VLA TECHNICAL REPORT #22

MODULE L2

50/600 MHZ MULTIPLIER

Harry Beazell

MARCH 1976

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F. M. Gardner, Phaselock Techniques (John Wiley & Sons, 1966)

1.0.1 NRAO DRAWING LIST

50/600 MHz MULTIPLIER MODULE (L2), PROJECT NO. 13230

Bill of Materials

50 MHz Phase Lock Board	A13430Z30
X12 Multiplier Board Assembly	A13230Z35
Multiplier Enclosure	A13230Z11
50/600 MHz Multiplier	A13230Z2
X12 Multiplier Assembly	A13230Z34

Assembly Drawings

50 MHz Phase Lock Board	C13230P40
X12 Multiplier Board Assembly	D13230P44
Multiplier Enclosure	C13230P21
50/600 MHz Multiplier	Not Drawn
X12 Multiplier Assembly	D13230P45

Schematic Diagrams

50 MHz Phase Lock Board	C13230S11
50/600 MHz Multiplier	D13230S16

Logic Diagrams

None

Printed Circuit Board

	Artwork	Silkscreen	Mechanical
50 MHz Phase Lock Board	B13230AB1	None	C13230M67
50/600 MHz Multiplier	D13230AB3	None	D13230M87

Block Diagrams

Block Diagrams	C13230B2

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None

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Sub-Dividers	B13230M13
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Divider	B13230M15
Divider	B13230M16
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End Cap	B13230M18
End Cap	B13230M19
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Side Cap	C13230M6-2
Top Cover and Bottom Plate	C13230M7-1
Top Cover and Bottom Plate	C13230M7-2
Left Side Plate	C13230M8
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Tuning Coil	B13230M70
Tuning Coil	B13230M71
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Tuning Coil	B13230M74
Tuning Coil	B13230M75
Tuning Coil	B13230M76
Tuning Coil	B13230M77
Tuning Coil	B13230M78
Tuning Coil	B13230M79
Tuning Coil	B13230M80

NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VIRGINIA
VERY LARGE ARRAY PROJECT

SPECIFICATION NO.: 13220N1

NAME: Voltage Controlled XTAL Oscillator

DATE: February 13, 1974

PREPARED BY: _____ APPROVED BY: _____

1. TYPE: Overtone resonator, fundamental oscillator and buffer amplifier output

2. OUTPUT FREQUENCY: = 50 MHz

3. OUTPUT POWER: = 10.0 mW min.

4. OUTPUT IMPEDANCE: = 50 Ω

5.
   a. Setability = 1×10^{-7} = 5 Hz over temp. range in 9.a
   b. Setability Range = a combination of mech. trim for 5 years aging and electrical trim for 30 day aging.

6.
   a. Voltage/Freq. Control = ± .5 kHz, ± 10 V 3 point average
   b. Linearity $\Delta f/\Delta V$ = .9 to 1.1
   c. Tuning Rate = 0 to 10 kHz full deviation
   d. Input Impedance = 2000 Ω or greater DC to 10 kHz

7. FREQUENCY STABILITY $\Delta f/f_o$ = 1×10^{-8} in .01 seconds
   1×10^{-8} in .1 seconds
   1×10^{-8} in 1.0 seconds
   2×10^{-8} in 10 seconds
   1×10^{-7} in 8 hours

8. OUTPUT CNR = 100 dB in 1 MHz BW

30 day drift must not limit 6 (a) (b)

9. ENVIRONMENTAL

a. Design to operate at a stable ambient or mounted on a controlled heat sink of 0.1° rms in the range of 20° to 55°C.

b. Warm up 30 min. to 1×10^{-7} of last setting.

c. Maintain $\Delta f/f = 1 \times 10^{-7}$ for any position (static 1g any direction)

10. POWER SOURCE

Supplies Available = ± 15V, (± 15V reg. .01%)

11. DESIGN (WITH OVEN IF NECESSARY): Smallest possible size and power consumption. Height not over 1.0".

12. INPUT POWER LEADS: Solder connections feed-thru filter A-B type SF or equivalent. No leads on top or bottom.

13. INPUT MODULATION: Solder F. T. internal RF decoupling of 100 dB or greater.

14. OUTPUT: Solder F. T.

2.0 FUNCTIONAL DESCRIPTION

The L2 module continues the basic frequency multiplication to provide the ultimate 600 MHz system phase standard. A phase lock filter at 50 MHz provides spectral limiting and subsequent multipliers provide system outputs at 50 MHz, 100 MHz, 200 MHz, and 600 MHz. A front panel indication of loop unlock is provided, and can be exercised by the L5 module. Data set monitoring of output signal levels and lock loop condition is provided.

3.0 DETAILED CIRCUIT DESCRIPTION

3.0.1 The Module Assembly (Ref. Block Diagram C13230B2)

The +20 dbm RF outputs of the 50/600 multiplier sub-assembly are connected to tubular bandpass filters to provide further rejection of harmonic and subharmonic signals. The 50 MHz, 100 MHz and 200 MHz filters are 8% bandwidth 4-pole units and the outputs are +19 dbm to +20 dbm. The undesired harmonics and subharmonics are greater than -70 dbc. The 600 MHz signal is filtered by a 50 MHz BW 4-pole filter and then provides two outputs, via a power divider and 10 db pad, of +16 dbm to +17 dbm and +6 dbm to +7 dbm. The undesired signals at ±50 MHz are greater than -55 dbc and at ±5 MHz are greater than -70 dbc.

3.0.2 50 MHz VCXO (Ref. Specification 13220N1)

The 50 MHz +10 dbm VCXO provides the +10 dbm drive signal to the 50/600 MHz multiplier. The control gain and zero frequency can be set by screwdriver adjustment. Nominal values are 50 MHz ±50 Hz at center zero V.D.C. and ±500 ±50 Hz for ±10.0 V.D.C.

3.0.3 50 MHz Phase Lock Board (Ref. Schematic C13230S11)

The 50 MHz, +10 dbm VCXO signal is phase compared in the 50/600 multiplier with the 50 MHz, 0 dbm reference signal from L_1. The phase error output at J_1 is terminated at E_7 and E_9 by R_{29} and C_7. This provides 51Ω for the sum terms (100 MHz) and 50 MHz and a high impedance at the DC Ø difference for maximum sensitivity. U_1 provides variable gain and R_{12} provides offset adjustment. An error viewing output is provided through R_{18}, R_{19} and C_4 to

E_6 and P_{1-22}. A loop control switch, U_2, is used to provide remote loop open/close control. Application of a +TTL "1" to P_{1-21} and E_4 opens the loop switch. A manual switch S_1 provides on-board O/C and remote positions for testing. The switch output is connected to the loop integrator U_3 through R_{24}. R_{23} provides a bias return for U_3 when the switch, U_2, is open. Offset trim for U_3 is provided by R_7. R_{24}, C, and R_1 determine the loop radian natural frequency, ωn and damping, ζ. The output of U_3 is applied to the VCXO through an isolating resistor R_2. Monitoring of this voltage is provided through an isolation resistor R_3 and E_3 to P_1-23. A front panel indicator LED is connected anode to E_{11} and cathode to E_{12}. When the voltage U_3 has value of about +2.5 volts, Q_1 will begin to conduct and current will flow through Q_1 emitter R_{31}, the L.E.D., and CR_1 to ground. At 5 volts and up, Q_1 is saturated and the L.E.D. is full on. Operation in the negative direction is through Q_2, the L.E.D., R_{31}, and CR_2.

3.0.4 Loop Characteristics

The basic purpose of the VCXO is to provide filtering to eliminate harmonics of 5 MHz and to restrict the AM and FM noise sidebands prior to further multiplication. Using the terminology of Gardner[1], the loop characteristics are derived. The detector gain K_D is determined by the output of the phase detector and the gain setting of U_1. The procedure is to set R_{21} to produce a level of ±10Vpp at the R_{28} or ±5Vpp at E_6 when the VCXO phase goes through 360°. If the error voltage vs phase is a sinusoid, then K_D is ≃ 10 Sin 1° V/1° at zero error. This value is: K_D = 0.175 V/1°. The oscillator control sens. is 50 Hz/volt. Therefore Ko = 50 x 360 = 18000 °/V. The combined gain $K_v = K_o K_D$ = 3150. Assuming a loop bandwidth that provides pull in and lock with a maximum open loop error of ±650 Hz (this is equal to the integrator U_3 output on the stop and the 50 Hz/V gain of the VCXO). The values for R_{24}, C_1 and R_1 provide the following:

$$T_1 = R_{24}\ C_1 = .001S \qquad t_2 = .001$$

$$W_n = \left(\frac{Kv}{t_1}\right)^{\frac{1}{2}} = 1775\ r/s = 282\ Hz$$

$$\zeta = \frac{\tau_2}{2}\ (Wn) = {}^{.001}/_{2}\ .1775 = \underline{.89}$$

$$DW_p = 2\sqrt{\zeta WnKv} = 709\ Hz$$

The loop tracks dynamically with an error of -40 db/decade below the loop corner frequency. This would give an error of -80 db at 2.82 Hz which provides excellent tracking of the 5 MHz (X10) oscillator signal. Outside the loop Wn the frequency response falls off 20 db per decade and the signal spectrum rapidly becomes that of the 50 MHz VCXO. Spectrum analyzer dynamicrange limits the ability to observe the spectrum at 5 and 50 MHz. The expected signal to FM noise can be calculated using the following method:

1. Assume: 50 MHz VCXO power = 0 dbm, 1st Amp in VCXO noise figure = 10 db. Amplifier output Bw = 5 MHz.
2. P_N fm single sideband = -177 dbm/Hz. P_N @ 600 MHz in a 300 K Hz BW = -177 dbm + Nf = 10 db + 10 log 300 KHz + 20 log $\frac{600}{50}$ = -90.4 dbm/300 KHz

   Ps/Pn = 90.4 db

Measured with a Tektronix 7L13, set to -30 dBm reference and 300 kHz resolution, the P_S/P_N 2 MHz on either side of the carrier is about 88 dBc, which is in good agreement with the calculated value. Measurements closer to the carrier are not possible due to the limits of the spectrum analyzer. With multiplication to 24 GHz the P_S/P_N would calculate to be 90.4 - 20 log $\frac{24\ GHz}{600\ MHz}$ = 90.4 - 32 = 58.4 in 300 kHz out to the $\pm$2.5 MHz points. Beyond $\pm$25 MHz as determined by the 600 MHz output bandpass filter, the level would be: (assuming a 20 dB nf and +10 dBm signal @ 600 MHz)

$$P_S/P_N = 177 - 20 - 58.4 - 32 + 10 = 76.6\ dB$$

With the 50 MHz VCXO locked to the 5 MHz x 10 reference, the spectrum within

the bandwidth of the loop, ± 282 Hz, is that of the 5 MHz VCXO multiplied to 24 GHz. The spec value for the 10544A at 100 Hz offset is S/N = 120 dB. The value at 24 GHz would be 120 dB/Hz - 20 log $\frac{24 \text{ GHz}}{5 \text{ MHz}}$ = 120 - 73.6 = 46.4 dB/Hz measured in a 30 Hz BW the value is P_S/P_N 30 Hz = 31.6 dB.

1 - REF 1.0.3.1

3.0.5 50/600 MHz Multiplier (Ref. Schematic D13230S16)

The 50/600 MHz unit accepts a +10 dbm 50 MHz signal from the VCXO and provides outputs of +20 dbm at 50 MHz, 100 MHz, 200 MHz, and 600 MHz. The DC phase error signal for the 50 MHz VCXO lock amplifier is provided by an internal phase comparator. All RF outputs are padded with a minimum 3 db pad and can be operated open or shorted without failure.

3.0.5.1 Input Power Divider

The +10 dbm 50 MHz VCXO signal from J_2 drives a power divider U_2. The +7 dbm signals drive a doubler stage Q_2 and a power amp stage Q_1.

