operation from a source between 100 and 105 volts. Current drain is 3ma, maximum. Special versions operate from as low as ±10V reference.
SQUARING:	Static accuracy is within 250mv. Other specifications as shown for multiplication.
DIVISION:	Static accuracy is 0.25% of full scale (500mv) for X=Y=100 volts. With X=Y, error increases inversely with magnitude of Y.
SQUARE ROOT:	At maximum output, performance is identical with multiplication mode.

3- Installation

3.1 The ***Model 3732P*** unit is normally mounted by plugging it into two adjacent unoccupied terminals on the computer problem board. Its two mounting prongs are electrically insulated. They may be removed by opening the case as described under "Maintenance".

3.2 The ***Model 3732R*** panel instrument mounts in a standard 19-inch computer rack.

3.3 The ***Model 3732B*** switch assembly is mounted to a panel by means of the locknut on the switch. The two gain potentiometers supplied with the instrument are furnished with hardware for panel-mounting. Figure 2 identifies the terminals on the rear circuit wafer of the assembly to which the potentiometers and all signal connections are soldered. Use a low power soldering iron when soldering at the printed circuit board terminals. To enable the Model 3732B to be used for all possible operations, a patch-connection system between the unit and the external amplifiers should be employed, like the terminals on the Model 3732P version.

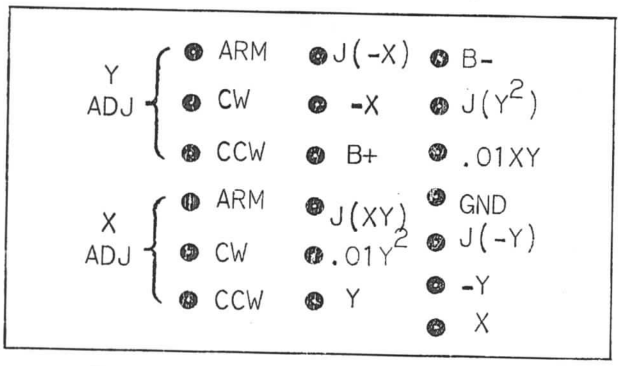


Figure 2 – Terminal Identification on Switch Assembly, Model 3732B

3.4 The ***Model 3732A*** plugs into a 15-pin receptacle connector*. Signal and reference voltage connections to the receptacle must be made according to Figure 3. The Model 3732A may be permanently programmed for a single mode of operation within a special system; however, a patch-connection system, as suggested for Model 3732B, will permit all operations that are possible with the other versions. The circuitry consists only of that portion indicated within brackets in Figure 6. The input and feedback resistors for the external amplifiers are not included. The use of 1% deposited-carbon resistors of the values shown in Figure 3 is recommended because of their good temperature stability. Each pair of resistors should be matched to the closest possible tolerance. (Donner specification is 0.01%). Connections for the basic operations are shown in Figure 4. By referring to Figure 5B, one can learn how to perform other operations. Note that jumpers are required between adjacent input terminals, as indicated in Figure 3, for all operations except multiplication and division.

*Methode part No.CD-615S(Donner stock No.J0148) or Amphenol part No.143-015(Donner stock No.J0069)