3.0.5.2 50 MHz Power Amplifier

Q_1 is biased class B and provides an output power of +25 dbm (316 MW) to the input of the 50Ω output pad R_4, R_5, R_7, and R_6. L_1 reflects a collector load of about 260 ohms to Q_1 and has a loaded tank Q_L of about 7. An output signal from R_4-R_5 provides a +7 dbm signal to the 50 MHz phase detector U_4, the main output is delivered to P_{13} and is set by the pad values to +20 dbm. A single diode CR_6 rectifies the output at L_1 and provides an isolated level output through a series 47K resistor R_8 and .001μf feed through C_{58}.

3.0.5.3 100 MHz Doubler

Q_2 is biased class B and operates similarly to Q_1. The circuit L_2 and C_5 are broadly resonant ($Q \approx 3.5$) at 50 MHz and provide a low impedance at 100 MHz for the AC base current. The output circuit C_8, L_3, L_{10}, L_{11}, and L_4 is a 2-pole 10% bandwidth flat phase filter designed to give a load of about 250 ohms to Q_2. A level of 200 MW (+23 dbm)

is available at the 4 db pad input. Divider U_2 provides 40 MW (+16 dbm) drive to both Q_3 and Q_4. The doubler level is monitored identically to the 50 MHz PA (CR_1, etc.).

3.0.5.4 100 MHz Power Amp

Q_3 is biased Class B, L_5 and C_{54} provide an input match between the 50Ω power divider U_2 and the ≈25Ω lower input resistance of Q_3. L_6 and C_{22} provide a tank with a Q_L of about 4 and an Rp of about 250Ω. An output power of +25 dbm is available and is tailored to +20 dbm by the 5 db pad R_{19}, R_{20} and R_{21}. A 100 MHz level monitor is provided (CR_2, etc.).

3.0.5.5 200 MHz Doubler

Q_4 is biased Class C and the output load is a 2-pole filter consisting of L_7, C_{46}, C_{45}, and L_8. L_7 resonates the collector C of Q_4. The filter provides a collector load of about 200 ohms and has a 10% bandwidth. Q_5 provides a buffered and further filtered output of about 80 MW to power divider U_3. The doubler is level monitored by CR_5, etc.

3.0.5.6 200 MHz Power Amp

Q_6 is driven from U_3 through a 2 db pad. Bias approaches Class A operation. The collector is matched to 50Ω by a T network consisting of L_{10}, L_{11} and C_{36}. Output Q is low (about 3) and a level of +23 dbm is available to the output 3 db pad R_{37}, R_{38} and R_{36}. Output level is monitored by CR_4, etc.

3.0.5.7 600 MHz Tripler and Power Amplifier

Q_7 is operated as a grounded base Class C tripler driven directly by the second U_3 output. Protection and P.S. decoupling is provided by R_{34} and C_{32}. The output is tuned by C_{33} and L_{12} and matched to the base of buffer amp Q_8. C_{30} tunes the base and stray inductance of Q_8. The output tank L_{13} and C_{27} provide a low Q_L to Q_8. Decoupling and protection are provided by R_{31} and C_{26}. The input of Q_9 is tuned by L_{14} and C_{24}. Q_9 is protected by a large emitter resistor R_{27} and is biased Class A by R_{29} and R_{22}. The output stray C and L_{15} are broadly resonant and an output of +23 dbm is available to a 50Ω load. A 3 db pad, R_{26}, R_{25} and R_{24}, provides a +20 dbm output. Level monitoring is provided by CR_3, etc.

4.0.1 Initial Alignment of Multiplier Chain

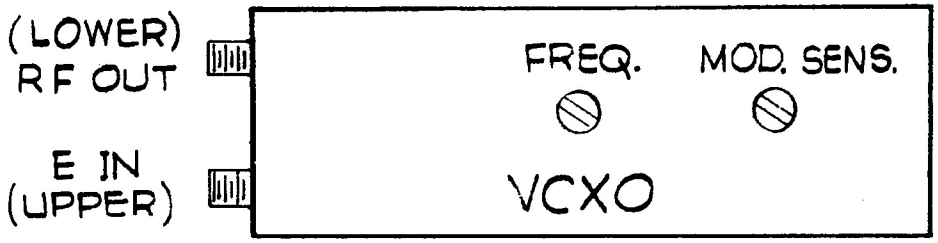
The various tuning adjustments are set to approximately mid-range values. By following the sequence of the circuit description 3.0.5 tuning can be readily accomplished by viewing individual outputs with a spectrum analyzer connected at the filter inputs. The tuning is the best compromise of maximum signal and minimum harmonics. Final adjustments are made by power meter on the filter outputs. In some cases, adjustment of bias resistors and output pads will be required. These values are indicated on the schematic as tailor points and the values shown are nominals.

4.0.2 Phase Lock Set Up Procedure on Bench

1. Apply 50 MHz signal from (L1,P1) to (L2,P10).
2. Apply 10 MHz from (L1,P2) to external oscillator input of HP5326B.
3. Set HP5326B to Freq. A, 1s.
4. Disconnect Ein cable from 50 MHz VCXO; connect precision +10V from HP6115A power supply to Ein.
5. Set switch on phase lock board to "open". Put scope on (P1-22).
6. With HP6115A voltage set to 0.00, adjust VCXO "Freq" pot to read 50,000,000 ±50 Hz on HP5326B.
7. With HP6115A at +10.00V set VCXO gain to give 50,000,500 ±50 Hz and with -10.00V read 49,999,500 ±50 Hz.
8. Replace RF cable. Set HP6115 at +1.00V (F_{VCXO} ~5,000,050 Hz). Set phase lock gain to give 10V p-p at (P1-22) of ~50 Hz phase error. Set offset to balance about zero.
9. Replace Ein cable and with switch still open set integrator offset to give VCXO frequency at 4,999,500 Hz (or less). This is about -12V on Ein.
10. Set switch to "C". Loop should lock to Freq = 50,000,000 Hz on counter.
11. Check (P1-22) phase error, voltage should be -100 to 200 mV when lock is locked.
12. Set switch to "R". Apply +5V to (P1-21). Loop should unlock.

4.0.3 Phase Lock Set Up Procedure in Bin

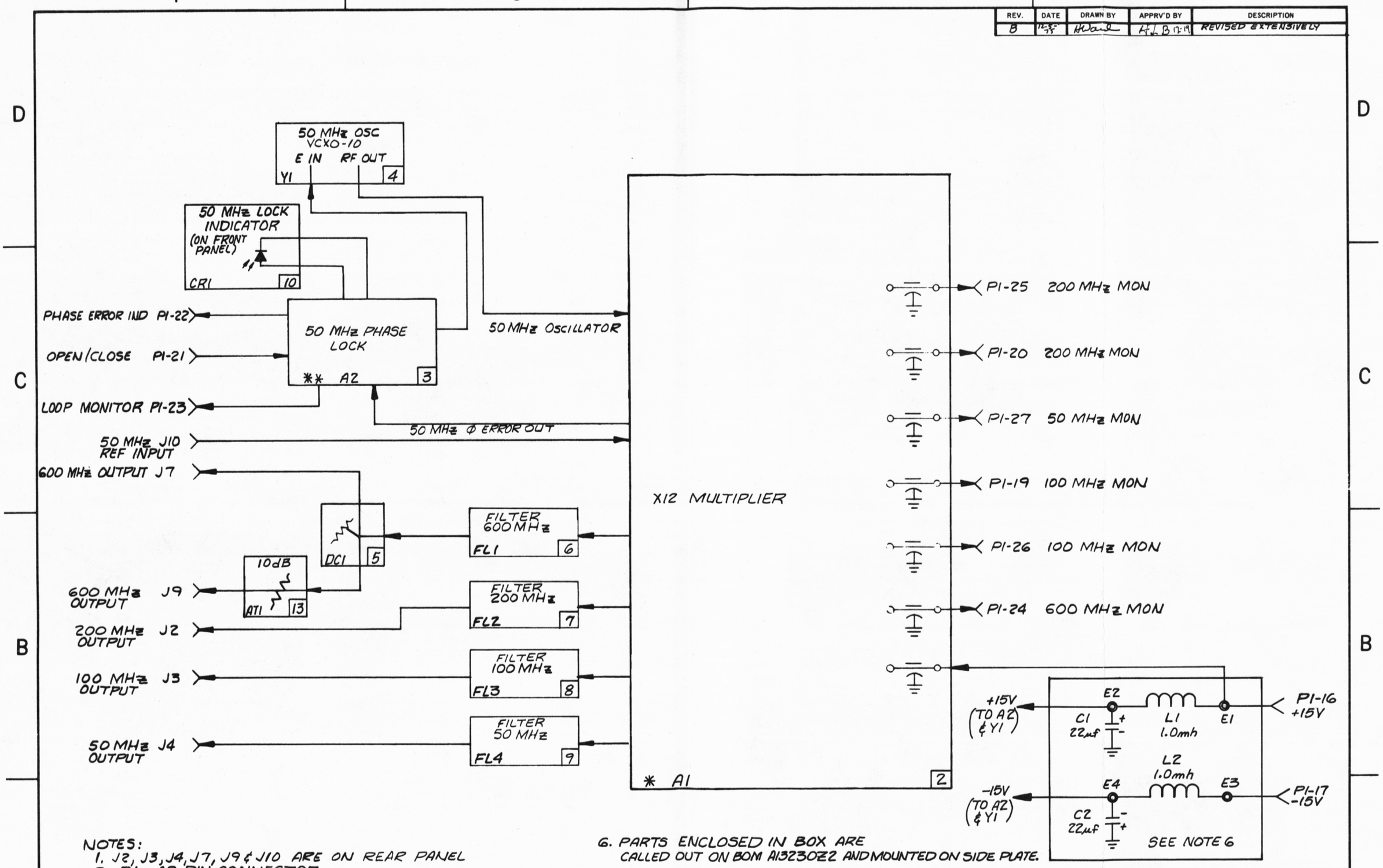
1. Place module on extender unit.
2. Remove right hand side cover.
3. Remove Ein and RFout cables from Isotemp VCXO-10 MHz osc.
4. Connect RFout to input of HP5326B and set 5326B to Frequency A, 1 sec. Connect system 10 MHz (L1, P2) 0 dBm to external osc. input and set switch to "ext" on rear of counter.
5. Connect Ein to a precision ±10V DC power supply such as HP6115A.
6. With Ein at .000V adjust "Freq" pot on VCXO to obtain 50,000,000 ±50 Hz on HP5326B.



7. With Ein at +10V adjust "Mod Sens" to obtain 50,000,500 ±10 Hz with -10V read 49,999,500 ±50 Hz.
8. Replace RFout cable. Set HP6115 at 1.00V F_{VCXO} ~5,000,050 Hz. Connect scope (TEK 475 or 5103N to "V" (P1-22)). Set Ø "AG" to give 10V p-p of ~50 Hz phase error. Set "AO" to balance error about zero.
9. Replace Ein cable and with switch still open, set "IO" to give beat frequency of about 500 Hz with voltmeter. Ein should be ~12V. If at +12V adjust offset to run to -12V.
10. Switch to closed loop. Loop error on scope will read -10 to -20 mV DC.
11. Check (P1-22) Ø error voltage with the loop locked should be -10 to -20 mV DC. AC component should be 10 mV p-p or less and mostly 60 Hz related.
12. Set switch to "R". Apply TTL level 1 to (P1-21). Loop should open. Observe front panel light when loop is locked. (Light on indicates loop is unlocked.)

5.0 SCHEMATIC DIAGRAMS

REV.	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION
B	12-8-75	H. Ward	H. L. B 12-19	REVISED EXTENSIVELY



NOTES:
1. J2, J3, J4, J7, J9 & J10 ARE ON REAR PANEL
2. P1 - 42 PIN CONNECTOR
3. * = ASSY DWG D13230P45, BOM A13230Z34, SCHEMATIC DWG D13230S16
   ** = ASSY DWG C13230P40, BOM A13230Z30, SCHEMATIC DWG C13230S11
4. ⟶ ARROW INDICATES SIGNAL FLOW
5. AT1 13 — ITEM NUMBERS PER BOM A13230Z2; REF DESIG PER IEEE NO. 315 & NRAO SPEC
6. PARTS ENCLOSED IN BOX ARE CALLED OUT ON BOM A13230Z2 AND MOUNTED ON SIDE PLATE.