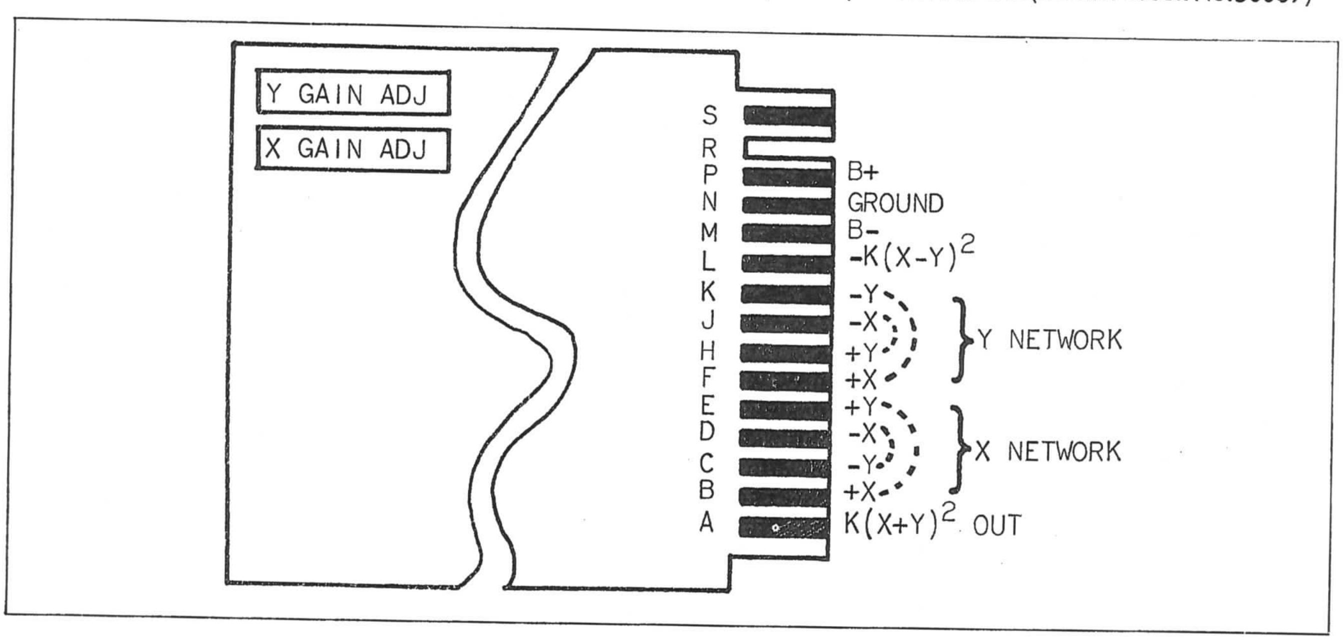
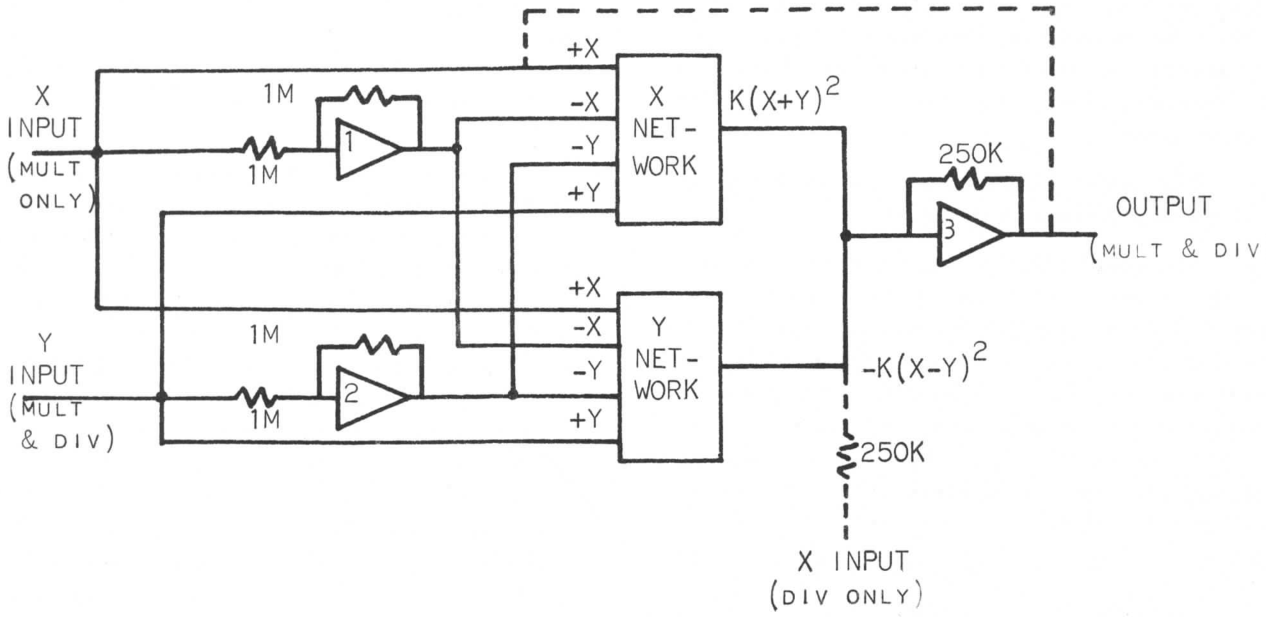
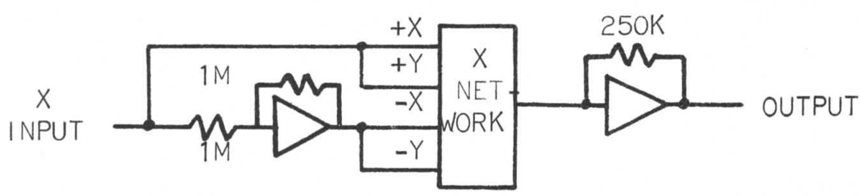


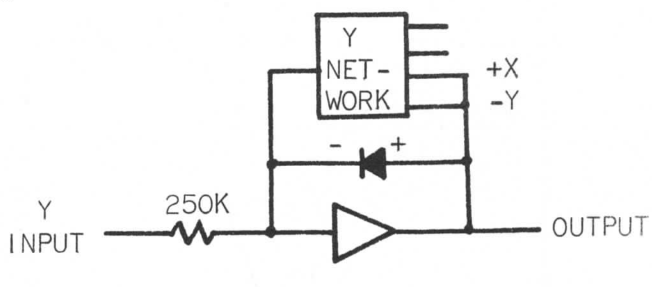
Figure 3 – Terminal Identification on Model 3732A (Card Version)
Connect jumpers as indicated except in multiplication and division.

A. CONNECTIONS FOR MULTIPLICATION AND DIVISION
(FOR DIVISION ADD CONNECTIONS SHOWN IN DOTTED LINES; OMIT 250K RESISTOR ACROSS AMPLIFIER NO. 3)





B. CONNECTIONS FOR SQUARING



C. CONNECTIONS FOR SQUARE ROOT

Figure 4 – Signal Connections for Model 3732A
Refer to Figure 5B for polarities of input and output voltages.

4-Operating Procedures

NOTE: All operating instructions are given for an instrument having a range of 100V. For a 10-volt range instrument, scale all inputs and outputs accordingly.

4.1 *GAIN ADJUSTMENT*

Before employing the Model 3732 in a problem circuit, it is necessary to adjust its accuracy while operating with the exact bias voltage level available in your computer. After this initial adjustment, subsequent accuracy checks should be made at weekly intervals or as demanded by the accuracy requirements of the problem, since the bias voltage level in the computer may drift. For optimum accuracy, the gains should be adjusted in the multiplication mode, if to be used for multiplication or division operations, and in the squaring mode if to be used for squaring or square root operations. Use a precision null voltmeter for all measurements (John Fluke Model 801 or equivalent is recommended.)

Steps:

1. Turn on the computer and allow the amplifier and power supply to warm up for approximately ten minutes. Balance the amplifiers according to the instructions given in the computer manual.
2. Make all connections for multiplication or squaring according to paragraph 4.2 or 3.4.
3. Apply input voltages of X = Y = + 100V.
4. Connect the null voltmeter to the output terminal of the output amplifier. Adjust the X Gain control for a reading of exactly -100V (or -10V).

4a. (OPTIONAL) Reverse the polarity of both input voltages and re-measure the output voltage. Readjust the X Gain control for an output reading exactly halfway between the two values measured in steps 4 and 4a.

5. If in the multiplication mode, change the polarity of one input voltage only. Adjust the Y Gain control for a reading of exactly +100V (or +10V) at the output.

5a. (OPTIONAL) Reverse the polarity of both input voltages and re-measure the output voltage. Readjust the Y Gain control for an output reading exactly halfway between the two values measure in steps 5 and 5A.

6. If in the squaring mode, connect the null voltmeter to the +.01Y^2 amplifier output and adjust the Y Gain for a reading of exactly +100 volts.

4.2 *TERMINAL CONNECTIONS*
(For Switch-Type Models)

The method for interconnecting the multiplier with external amplifiers for each type of operation is illustrated in Figures 5A and 5B. (Terminal identification is shown for Model 3732P; Model 3732R uses a slightly different terminal arrangement.) Connect the ground and reference voltage terminals to the computer. No amplifier input or feedback resistors are used on the associated computer since these are wired internally in the multiplier. Each "J" terminal on the multiplier, therefore, must be connected directly to the junction terminal adjacent to the amplifier symbol on the computer patchboard.

Place the selector switch in the SQUARE position for all operations except multiplication and division.

The polarity of input and output voltages for each mode of operation is indicated by the graph or explanation accompanying each connection diagram of Figure 5.

Space does not permit the inclusion of connection diagrams for all possible modes of operation. The user may be able to discover other connections for himself, or he may write to the factory for information on special operations.

MULTIPLICATION
(4 quadrants)

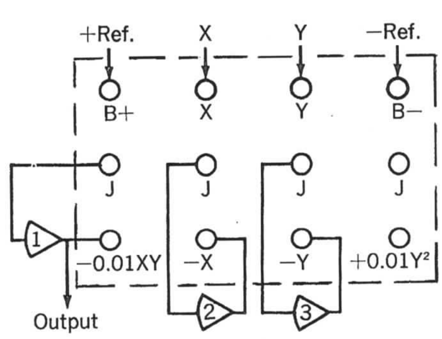
Output: —0.01XY

Switch: MULTIPLY

Inputs: X, Y
(each —100 V. to +100 V.)

If —X and/or —Y available in problem, omit amplifier #2 and/or #3.

For output = +0.01XY, reverse Y and —Y connections.



DIVISION
(2 quadrants)

Output: $-100\frac{X}{Y}$

Switch: DIVIDE

Inputs: X, Y
(X: —100 V. to +100 V.)
(Y: always + and greater than |X|.)

If Y always negative voltage, revers Y and —Y connections. Output wi then be $+100\frac{X}{Y}$.

Figure 5A — Connections for Multiplication and Division

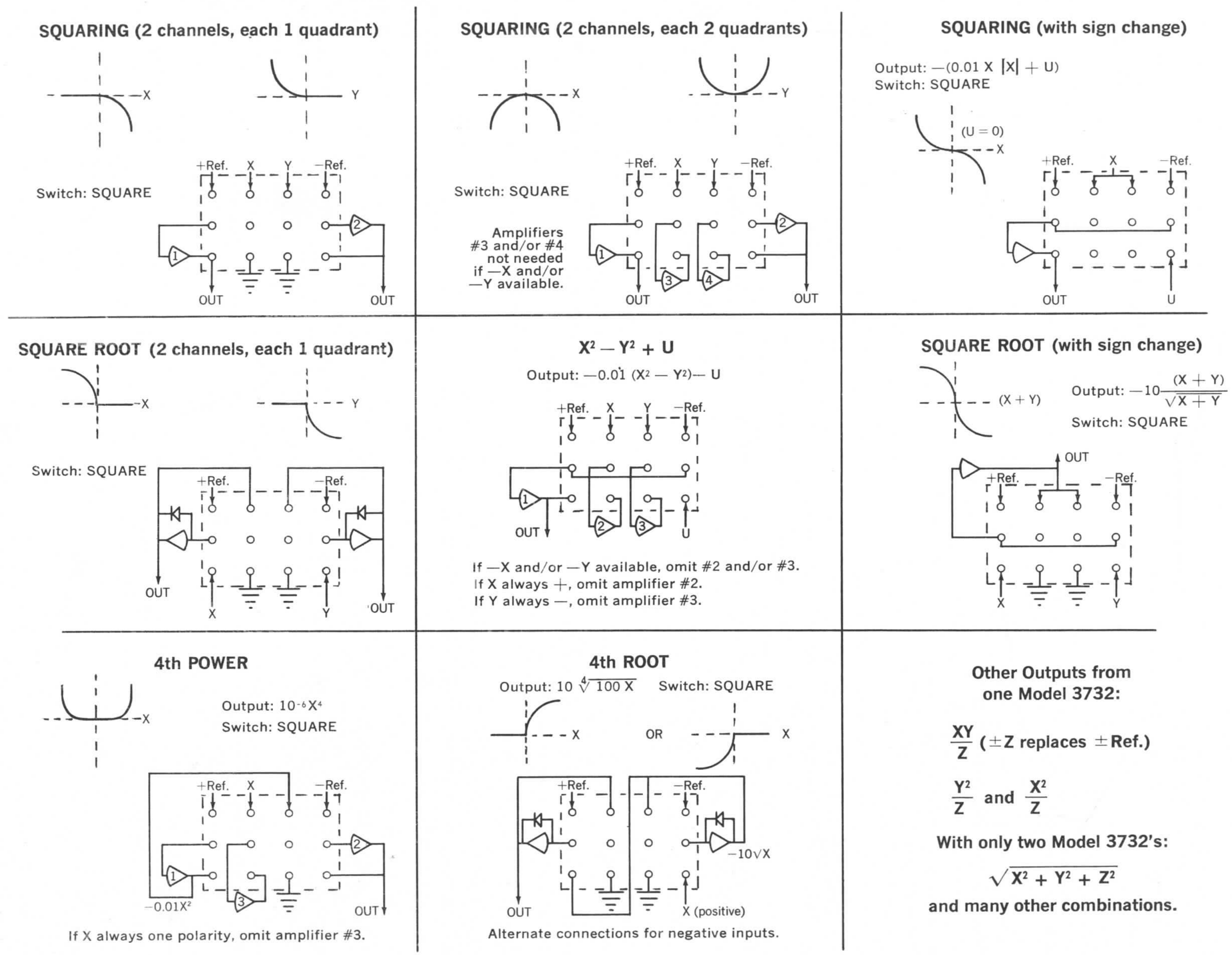


Figure 5B – Connections for Squaring, Square Root, Etc.