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX): ±
2 PLACE DECIMALS (.XX): ±
1 PLACE DECIMALS (.X): ±

MATERIAL:

FINISH:

VLA PROJECT: 50/600 MHz MULTIPLIER L2

TITLE: BLOCK DIAGRAM

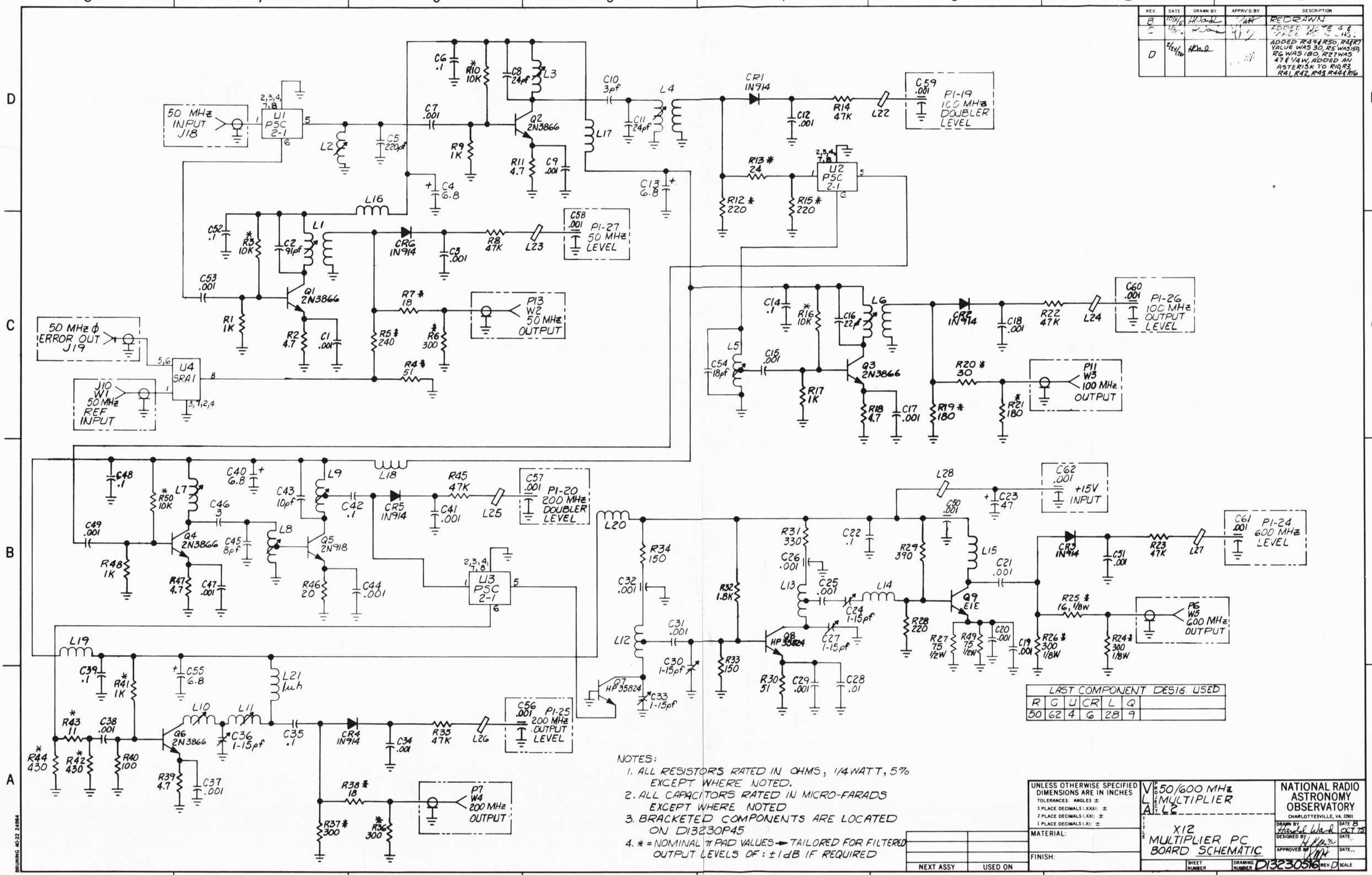
NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

DRAWN BY Harold Ward — DATE 6 MAY 75
DESIGNED BY H. L. B. 7-8-75 — DATE
APPROVED BY — DATE MAY 7-75

SHEET NUMBER — DRAWING NUMBER C13230B2 — REV. B — SCALE

BRUNING 40-22 24984

REV.	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION
B	10/18/6	H. Ward		REDRAWN
C	1/5/			ADDED NOTE 4 & VALUE ADDED R43
D	2/24/76	H. Ward		ADDED R49 & R50, R44 & R47 VALUE WAS 30, R5 WAS 150, R6 WAS 180, R27 WAS 47 & 1/4W, ADDED AN ASTERISK TO R10, R3, R41, R42, R43, R44 & R16



LAST COMPONENT DESIG. USED					
R	C	U	CR	L	Q
50	62	4	6	28	9

NOTES:
1. ALL RESISTORS RATED IN OHMS, 1/4 WATT, 5% EXCEPT WHERE NOTED.
2. ALL CAPACITORS RATED IN MICRO-FARADS EXCEPT WHERE NOTED
3. BRACKETED COMPONENTS ARE LOCATED ON D13230P45
4. * = NOMINAL π PAD VALUES → TAILORED FOR FILTERED OUTPUT LEVELS OF: ±1dB IF REQUIRED

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX): ±
2 PLACE DECIMALS (.XX): ±
1 PLACE DECIMALS (.X): ±
MATERIAL:
FINISH:

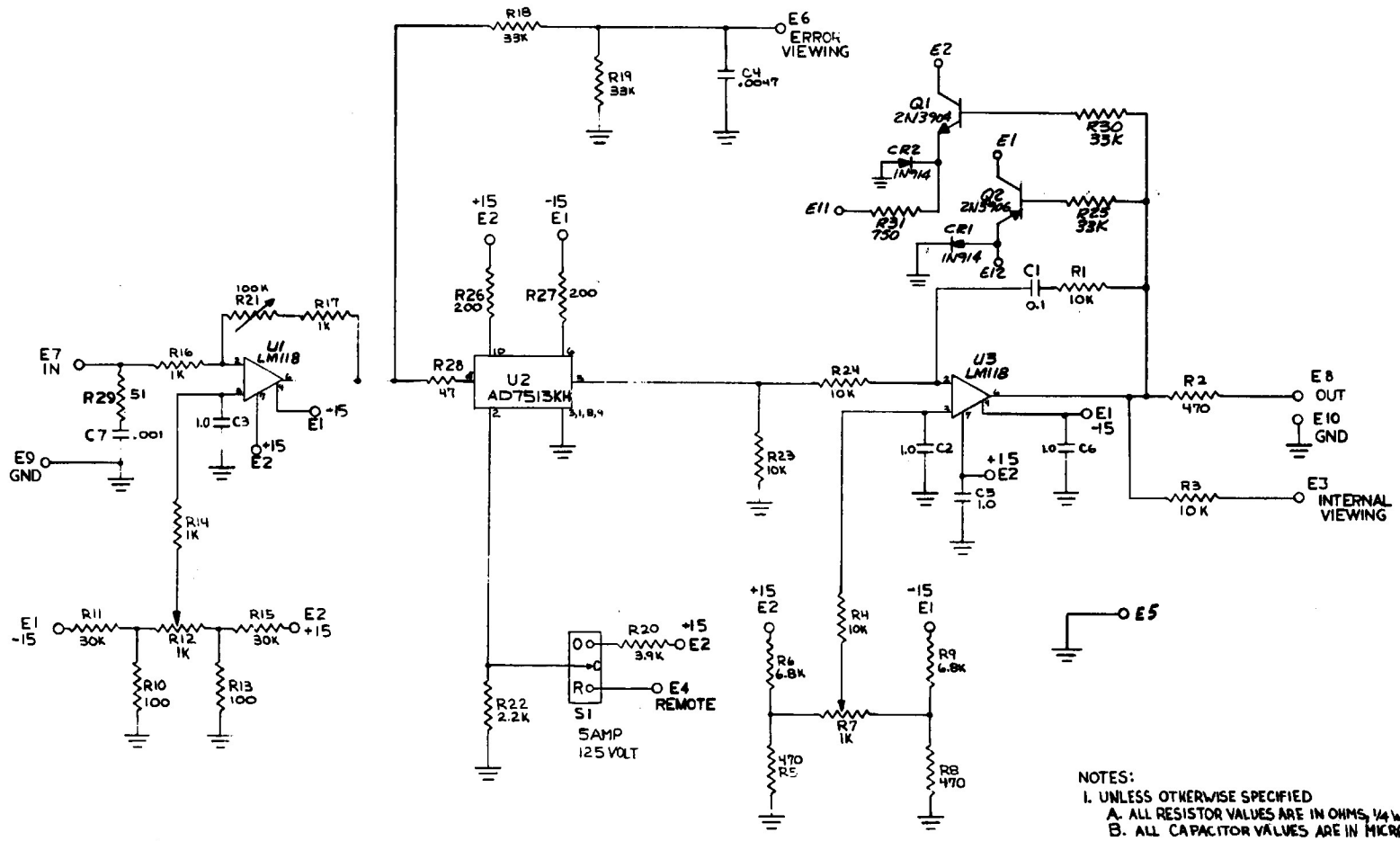
PROJECT: VLA 50/600 MHz MULTIPLIER
TITLE: X12 MULTIPLIER PC BOARD SCHEMATIC

NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

DRAWN BY Harold Ward DATE OCT 75 REV. B
DESIGNED BY DATE
APPROVED BY DATE
SHEET NUMBER DRAWING NUMBER D13230516 REV. D SCALE

BRUNING 40-22 24984

5-3



NOTES:
1. UNLESS OTHERWISE SPECIFIED
   A. ALL RESISTOR VALUES ARE IN OHMS, 1/4 WATT
   B. ALL CAPACITOR VALUES ARE IN MICROFARADS.

LAST COMPONENT DESIG. USED								
R	C	E	U	S	CR	Q		
51	7	12	3	1	2	2		

COMP. DESIG. NOT USED								

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX): ±
2 PLACE DECIMALS (.XX): ±
1 PLACE DECIMALS (.X): ±

MATERIAL:

FINISH:

PROJECT: VLA L2 50/600 MHz MULTIPLIER

TITLE: 50 MHZ PHASE LOCK BOARD SCHEMATIC

NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

DRAWN BY T. HUZAK DATE 12-19-74
CHECKED BY DATE
APPROVED BY DATE 5-22-75

SHEET NUMBER — DRAWING NUMBER C132305// REV. — SCALE —

6.0 BILLS OF MATERIALS

Bills of Materials are included for the following sub-assemblies of Module L2:

A13230Z30	50 MHz Phase Lock Board
A13230Z35	X12 Multiplier Board
A13230Z11	X12 Multiplier Enclosure
A13230Z2	50/600 MHz Multiplier
A13230Z34	X12 Multiplier Assembly

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

[X] ELECTRICAL [ ] MECHANICAL BOM # A13230Z30 REV _____ DATE 3/3/75 PAGE 1 OF 3

MODULE # L2 NAME 50/600 MHz Multiplier DWG # _____ SUB ASMB 50 MHz Phase Lock Board DWG # C13230P40

SCHEMATIC DWG # C13230S11 LOCATION _____ QUA/SYSTEM _____ PREPARED BY HWard APPROVED NZB

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	A13230Z30	Assembly	-	
2		NRAO	C13230M67	Board Detail	1	
3	R1,R3,R4, R23,R24		RCR07 103-5S	Resistor	5	
4	R2,R5 R8		RCR07 471-5S	Resistor	3	
5	R6,R9		RCR07 682-5S	Resistor	2	
6	R7,R12	Bourns	3339H-1-102	1 K ohm potentiometer	2	
7	R10,R13		RCR07 101-5S	Resistor	2	
8	R15,R11		RCR07-303-5S	Resistor	2	
9	R14,R16 R17		RCR07 102-5S	Resistor	3	
10	R25, R30 R18, R19		RCR07 333-5S	Resistor	4	
11	R20		RCR07 392-5S	Resistor	1	
12	R26,R27		RCR07 201-5S	Resistor	2	
13	R28		RCR07 470-5S	Resistor	1	
14	R29		RCR07 510-5S	Resistor	1	
15	R22		RCR07 222-5S	Resistor	1	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

[X] ELECTRICAL [ ] MECHANICAL BOM # A13230Z30 REV _____ DATE 3/3/75 PAGE 2 OF 3

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16	R21	Bourns	3339H-1-104	100 K ohm Potentiometer	1	
17	C2,3,5, 6	Erie	8131-050-651-105M	1 MF Capacitor	4	
18	C4	Erie	8121-050-651-472M	.0047 MF Cap	1	
19	C1	Sprague	192P1049R8	0.1 Mylar Cap. ± 10% 80 V.D.C.	1	
20	E1-E12	Keystone	1587-1	Turret Terminal	12	
21	U1,U3	National Circuits	LM-118	I.C.	2	
22		Robinson-Nugent	DP 5178	I.C. Socket 8 Pin	2	
23	U2	ANALOG-DEVICES	AD7513KH	I.C.	1	
24		Robinson-Nugent	DP 51710-23	I.C. Socket 10 Pin	1	
25		Keystone	1596-2	Standoffs	4	
26	C7	Erie	8101-050-651-102M	.001 MF Capacitor	1	
27	S1	J.B.T.	JMT-121	5 AMP, 125 Volt switch	1	
28		NRAO	C13230S11	Schematic	Ref	
29		NRAO	B13230AB1	Artwork Master	Ref	
30	Q1		2N3904	TRANSISTOR	1	
31	CR1, CR2		1N914	DIODE	2	
32	R31		RCR07 751-5S	RESISTOR	1	

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NATIONAL RADIO ASTRONOMY OBSERVATORY

[X] ELECTRICAL [ ] MECHANICAL BOM # A13230Z30 REV _____ DATE 3/3/75 PAGE 3 OF 3

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
33	Q2		2N3906	TRANSISTOR	1	
34		CINCH	3-LPS-B	TRANSISTOR SOCKET	2	

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NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13230Z35 REV A DATE 2 MAY 75 PAGE 1 OF 4

MODULE # L2 NAME 50/600 MHZ MULT DWG # A13230Z2 SUB ASMB X12 MULT. PC BOARD ASSY. DWG # D13230P44

SCHEMATIC DWG # D13230S16 LOCATION _____ QUA/SYSTEM _____ PREPARED BY T. HYZAK APPROVED HRB

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	A13230Z35	PC BOARD ASSEMBLY	—	
2		NRAO	D13230M87	PC BOARD	1	
3	R1,9,17 41,48		RCR07 102-5S	RESISTOR 1/4W 1K	5	
4	R2,11,18 39,47		RCR07 4R7-5S	RESISTOR 4.7 OHMS	5	
5	R3,10 16		RCR07 103-5S	RESISTOR 10K	3	
6	R4,7 20		RCR07 300-5S	RESISTOR 30 OHMS	3	
7	R5,33 34		RCR07 151-5S	RESISTOR 150 OHMS	3	
8	R6,19 21		RCR07 181-5S	RESISTOR 180 OHMS	3	
9	R8,14,22 23,35,45		RCR07 473-5S	RESISTOR 47K	6	
10	R12,15 28		RCR07 221-5S	RESISTOR 220 OHMS	3	
11	R13		RCR07 240-5S	RESISTOR 1/4W 24 OHMS	1	
12	R24,26		RCR05 301-5S	RESISTOR 1/8W 300 OHMS	2	
13	R25		RCR05 160-5S	RESISTOR 1/8W 16 OHMS	1	
14	R27		RCR07 470-5S	RESISTOR 1/4W 47 OHMS	1	
15	R29		RCR07 391-5S	RESISTOR 1/4W 390 OHMS	1	

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NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13230235 REV A DATE 2 MAY 75 PAGE 2 OF 4

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16	R30		RCR07 510-5S	RESISTOR 1/4W 51 OHMS	1	
17	R31		RCR07 331-5S	RESISTOR 330 OHMS	1	
18	R32		RCR07 182-5S	RESISTOR 1.8K	1	
19	R36, 37		RCR07 301-5S	RESISTOR 300 OHMS	2	
20	R38		RCR07 180-5S	RESISTOR 18 OHMS	1	
21	R40		RCR07 101-5S	RESISTOR 100 OHMS	1	
22	R42, 44		RCR07 431-5S	RESISTOR 430 OHMS	2	
23	R43		RCR07 110-5S	RESISTOR 11 OHMS	1	
24	R46		RCR07 200-5S	RESISTOR 1/4W 20 OHMS	1	
25	CR1-6		1N914	DIODE	6	
26	*	ERIE	8101-050-651-102M	CAPACITOR .001 uF	21	
27	C2	ELMENCO	CM04ED910J03	CAPACITOR 91 PF.	1	
28	C4, 13 40 55	KEMET	CS13BF685K	CAPACITOR 6.8 uF	4	
29	C5	ELMENCO	CM04ED221J03	CAPACITOR 220 PF.	1	
30	C6, 14, 22, 35, 39, 42, 48, 52	ERIE	8121-050-651-104M	CAPACITOR 0.1 uF	8	
31	C8, 11	ELMENCO	CM04ED240J03	CAPACITOR 24 PF	2	
32	C10, 46	ELMENCO	CM04ED030J03	CAPACITOR 3.0 PF	2	

* C1, 3, 7, 9, 12, 15, 17, 18, 21, 25, 29, 31, 34, 37, 41, 44, 47, 49, 51, 38, 53

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NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13230235 REV A DATE 2 MAY 75 PAGE 3 OF 4

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
33	C16	ELMENCO	CM04ED220J03	CAPACITOR 22 PF	1	
34	C19,20	AMER. TECH. CERAMICS	100B102CM100	CAPACITOR 1000PF CHIP	2	
35	C23	KEMET	CS13BF476K	CAPACITOR 47uF	1	
36		NRAO	D13230516	SCHEMATIC	REF	
37	C26,32 50	SPECT. CONTROL	FA5C-102W	CAP(FEED THRU-SOLDER).001uF	3	
38	C24,27, 30,33,36	E.F. JOHNSON	187-0109-005	VARIABLE CAP 1.0-15 PF	5	
39	C43	ELMENCO	CM04ED100J03	CAPACITOR 10 PF	1	
40	C45	ELMENCO	CM04ED080J3	CAPACITOR 8.0 PF	1	
41	Q1-4 Q6		2N3866	TRANSISTOR	5	
42	Q5		MPS918	TRANSISTOR	1	
43	Q7-8	HEWLETT-PACKARD	H-P 35824	TRANSISTOR	2	
44	Q9	CTC	E1E	TRANSISTOR	1	
45	U1-3	MINI CIRCUITS LABS.	PSC 2:1	POWER SPLITTER	3	
46	U4	MINI CIRCUITS LABS.	SRA 1	DOUBLE BALANCED MIXER	1	
47	L21	MILLER	9230-20	CHOKE 1.uh	1	
48	C28	ERIE	8121-050-651-103M	CAPACITOR .01 UF	1	
49	C54	ELMENCO	CM04ED180J03	CAPACITOR 18 PF	1	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13230235 REV A DATE 2 MAY 75 PAGE 4 OF 4

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
50	L1	NRAO	B13230M70	INDUCTOR (MAKE FROM CAMBION 534-3624-07)	1	
51	L2	NRAO	B13230M71		1	
52	L3	NRAO	B13230M72		1	
53	L4	NRAO	B13230M73		1	
54	L5	NRAO	B13230M74		1	
55	L6	NRAO	B13230M75		1	
56	L7	NRAO	B13230M76		1	
57	L8	NRAO	B13230M77		1	
58	L9	NRAO	B13230M78		1	
59	L10	NRAO	B13230M79		1	
60	L11	NRAO	B13230M80	INDUCTOR (MAKE FROM CAMBION 534-3624-07)	1	
61	L12	BELDEN	8019	INDUCTOR (WIRE)	1" LG.	
62	L13			INDUCTOR (WIRE)	1" LG.	
63	L14			INDUCTOR (WIRE)	1" LG.	
64	L15	BELDEN	8019	INDUCTOR (WIRE)	1 1/4" LG	
65	L16,17 18,19,20	NRAO	C13210M2-10	INDUCTOR	5	
66		NRAO	D13230AB3	ARTWORK MASTER	REF	

BILL OF MATERIAL

[ ] ELECTRICAL [X] MECHANICAL BOM # A13230 Z11 REV A DATE 12/4/74 PAGE 1 OF 2

MODULE # L2 NAME 50/600 MHz. Mult. DWG # D13230 P2 SUB ASMB Multiplier Enclosure DWG # C13230 P21

SCHEMATIC DWG # _____ LOCATION _____ QUA/SYSTEM _____ PREPARED BY T. Hyzak APPROVED [signature]

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		N.R.A.O.	C13230 P21	Multiplier Enclosure	--	
2		N.R.A.O.	C13230 M6-1	Side Cap	1	
3		" "	C13230 M7-1	Top Cover	1	
4		" "	B13230 M19	End Cap	1	
5		" "	B13230 M18	End Cap	1	
6		" "	C13230 M6-2	Side Cap	1	
7		" "	B13230 M 17-1	End Rail	2	
8		" "	B13230 M17-2	Side Rail	2	
9		" "	B13230 M13	Sub-Divider	3	
10		" "	B13230 M14	Sub-Divider	2	
11		" "	B13230 M16	Sub-Divider	1	
12		" "	B13230 M15	Sub-Divider	1	
13		" "	A13230 M10	Multi-Divider	1	
14						
15		" "	A13230 M9	Multi-Divider	5	

BILL OF MATERIAL

☐ ELECTRICAL ☒ MECHANICAL BOM # A13230 Z11 REV A DATE 12/4/74 PAGE 2 OF 2

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16		N.R.A.O.	B13230 M7-2	Base Plate	1	
17		" "	4-40*.500	Screws,S.S.,Flat Head	18	
18		" "	4-40*.375	" " " Round Head	14	
19		" "	4-40*.375	"" " " Flat Head	10	
20		" "	4-40*.500	" " " Round Head	8	
21		" "	4-40*.375	" " " Round Head	7	
22		" "	4-40*.250	" " " Round Head	3	

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NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13230Z2 REV _____ DATE _____ PAGE 1 OF 3

MODULE # L2 NAME 50/600 MHz MULTIPLIER DWG # D13230P2 SUB ASMB _____ DWG # _____

SCHEMATIC DWG # _____ LOCATION _____ QUA/SYSTEM _____ PREPARED BY _____ APPROVED _____

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	A13230Z2	50/600 MHz MULT. ASSY	—	
2		NRAO	A13230Z34	X12 MULTIPLIER ASSY	1	
3		NRAO	A13230Z30	50 MHz PHASE LOCK BRD. ASSY	1	
4		ISOTEMP	VCXO-10	50 MHz OSC	1	
5		MERIMAC	PDM-20-500	POWER DIVIDER	1	
6		K+L MICROWAVE	4B120-600/50	BANDPASS FILTER	1	
7		K+L MICROWAVE	4B120-200/16	BANDPASS FILTER	1	
8		K+L MICROWAVE	4B120-100/8	BANDPASS FILTER	1	
9		K+L MICROWAVE	4B120-50/4	BANDPASS FILTER	1	
10		MONSANTO	MV 5025	LIGHT EMITTING DIODE (RED)	1	
11		UNIFORM-TUBES	UT-141A	SEMI-RIGID CABLE .141 DIA	1 FT.	
12		OMNI-SPECTRA	OSM 201-1A	PLUG/.141 SEMI RIGID CABLE	9	
13		NARDA	4772-10	10 DB ATTEN. (MICRO PAD)	1	
14		AMP	204186-5	BIN/MODULE POWER CONN.	1	
15		AMP	202394-2	POWER CONNECTOR GUARD	1	

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NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13230Z2 REV _____ DATE _____ PAGE 2 OF 3

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16		OMNI-SPECTRA	OMQ-3043-75	JACK / SEMI-RIGID CABLE	6	
17		OMNI SPECTRA	OSM 511-3	PLUG/CABLE CONNECTOR	2	
18		OMNI SPECTRA	OSM202-1A	JACK/.141 SEMI RIGIDCABLE	1	
19		OMNI SPECTRA	OSM 531-1	RIGHT ANGLE PLUG/CABLE	5	
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NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☒ MECHANICAL BOM #A13230Z2 REV _____ DATE _____ PAGE 3 OF 3