5-Principle of Operation

5.1 MULTIPLICATION

The Model 3732 performs multiplication by electrical simulation of the algebraic expression:

$$\left(\frac{X + Y}{2}\right)^2 - \left(\frac{X - Y}{2}\right)^2 = XY$$

The basic analogous computer circuit for this expression is represented by the diagram in Figure 6.

The two voltages representing X and Y are each made available to the input summing networks in two polarities by means of two external inverting amplifiers. The voltage polarities applied to the positive summing network result in a voltage proportional to X + Y, regardless of whether X and Y are positive or negative, while those applied to the negative summing network result in X − Y.

The diodes in the input summing network form absolute-value circuits which limit each resultant voltage to positive only for the X channel and negative only, for the Y channel.

The following squaring networks are the heart of the multiplier. Each network is a fixed-purpose diode function generator, one designed to operate only with positive input voltages and the other only with negative. These networks are identical except for the polarity of diode connections and bias voltages. A network consists of eight diode networks in parallel, each biased at a successively higher level in 10-volt steps by the voltage divider network, R 110 through R124 (even numbers only). Each diode in the positive network starts to conduct when the positive voltage applied from the input summing network exceeds its negative bias voltage. The amount of current through each diode path is determined by the value of limiting resistor, R111 through R125 (odd numbers only). The sum of the currents through all diode paths plus that through resistor R109 produces a non-linear output current curve of nine segments which approximates the square curve

$$K\left(\frac{X + Y}{2}\right)^2 \quad \text{(or} \quad -K\left(\frac{X - Y}{2}\right)^2$$

for the negative network) as suggested by Figure 7.

Each breakpoint in the curve occurs when a diode starts to conduct. The slope of each segment is determined by the amount of current through each diode path.

The two squaring network output currents are summed and then converted to the proper output voltage range (±100V) by the external output amplifier, which also changes the sign. The gain of the instrument is set for precise accuracy by the reference voltage screwdriver adjustments (R129) which are accessible from the outside of the case. By substituting different values of resistors (those marked * on the schematic), the Model 3732 can be made to operate from many reference voltage levels. Regulation of this supply should be at least ±0.1% for rated accuracy.

5.2 SQUARING

When the function switch is placed at the SQUARING position, the two squaring networks are entirely disconnected from one another, each requiring a separate input and output amplifier. Only one input variable is applied to each channel, but normally in two polarities. If X is always positive, or Y always negative, the X or Y amplifiers may be omitted and the corresponding terminal −X or −Y grounded. Because of the absolute value circuits, the $.01X^2$ output will always be negative and the $.01Y^2$ output always positive, regardless or the polarity of input voltages.

5.3 DIVISION

The circuit diagram for division operation is shown in Figure 8.

Assuming Z as the output voltage of amplifier 3, then the multiplier output is .01YZ. An analysis of the amplifier summing junction according to Kirchhoff's Laws shows that $X = -K \cdot YZ$ since no current flows to amplifier 3. Therefore, $Z = -\frac{K \cdot X}{Y}$, giving the division form.

For stable operation, the voltage fed back to the amplifier summing junction through the multiplier must be of the same polarity as the amplifier output voltage. This condition occurs only when Y is positive. (The multiplier output in this case appears at the summing junction of amplifier 3 and therefore has no sign reversal.)

5.4 SQUARE ROOT

The analysis and diagram given above for the division circuit applies, in general, to the square root operation also. In this case, each squaring circuit may be used individually in the feedback path of an amplifier. The output of the squaring network is assumed to be $+.01Z^2$, the "Y" input not being used in the X channel and vice-versa. Only a negative X input voltage can be applied (at the −.01XY jack) and only a positive Y input voltage (at the Y^2 jack) to prevent instability as described under "Division". A diode must be placed externally across the amplifier terminals to avoid instability when X or Y equals zero.