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
33		NRAO	B13230M20	FRONT PANEL	1	
34		NRAO	C13210M4	REAR PANEL	1	
35		NRAO	B13050M4	GUIDES	4	
36		NRAO	B13050M23	BAR SUPPORT	3	
37		NRAO	B13230M23	RIGHT TOP BAR SUPPORT	1	
38		NRAO	C13050M22-1	PERFORATED COVER	2	
39		NRAO	B13050M18	SIDE PLATE RIGHT	1	
40		NRAO	C13230M8	SIDE PLATE LEFT	1	
41		SOUTHCO	47-11-204-10	CAPTIVE SCREW	4	
42		NRAO	A13230M12	FILTER HOLD DOWN CLAMP	1	
43		NRAO		POWER DIVIDED MOUNT	1	
44			4-40×.375LG	FLAT HEAD S.S. SCREW	12	
45			2-56×.375LG	FLAT HEAD S.S. SCREW	4	
46			6-32×1.25LG	FLAT HEAD S.S. SCREW	1	
47			6-32×.250	FLAT HEAD S.S. SCREW	18	
48			4-40×.750	FLAT HEAD S.S. SCREW	1	
49			4-40×.500	PAN HEAD S.S. SCREW	2	

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NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13230Z34 REV _____ DATE _____ PAGE 1 OF 1

MODULE # L2 NAME 50/600MHZ MULTIPLIER DWG # _____ SUB ASMB X12 MULTIPLIER ASSY DWG # D13230P45

SCHEMATIC DWG # _____ LOCATION _____ QUA/SYSTEM _____ PREPARED BY _____ APPROVED _____

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	A13230Z34	X12 MULTIPLIER ASSY	—	
2		NRAO	A13230Z35	X12 MULT. PC BOARD ASSY	1	
3		NRAO	C13230P21	X12 MULT ENCLOSURE ASSY	1	
4		OMNI-SPECTRA	OSM 211	SMA CONNECTOR	2	
5	C56 - C62	SPECTRUM-CONTROL	FA-5C	.001 UF FEEDTHRU CAP	7	✓
6	L22 - L28	FERROXCUBE	56-590-65/38	FERRITE BEAD	6	✓
7		BELDEN	8021	WIRE #22AWG	8 IN	
8						

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7.0 MANUFACTURERS' DATA SHEETS

This section contains data sheets on the following:

1. HP35824 Transistor
2. CTC - EIE Transistor
3. Mini Circuits Labs PSC2.1 Power Divider
   SRA-1 Balanced Mixer
4. Merimac PDM-20-500 Power Divider
5. Ferroxcube 56-590-65/3B Ferrite Bead

HEWLETT hp PACKARD

HIGH FREQUENCY TRANSISTOR

MODEL 35824A

Description

The 35824A, small signal silicon NPN transistor, expands the package flexibility of the HP 21 series transistor. The combination of this high performance but low cost chip in the inexpensive TO-72 Package offers an excellent device in the 100 to 2000 MHz band. It can provide 100 mW linear power out with 12 dB gain at 1 GHz; saturated power out equals 250 mW. The 35824A is an inexpensive and versatile transistor for use in both oscillator or amplifier circuits.

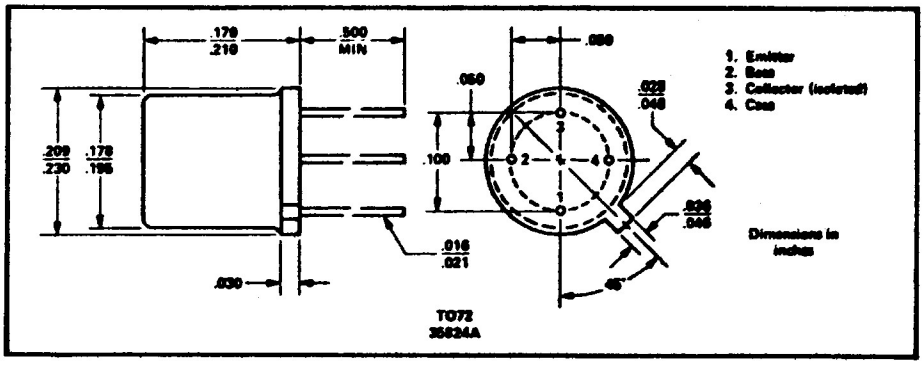


Figure 1. Outline Drawing.

Absolute Maximum Ratings (CASE TEMPERATURE = 25°C)

Symbols	Parameters	Limits
V_{CBO}	Collector to Base Voltage	25 V
V_{CEO}	Collector to Emitter Voltage	20 V
V_{EBO}	Emitter to Base Voltage	3.0 V
I_c	Collector Current	35 mA
T_j	Operating Junction Temperature	175°C
T_{STG}	Storage Temperature	−65°C to +200°C
P_t	Total DC Device Dissipation	400 mW
θ_j	Thermal Resistance (Junction to Ambient)	375°C/W

Outline Drawing Tabulations

Inches	Milli-meters	Inches	Milli-meters
0.016	0.41	0.100	2.54
0.021	0.53	0.170	4.32
0.028	0.71	0.178	4.52
0.030	0.76	0.195	4.95
0.036	0.91	0.209	5.31
0.046	1.17	0.210	5.33
0.048	1.22	0.230	5.84
0.050	1.27	0.500	12.70

Electrical (CASE TEMPERATURE = 25°C)

Symbols	Parameter and Test Conditions	Units	Min	Typ	Max
BV_{CBO}	Collector-Base breakdown voltage at $I_C = 0.1$ mA, $I_E = 0$	V	25		
I_{EBO}	Emitter Cutoff current at $V_{EB} = 2.0$ V, $I_C = 0$	μA			10
BV_{CEO}	Collector-Emitter breakdown voltage at $I_C = 0.5$ mA, $I_B = 0$	V	20	25	
I_{CBO}	Collector Cutoff current at $V_{CB} = 10$ V, $I_E = 0$	μA			20
h_{fe}	Forward Current transfer ratio at $V_{CE} = 15$ V, $I_B = 0.15$ mA		15	25	125
f_{max}	Frequency at which G_a (max) = 0 dB, $V_{CB} = 15$ V, $I_C = 15$ mA	GHz		4	
f_s	Frequency at which $\|S_{21}\|^2 = 0$ dBm at $V_{CB} = 15$ V, $I_C = 15$ mA	GHz		3	
NF_1 NF_2	Noise Figure (common emitter) at $V_{CB} = 10$ V, $I_C = 5$ mA, $f_1 = 0.5$ GHz, $f_2 = 1$ GHz	dB dB		2.8 3.0	

NOTE: All DC tests performed per MIL-STD-750

Typical Performance Curves

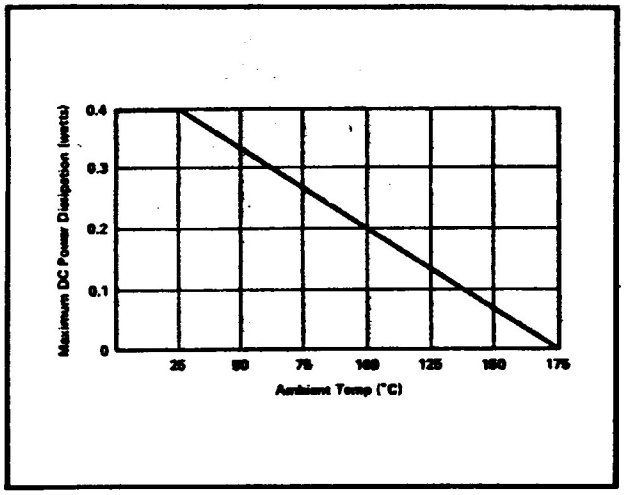


Figure 2. DC Power vs. Temperature Derating Curve.

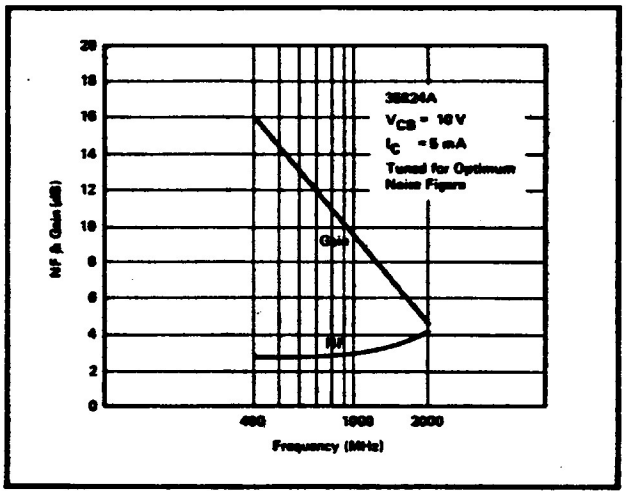


Figure 3. Noise Figure (and Gain) vs. Frequency at Optimum Bias.

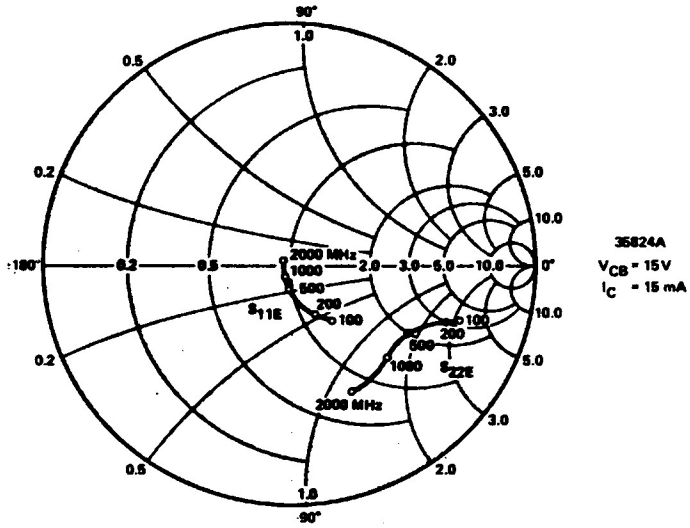


Figure 4. Common Emitter Input and Output Reflection Coefficients.

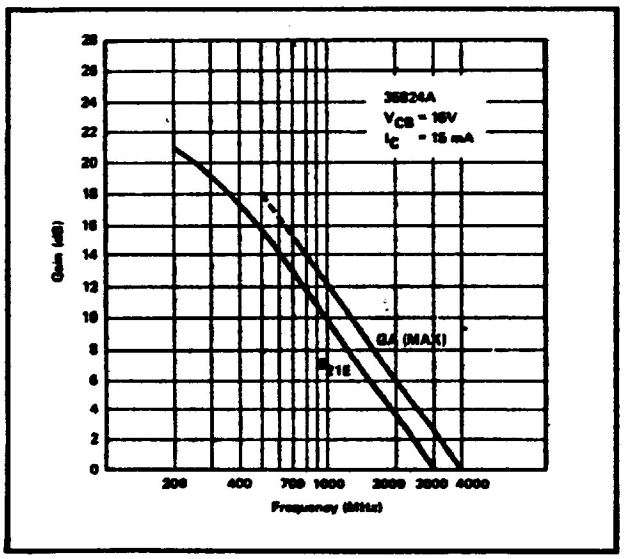


Figure 5. Gain vs. Frequency at Optimum Bias.

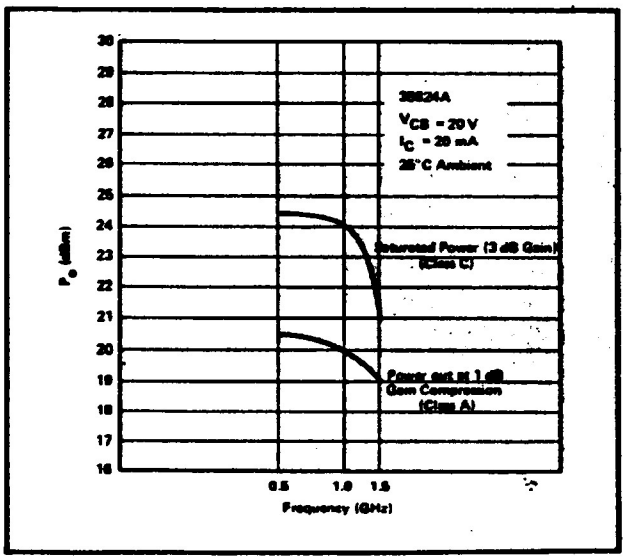


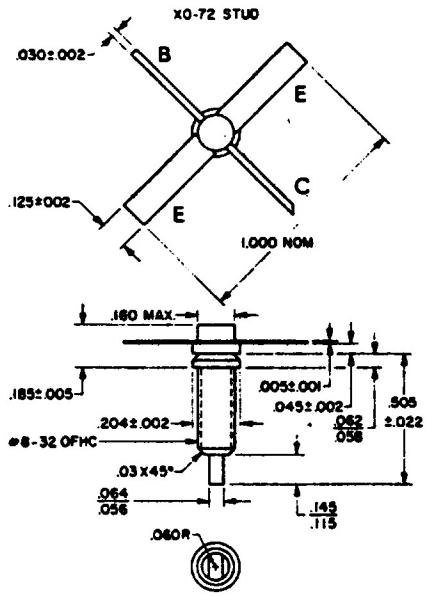
Figure 6. Power Out vs. Frequency at Optimum Bias.

COMMUNICATIONS TRANSISTOR CORPORATION

E1E
F1E

MICROWAVE ● CLASS A LINEAR RF POWER TRANSISTORS

GENERAL DESCRIPTION - The E1E & F1E are specifically designed for operation in Class A broadband or narrow-band applications covering the frequency range of 200-3000 MHz.

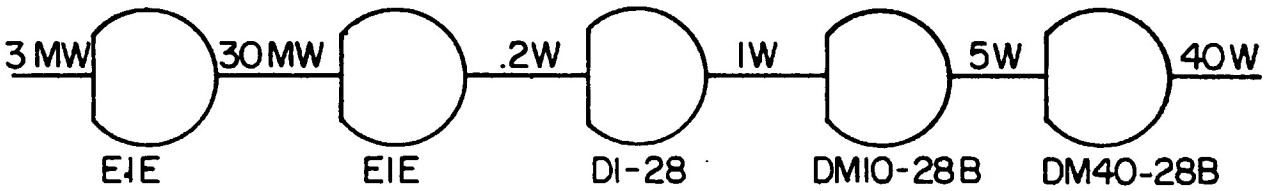


Note: Studless package also available

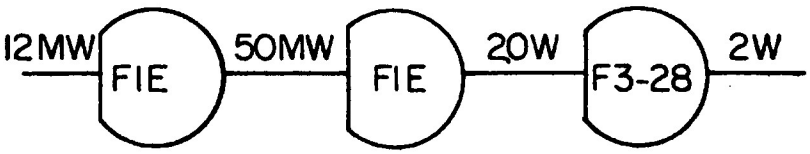
FEATURES

- SUPERIOR LINEARITY DUE TO HIGHER f_T.
- MAXIMUM RELIABILITY DUE TO SINGLE CHIP CONSTRUCTION.
- GREATER HIGH FREQUENCY PERFORMANCE IN LOW INDUCTANCE CERAMIC STRIPLINE PACKAGES.
- IDEAL FOR USE IN LINEAR APPLICATIONS REQUIRING OPERATION IN CLASS A DUE TO IMPROVED FORWARD BIASED SAFE AREA.

750-1000 MHz



2100-2300 MHz



COMMUNICATIONS TRANSISTOR CORPORATION
301 Industrial Way, San Carlos, California 94070
An Affiliate of Eimac Varian
(415) 591-8921 TWX 910-376-4893

COMMUNICATIONS TRANSISTOR E1E ● F1E

ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS

MAXIMUM TEMPERATURES	E1E	F1E
Storage Temperatures	-65° C to + 200° C	-65° C to + 200° C
Operating Junction Temperatures	200° C	200° C
Lead Temperature (Soldering 8 seconds time limit) ≤ 1/32" from Ceramic	260° C	260° C
MAXIMUM POWER DISSIPATION (Note 2)		
Total Power Dissipation at 25° C Case Temperature	5.3 W	5.3 W
MAXIMUM VOLTAGES AND CURRENT		
BV_{CBO} Collector to Base Voltage	50 V	50 V
BV_{EBO} Emitter to Base Voltage	4 V	4 V
LV_{CEO} Collector to Emitter Voltage	20 V	20 V
I_C Collector Current	.25 A	.25 A

ELECTRICAL CHARACTERISTICS (25° C unless otherwise specified)

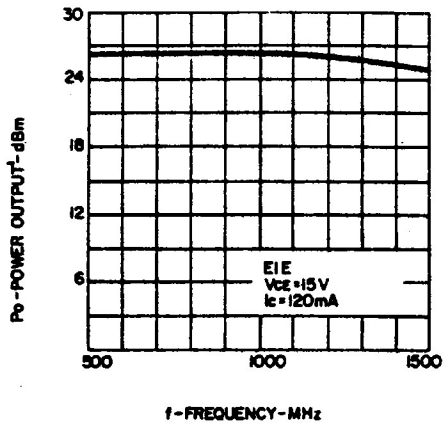
SYMBOL	CHARACTERISTIC	E1E	F1E	UNIT	LIMIT	TEST CONDITIONS
	100% TESTED AND GUARANTEED					
P_g	Power Gain (Note 3)	9.0		dB	MIN.	f = 1 GHz
			7.0	dB	MIN.	f = 2 GHz
LV_{CEO}	Collector to Emitter Voltage	20	20	VOLTS	MIN.	Ic = 10 mA
BV_{EBO}	Emitter to Base Voltage	4.0	4.0	VOLTS	MIN.	Ic = 5 mA
BV_{CBO}	Collector to Base Breakdown Voltage	50	50	VOLTS	MIN.	Ic = 10 mA
H_{fe}	Current Gain	20	20	---	MIN.	V_{CE} = 5V, Ic = 50 mA

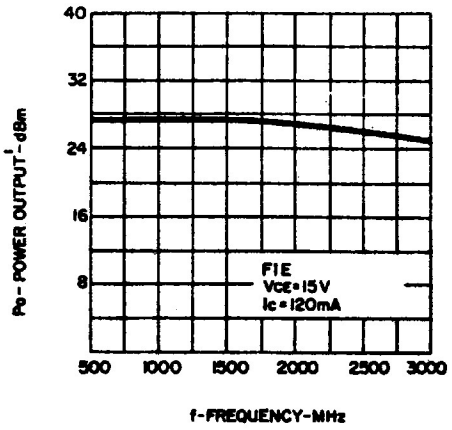
NOTES:

1. At 1 dB compression point.
2. These ratings give a maximum junction temperature of 200° C with junction to case thermal resistance of 33° C/watt.
3. Values measured at bias point: V_{CE} = 15 Volts, Ic = 120 mA.