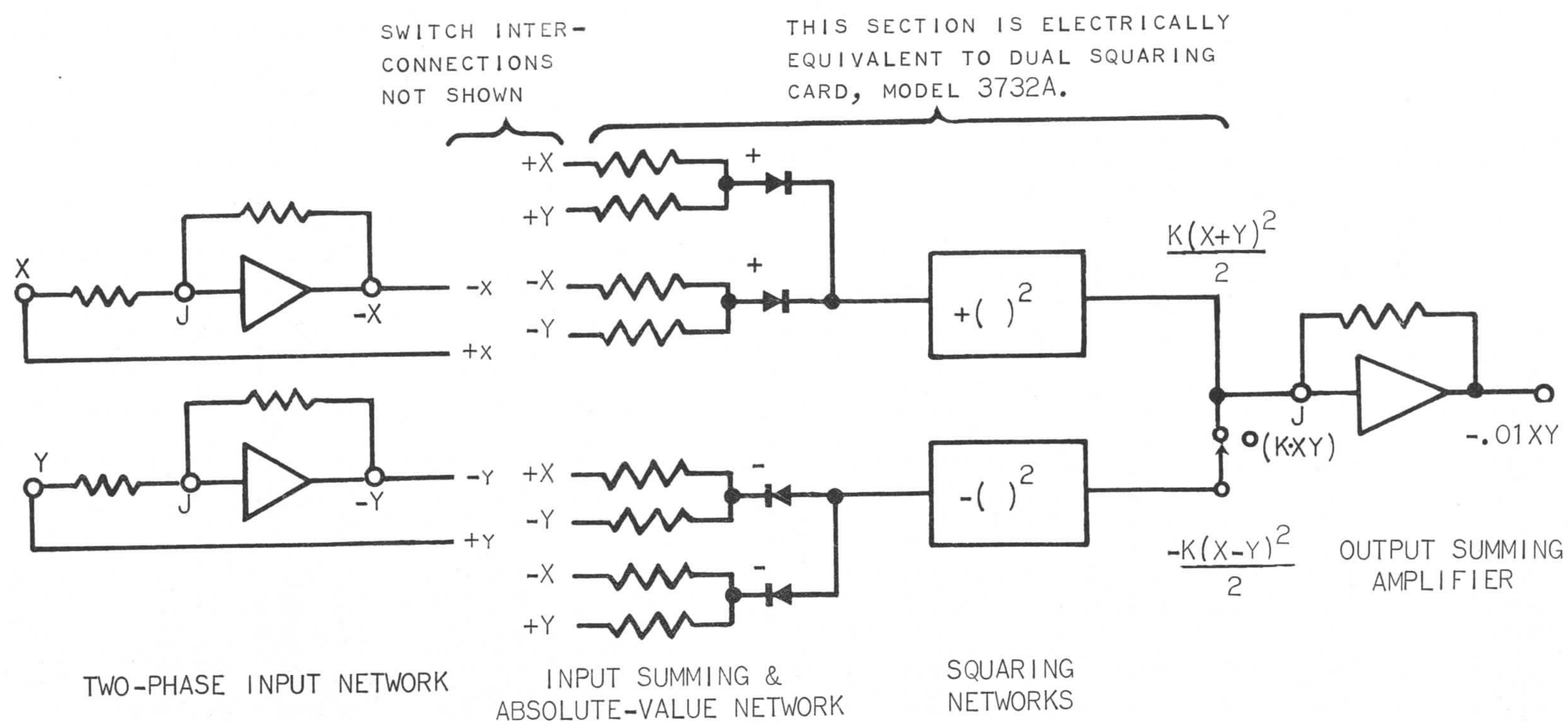


Figure 6 – Functional Block Diagram of the Model 3732
(Shown in Multiplication Mode)

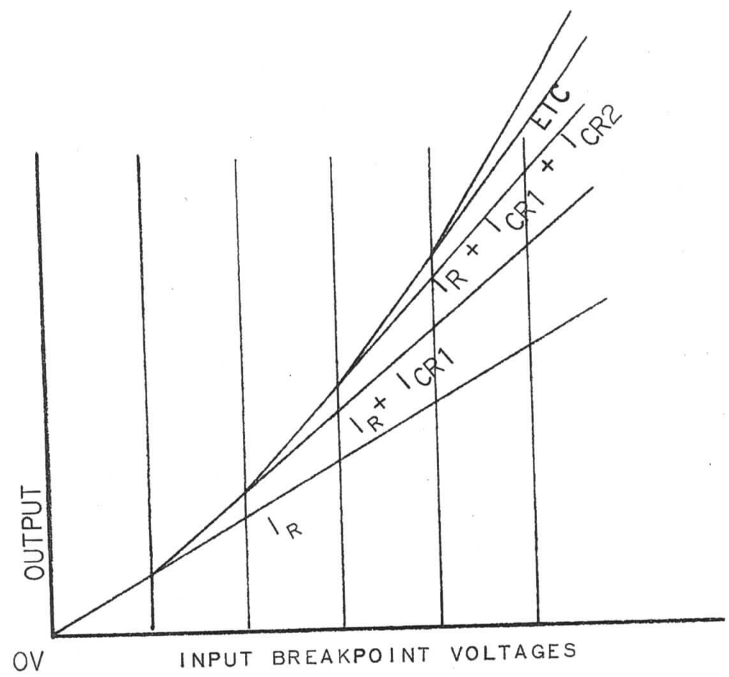


Figure 7 – The Square Curve is simulated by Straight Lines representing the Summation of Output Currents from Consecutively-Conducting Diode Networks

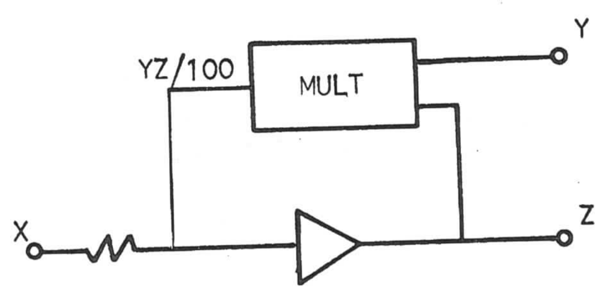


Figure 8 – Diagram of the Division Circuit

6- Maintenance

6.1 PRELIMINARY

There is no routine maintenance to be performed on the Model 3732 except the gain adjustment procedure described in paragraph 3.2. If the multiplier does not perform properly, first check all external associated components, input signal sources, computer amplifiers, reference voltage sources, and patchcords.

Because of the nature of the Model 3732 circuitry and its construction, detailed trouble-shooting instructions are not practical. The instrument contains only passive elements and, with normal precautions, very little is likely to go wrong with it. The internal construction consists of highly compact printed circuit wafers. Replacement of components should be attempted only by persons thoroughly experienced with this type of repair. It is recommended that all repair work be done by factory or authorized personnel, whether or not the instrument is still under warranty.