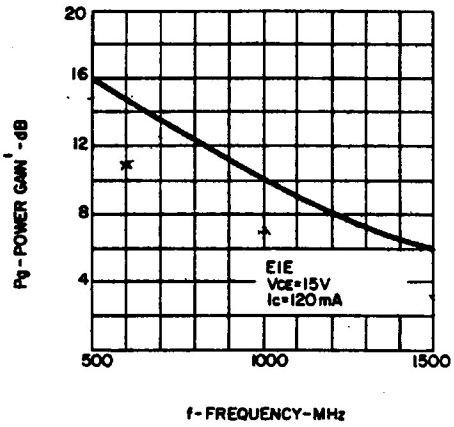
COMMUNICATIONS TRANSISTOR E1E ● F1E

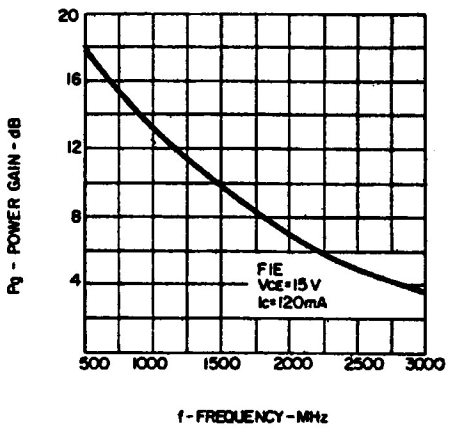
POWER OUTPUT VERSUS FREQUENCY



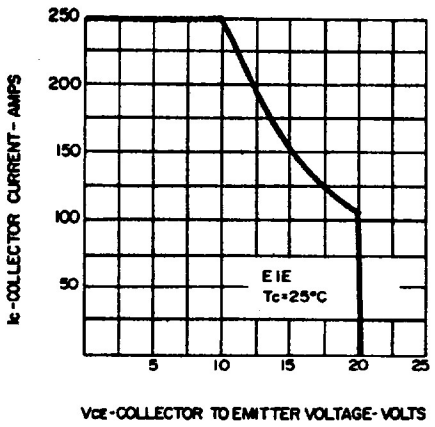


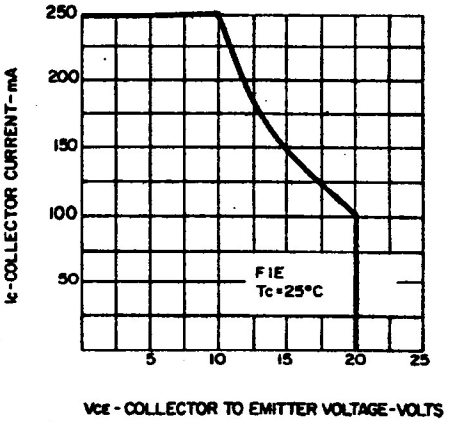
POWER GAIN VERSUS FREQUENCY



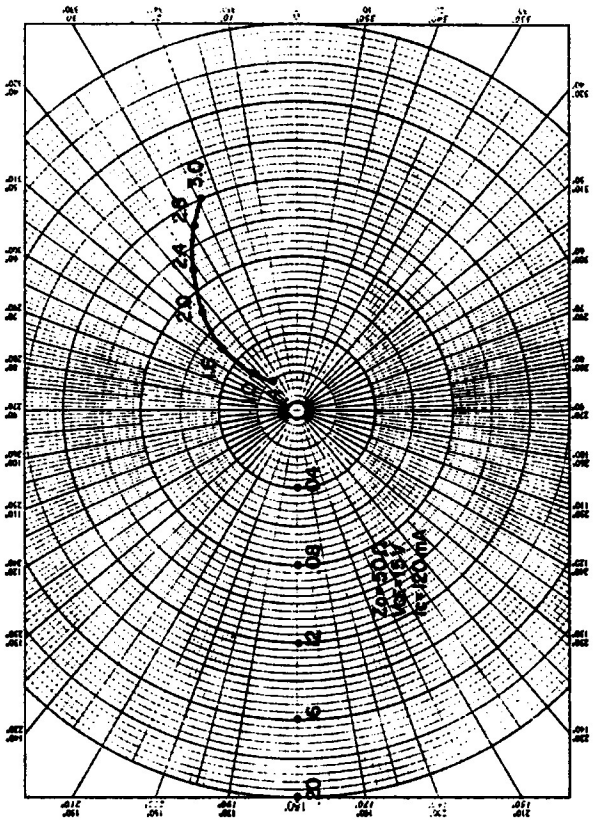


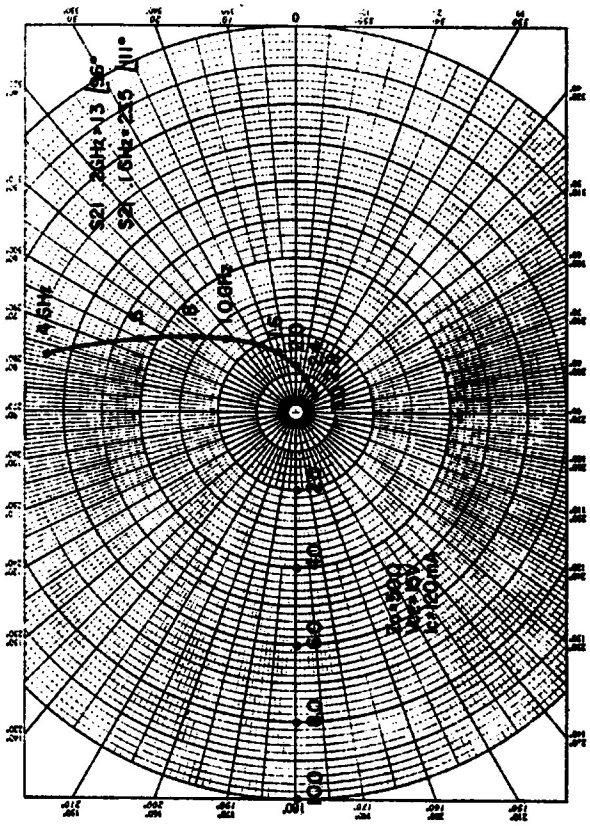
DC SAFE OPERATING AREA

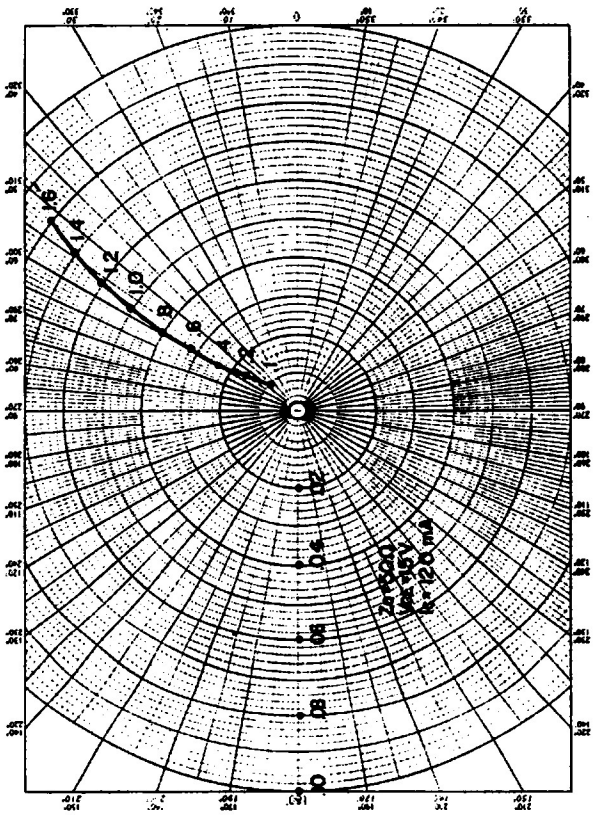




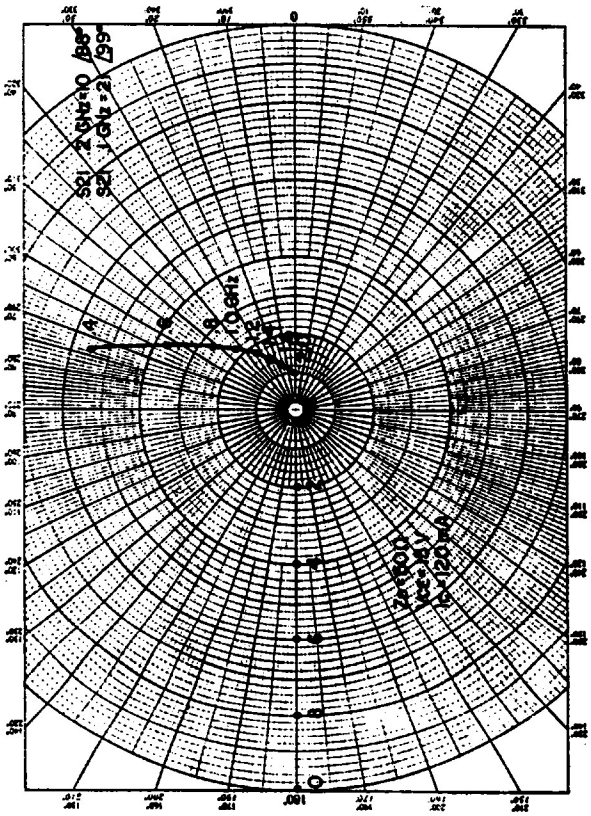
COMMUNICATIONS TRANSISTOR E1E ● F1E





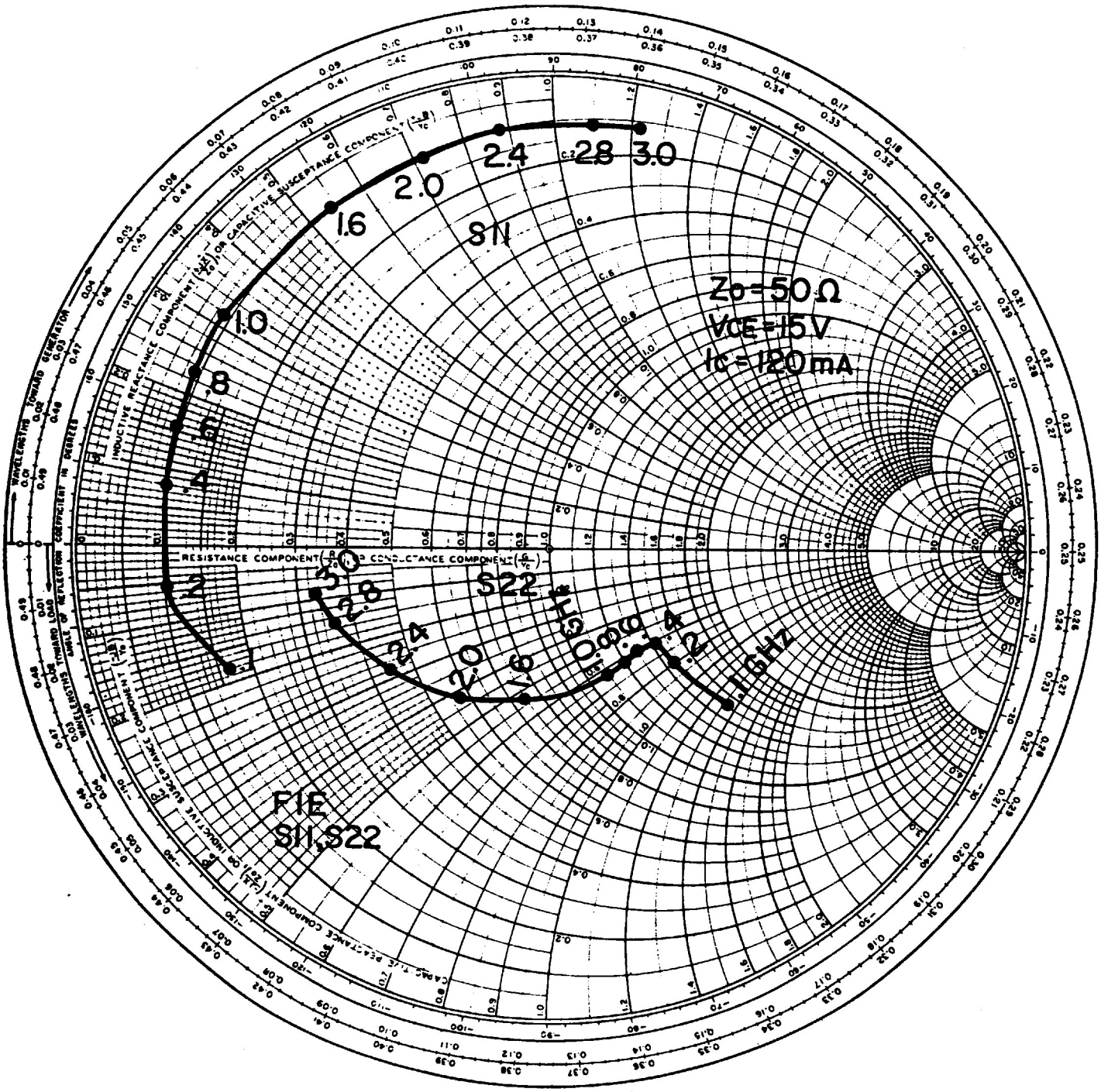


S12

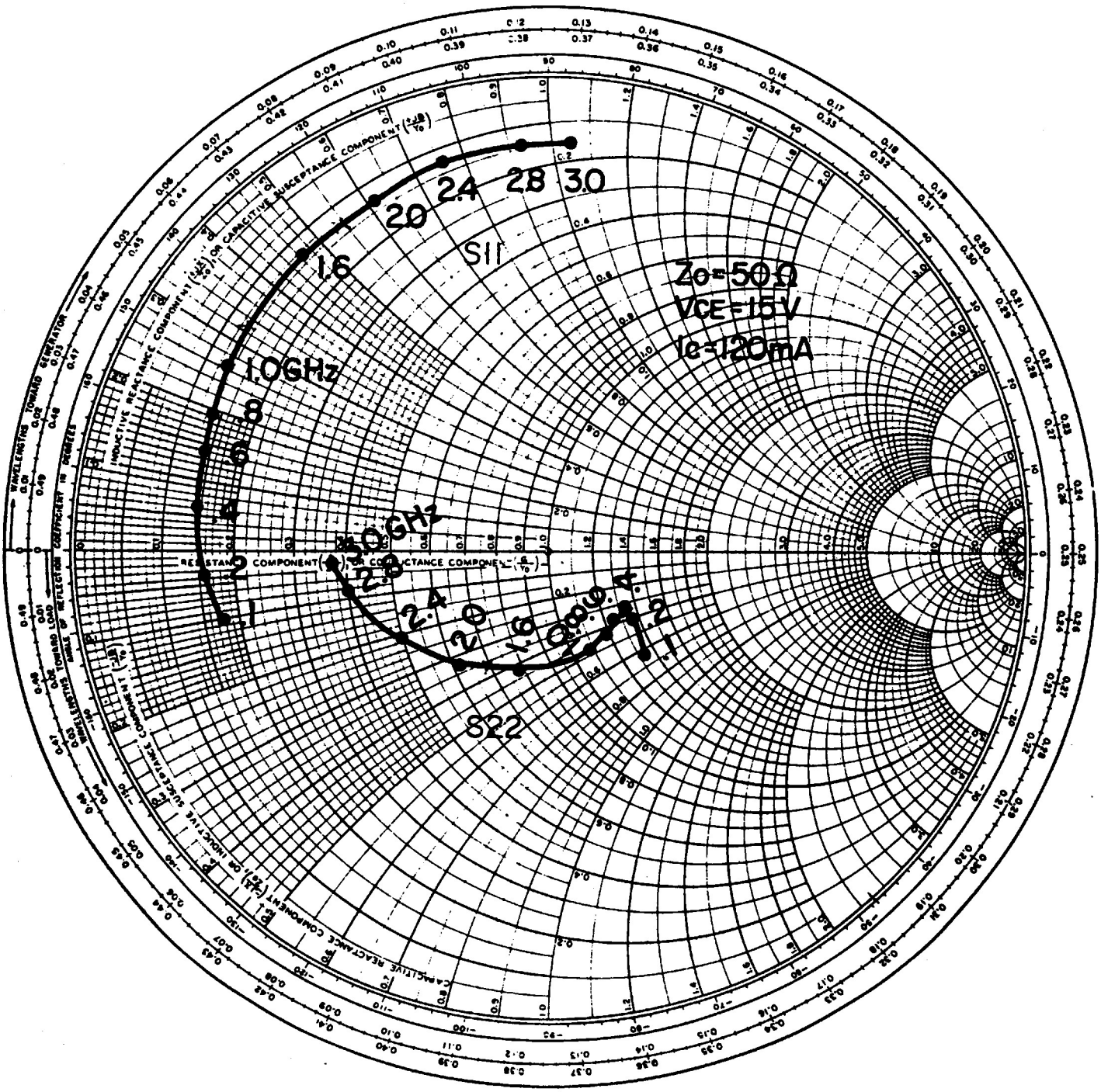


S21

F1E S11, S22



E1E S11, S22



POWER SPLITTER-COMBINER

TWO WAY IN PHASE 0°

PSC-2 SERIES

MODEL PSC-2-1 100 KHz-400 MHz
MODEL PSC-2-2 2 KHz- 60 MHz

FOR CONNECTOR VERSION
SEE ZSC-2 SERIES

FEATURES

MINIATURE SIZE, .128 CU. INCHES

EXTRA WIDE BAND, 2KHz - 400MHz

EXCEPTIONALLY GOOD BALANCE

LOW INSERTION LOSS

HIGH ISOLATION

RFI SHIELDED

HERMETICALLY SEALED METAL CASE

LOW COST FROM $9.95
IN SMALL QUANTITIES

APPLICATIONS

ADD OR SUBTRACT SIGNALS VECTORIALLY

OBTAIN MULTI IN-PHASE OUTPUT SIGNALS PROPORTIONAL TO THE LEVEL OF A COMMON INPUT SIGNAL

SPLIT AN INPUT SIGNAL INTO MULTI-OUTPUTS

COMBINE SIGNALS FROM DIFFERENT SOURCES TO OBTAIN A SINGLE PORT OUTPUT

PROVIDE CAPABILITY TO OBTAIN RF LOGIC ARRANGEMENTS

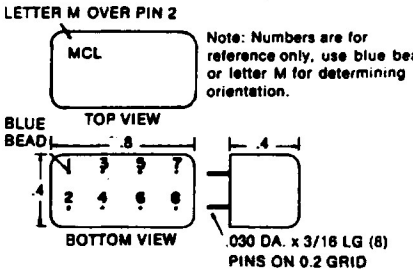
DESCRIPTION

The model PSC-2 2-way power splitter/combiner is a high performance broad band hybrid junction. Internally, terminations and transformers are provided to ensure a well matched 50 ohm impedance at all ports. Signals fed into the input S port are equally divided, in phase, to the two output (1 and 2) ports. Similarly, signals fed into ports 1 and 2 are vectorially summed at the output S port.