6.2 TROUBLE-SHOOTING

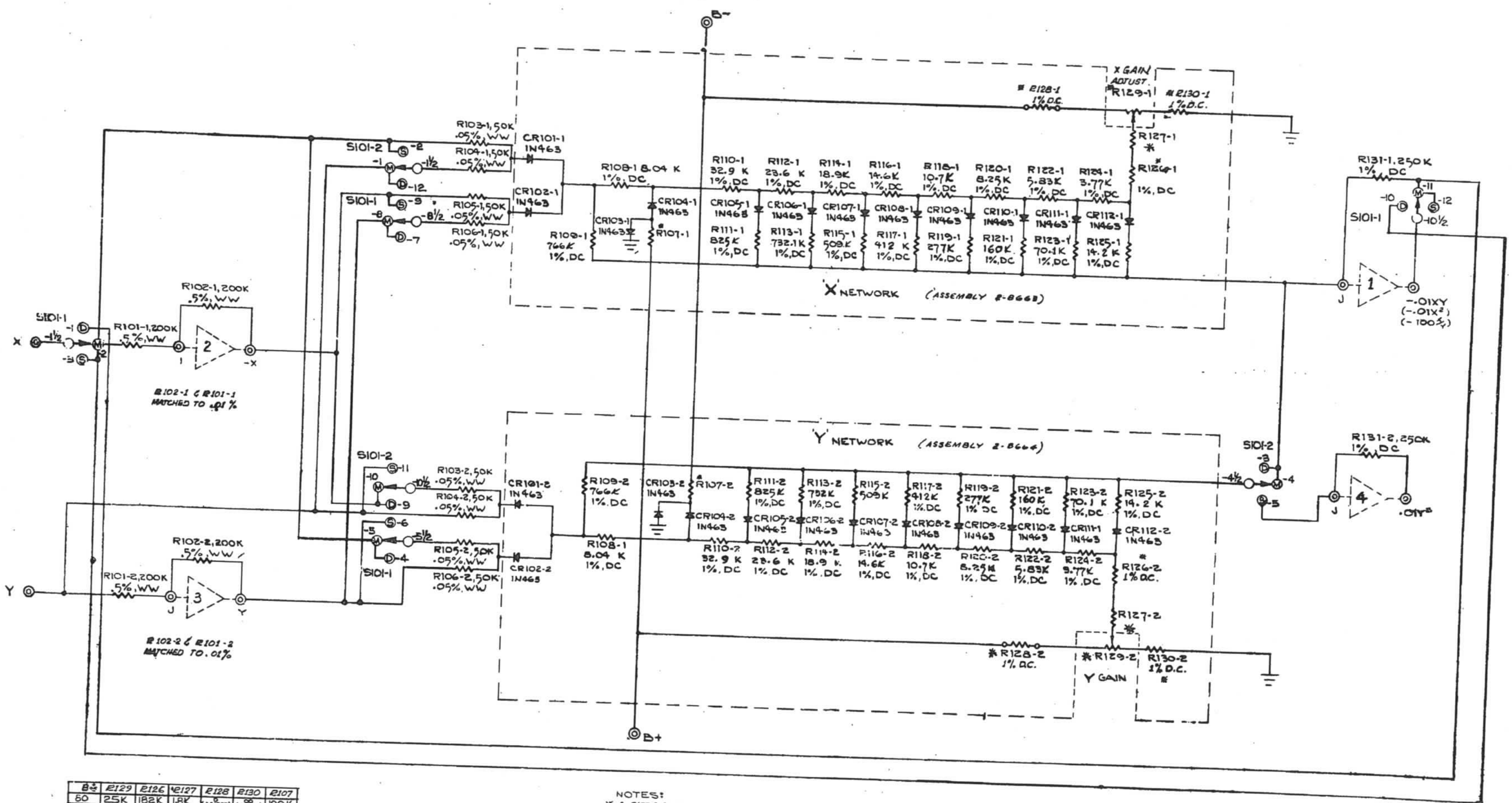
If repair of a switch-type instrument is undertaken, first check the amplifier resistors wired between the terminals with the Model 3732 switch in the "Square" mode.

Measure between terminals	Resistance
X & J (adjacent)	200K
-X & J	200K
Y & J	200K
-Y & J	200K
.01XY & J	250K
$.01Y^2$ & J	250K
B+, B- & Ground	100K or 75K (depends on meter polarity)

After disassembling the instrument according to paragraph 6.3, check all diodes by measuring their resistance using both meter polarities. A very high and a very low resistance reading should be obtained. Measure the values of individual resistors in the networks.(The values of all resistors are visible.

6.3 DISASSEMBLY

On the plug-in unit, Model 3732P, remove the nut at the bottom of the case and separate the two parts of the case, taking care not to break the leads to the top terminals. On all multiplier units, remove the switch knob by loosening the set screws and then detach the switch assembly by removing the lock nut. Carefully pull the switch assembly out of the lower part of the Model 3732P case. Remove the two nuts on the long through-screws which hold the electronic assembly together. The circuit wafers can now be spread apart to permit checking and replacement of components.



B±	R129	R126	R127	R128	R130	R107
60	25K	182K	1.8K	0 (JUMPER)	∞ (OPEN)	100K
85	10K	191K	820Ω	0 (JUMPER)	68.1K	100K
150	10K	162K	0 (JUMPER)	59K	68.1K	100K
300	25K	59K	270Ω	20K	68.1K	300K
100/105	5K	182K	3.3K	11.8K	51.1K	100K

FIG. 1

DIVIDE MULTIPLY SQUARE

FIG. 2
SWITCH POSITIONS

NOTES:

* 1. R107, R126, R127, R128, R129 & R130 ARE SELECTED FOR CORRECT BIAS. SEE CHART FIG. 1

2. S101 ROTARY SWITCH - DSC DWG. 6707

** 3. RESISTORS APPROPRIATE FOR 105V BIAS SUPPLIED AS STANDARD

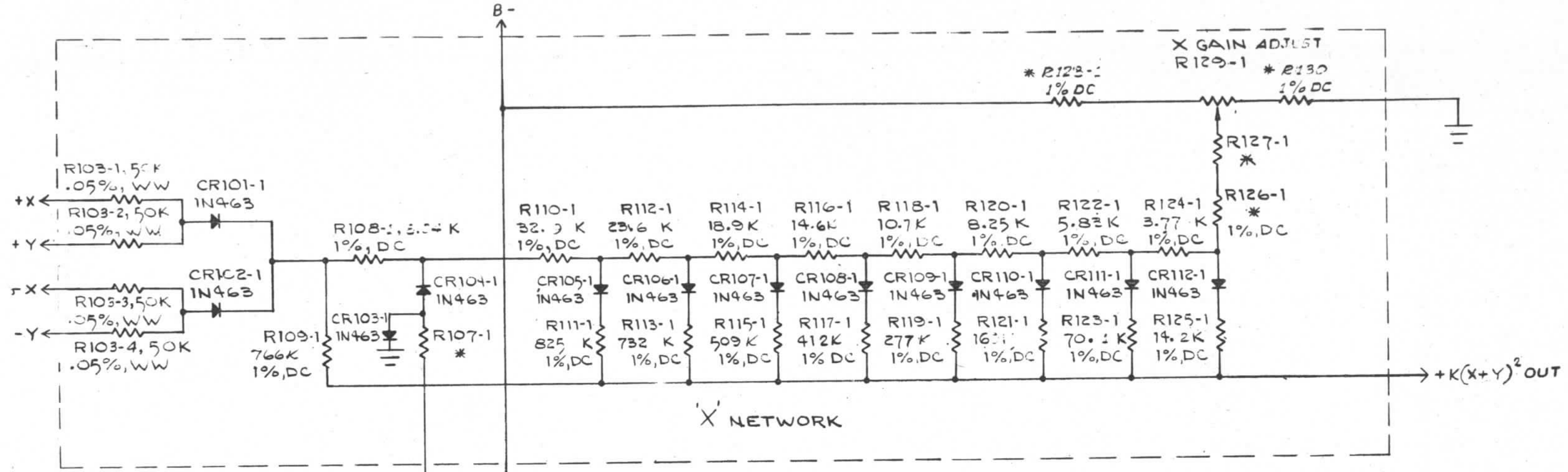
4. RESISTORS ARE 10%, ½W, COMP. CARBON UNLESS OTHERWISE NOTED

REVISIONS	ECO NO.	ISSUE	DATE	APP.
SK.1 [illegible] EL.)	1346	B	6-15-61	[illegible]
CHANGE FIG. 1 PER E.C.O.	1375	C	8-16-61	[illegible]

DRAWN D[illegible]	DATE 3-3-61	UNLESS SPECIFIED. DIMENSIONS: INCHES TOLERANCES DECIMAL ANGULAR
CHECKED		SURFACE FINISH
PROJ. ENG.	4/18/61	SCALE 2
APPROVED		NEXT ASSEM. 6719
MODEL 3732B, 3R, 3DR, 3P 3732 - 3738P	TITLE SCHEMATIC QUARTER-SQUARE MULTIPLIER	DWG. NO. 6702 SIZE C

DONNER SCIENTIFIC COMPANY

REVISIONS	ECO NO.	ISSUE	DATE	APP.
REVISE FIG. 1 PER E.C.O.	1375	B	8-16-61	



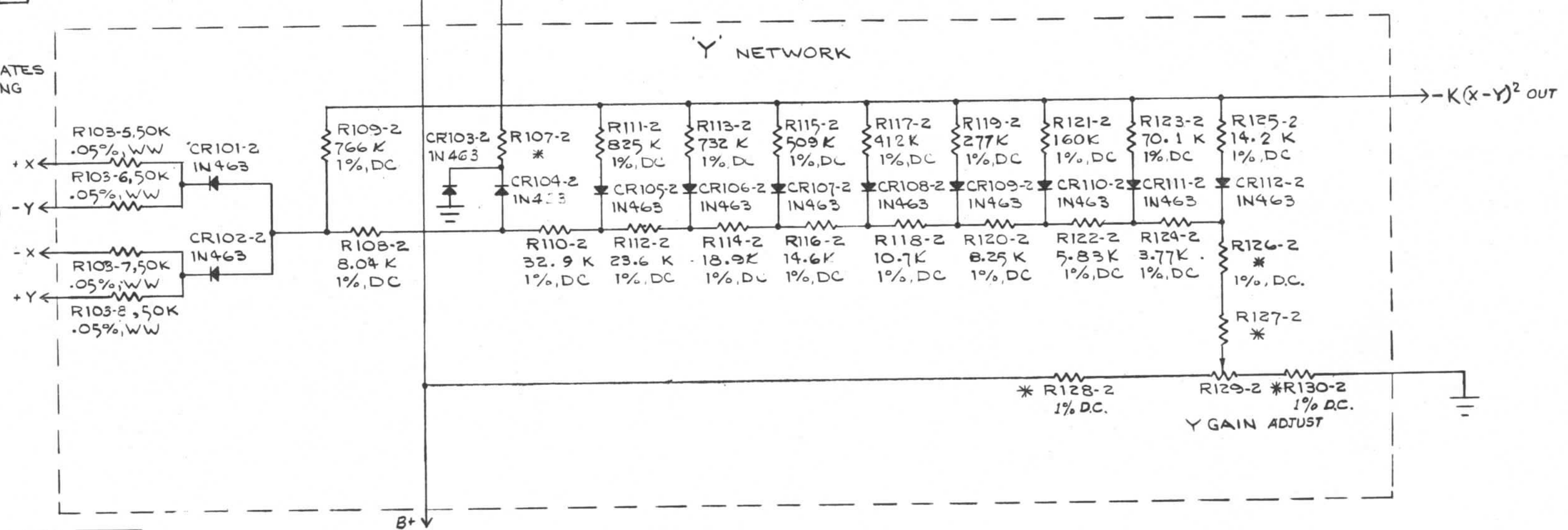
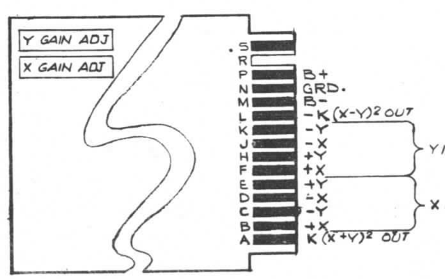


FIG. 1

B+	R129	R126	R127	R128	R130	R107	K
80	25K	182K	1.8K	0 (JUMPER)	∞ (OPEN)	100K	.01
85	10K	191K	820 Ω	0 (JUMPER)	68.1K	100K	[illegible]
100/105	5K	182K	3.3K	11.8K	51.1K	100K	.01
150	10K	162K	0 (JUMPER)	59K	68.1K	100K	[illegible]
300	25K	59K	270K	210K	68.1K	300K	[illegible]

NOTES:

1. PART NO. 2-8010S DESIGNATES A SINGLE-CHANNEL SQUARING CARD.
* 2. R107, R126, R127, R128, R129 & R130 SELECTED FOR CORRECT BIAS. SEE FIG. 1.
3. R103-1 THRU R103-8 (SET OF 8) ARE MATCHED TO 0.01%
4. RESISTORS APPROPRIATE FOR 105V BIAS SUPPLIED AS STANDARD.
5. RESISTORS ARE 10%, ½W, COMP CARBON UNLESS OTHERWISE NOTED.
6. FOR VALUES OF 'K' SHOWN IN FIG. 1., OUTPUTS ARE IN MICROAMPERES.



P.C. TERMINATIONS

FINISH		UNLESS SPECIFIED: DIMENSIONS: INCHES TOLERANCES DECIMAL ANGULAR
DRAWN Dee	DATE 2-28-61	
CHECKED HAD		
PROJ. ENG.	4/17/61	SURFACE FINISH
APPROVED	4/18	SCALE
		NEXT ASSEM. 8091
MODEL 7602 3732 A	TITLE ASSEMBLY PT. NO. 2-8010 SCHEMATIC-DUAL SQUARING NETWORK	DWG. NO. 8494 ISSUE B

DET. NO. | ITEM | MATERIAL | QUAN./UNIT

DONNER SCIENTIFIC COMPANY

'STRON SD DONNER
CORPORATION

PLUG-IN COMPUTING COMPONENTS
FOR MODELS 3000, 3300, 3400 AND 3500 ANALOG COMPUTERS

ITEM	VALUE		STOCK NUMBER	UNIT PRICE
PATCH CORDS	4 Inch	Green	3901	$2.00
Plug-in	8 "	Yellow	3902	2.00
	12 "	Red	3903	2.00
	24 "	Black	3904	2.00
RESISTORS	0.1 Megaohm	Orange	3910	5.00
Plug-in, 1.0%	0.2 "	Red	3911	3.10
Deposited Carbon	0.5 "	Yellow	3912	5.90
	1.0 "	Green	3913	5.90
	2.0 "	Blue	3914	5.90
	5.0 "	Grey	3915	5.50
	10.0 "	Black	3916	7.40
RESISTORS	0.1 "	Orange	3920	7.60
Plug-in, 0.1%	0.2 "	Red	3921	7.40
wire wound	0.5 "	Yellow	3922	9.60
	1.0 "	Green	3923	20.00
	2.0 "	Blue	3924	15.80
CAPACITORS	0.01 mfd		3930	8.40
Plug-in, 0.1%	0.1 mfd		3931	7.60
Polystyrene	1.0 mfd		3932	10.00
SHUNT	zero ohm	White	3940	2.50
RELAY	Double pole, double throw		3965	45.00

Prices f.o.b. Factory, Concord, California
Subject to change without notice

888 Galindo Street
Concord, California 94520
Phone: (415) 682-6161
TWX: 910-481-9478
Cable: SYSTRONDONNER

November 27, 1967

RECOMMENDED COMPUTING COMPONENT SELECTIONS FOR MODELS 3000, 3300, 3400 AND 3500 ANALOG COMPUTERS

	SELECTION A (1%)			SELECTION B (1%)			SELECTION C (0.1%)			SELECTION C (0.1%)		
ITEM	QTY.	Value	Stock No.	QTY.	Value	Stock No.	QTY.	Value	Stock No.	QTY.	Value	Stock No.
Patch Cords	16	4"	3901	25	4"	3901	25	4"	3901	25	4"	3901
	8	8"	3902	15	8"	3902	15	8"	3902	20	8"	3902
	8	12"	3903	10	12"	3903	10	12"	3903	20	12"	3903
	4	24"	3904	10	24"	3904	10	24"	3904	10	24"	3904
Resistors	5	0.1MΩ	3910	5	0.1MΩ	3910						
1% deposited				5	0.2MΩ	3911						
carbon	5	0.5MΩ	3912	5	0.5MΩ	3912						
	5	1.0MΩ	3913	10	1.0MΩ	3913						
	5	2.0MΩ	3914	5	2.0MΩ	3914	2	2.0MΩ	3914	5	2.0MΩ	3914
				5	5.0MΩ	3915	2	5.0MΩ	3915	5	5.0MΩ	3915
	5	10.0MΩ	3916	5	10.0MΩ	3916	2	10.0MΩ	3916	5	10.0MΩ	3916
Resistors							10	0.1MΩ	3920	15	0.1MΩ	3920
0.1% wire							5	0.2MΩ	3921	5	0.2MΩ	3921
wound							5	0.5MΩ	3922	5	0.5MΩ	3922
							5	1.0MΩ	3923	5	1.0MΩ	3923
Capacitors				2	0.01mfd	3930	3	0.01mfd	3930	3	0.01mfd	3930
0.1% Poly-	3	0.01mfd	3931	3	0.1 mfd	3931	5	0.1 mfd	3931	5	0.1 mfd	3931
styrene	3	1.0 mfd	3932	3	1.0 mfd	3932	5	1.0 mfd	3932	5	1.0 mfd	3932
Shunt Plug							15	zero	3940	20	zero	3940
Price	$200.00			$295.00			$455.00			$590.00		

Prices f.o.b. Factory, Concord, California, subject to change without notice.

Note: For information on other plug-in devices, refer to opposite side.

November 27, 1967