The PSC-2 features exceptionally good amplitude and phase balance between the signals at the 2 output ports. Typically, over most of the frequency range, the phase balance is within 1 degree and the amplitude balance is within .05 dB.

The PSC-2 is ruggedly constructed to provide reliable service under severe environmental conditions. Internally, every component is bonded to the header for added strength to protect against shock and vibration. This hermetically sealed unit performs well under high relative humidity conditions and over temperature extremes from −55°C to +100°C.

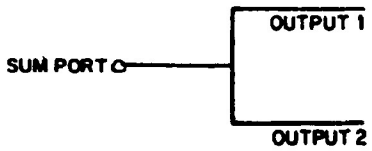
Every unit is 100% tested and inspected under strict MCL quality control standards to ensure superior electrical performance and reliability. The exceptionally low cost of the PSC-2 is attributable to the breakthrough in production techniques achieved by MCL during the manufacture of its high performance low price double balanced mixers. Utilizing this technology, the high performance PSC-2 is offered at a remarkable price of ½ to ⅓ of competitive units.



Note: Numbers are for reference only, use blue bead or letter M for determining orientation.

WEIGHT 5.2 grams .18 ounces

PIN CONNECTIONS	PSC-2-1 PSC-2-2
SUM PORT	1
OUTPUT 1	5
OUTPUT 2	6
GROUND	2,3,4,7,8



ABSOLUTE MAXIMUM RATINGS

Operating and Storage Temperature	−55° C to +100° C
Pin Temperature (10 seconds)	510° F

MINI-CIRCUITS LABORATORY 2913 Quentin Rd., Brooklyn, N.Y. 11229 (212) 252-5252

POWER SPLITTER-COMBINER

TWO-WAY IN PHASE 0°

MODEL PSC-2-1 100KHz-400MHz
MODEL PSC-2-2 2KHz-60MHz

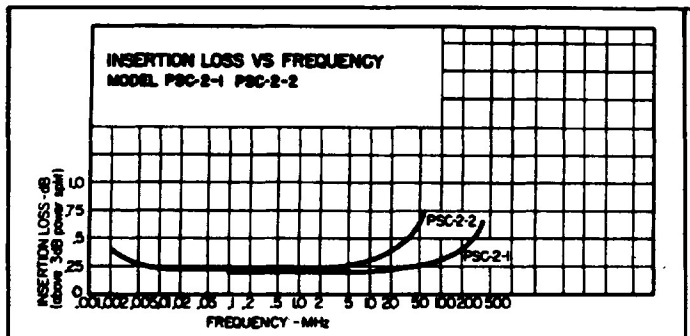
FOR CONNECTOR VERSION SEE ZSC-2 SERIES

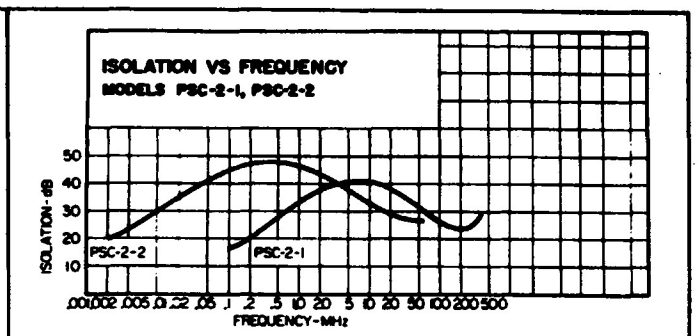
SPECIFICATIONS	MODEL PSC-2-1	
Frequency Range (MHz)	.1-400MHz	
Nominal Phase Difference Between Output Ports	0°	
Impedance, All Ports	50 ohms	
Isolation Between Output 1 and 2, dB	Typical	Minimum
2-40MHz	40	30
.4-400MHz	25	20
.1-.4MHz	20	15
Insertion Loss, dB (above 3dB split)	Typical	Maximum
.1-100MHz	.2	.5
100-200MHz	.4	.75
200-400MHz	.6	1.0
Phase Unbalance, degrees	Typical	Maximum
0.1-100MHz	.5	2
100-200MHz	1	3
200-400MHz	2	4
Amplitude Unbalance, dB	Typical	Maximum
.1-100MHz	.05	.15
100-200MHz	.05	.2
200-400MHz	.1	.3
VSWR	1.2 typical	
Matched Power Rating	1 watt maximum	
Internal Load Dissipation	⅓ watt	
Price	**$9.95 (6-49)**	

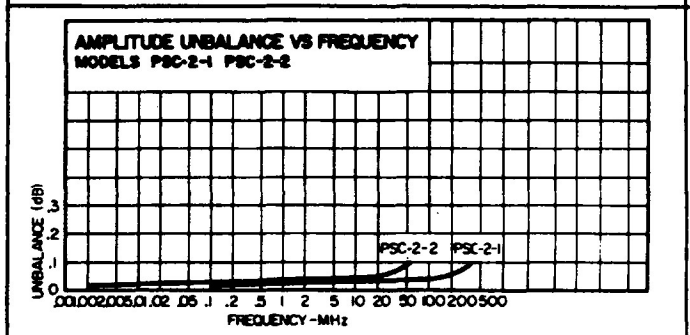
Delivery
From Stock, One week maximum

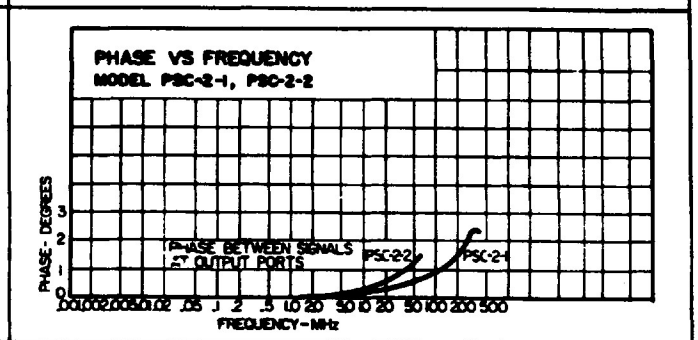
SPECIFICATIONS	MODEL PSC-2-2	
Frequency Range (MHz)	2KHz-60MHz	
Nominal Phase Difference Between Output Ports	0°	
Impedance, All Ports	50 ohms	
Isolation Between Output 1 & 2, dB	Typical	Minimum
15KHz-6MHz	40	30
2KHz-60MHz	27	20
Insertion Loss, dB (above 3dB split)	Typical	Maximum
10KHz-3MHz	.2	.4
2KHz-20MHz	.3	.6
20MHz-60MHz	.6	1.0
Phase Unbalance, degrees	Typical	Maximum
10KHz-3MHz	.5	2
2KHz-20MHz	1	3
20MHz-60MHz	2	4
Amplitude Unbalance, dB	Typical	Maximum
2KHz-20MHz	.05	.15
20MHz-60MHz	.1	.3
VSWR	1.2 typical	
Matched Power Rating	1 watt maximum	
Internal Load Dissipation	⅓ watt	
Price	**$19.95 (6-49)**	

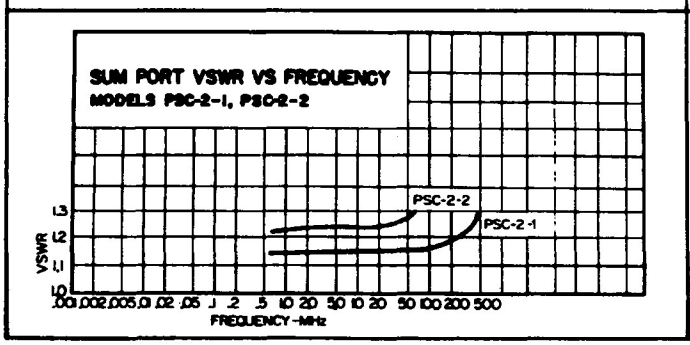
Delivery
From Stock, One week maximum

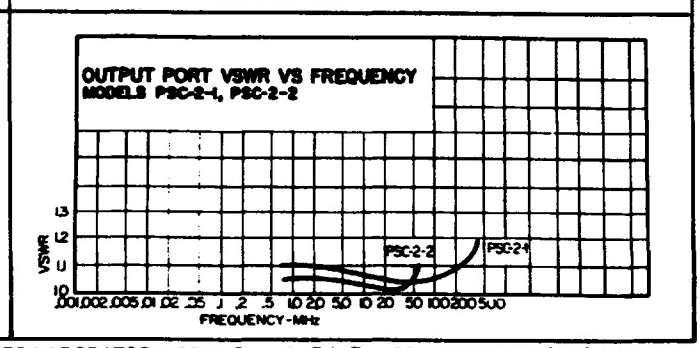












DOUBLE BALANCED MIXERS

STANDARD LEVEL (+7dBm LO)

SRA SERIES

MODEL	SRA-1	.5- 500 MHz
MODEL	SRA-1-1	.1- 500 MHz
MODEL	SRA-1W	1- 750 MHz
MODEL	SRA-2	1-1000 MHz
MODEL	SRA-4	5-1250 MHz
MODEL	SRA-3	.025- 200 MHz
MODEL	SRA-6	.003- 100 MHz

FOR CONNECTOR VERSION
SEE ZAD SERIES

FEATURES

MINIATURE SIZE, .128 CU. INCHES

BROAD FREQUENCY RANGE
3KHz - 1250MHz

HIGH ISOLATION 40 dB

LOW CONVERSION LOSS 6dB

HERMETICALLY SEALED METAL CASE

PC BOARD MOUNTING

LOW COST FROM $9.95
IN SMALL QUANTITIES

APPLICATIONS

FREQUENCY MIXING

PULSE AND AMPLITUDE MODULATION

PHASE DETECTION

CURRENT CONTROLLED ATTENUATION

FAST SWITCHING

BI-PHASE MODULATION

DESCRIPTION

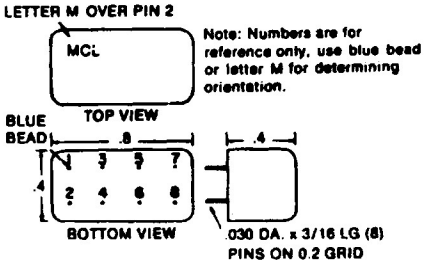
Having a volume of only .128 cu. inches, the SRA series covers a very broad frequency range from 3KHz to 1250MHz. Offered at the lowest prices available in the industry, these rugged units provide low conversion loss, 6 dB, high isolation 40 dB, and exceptional unit to unit matched performance.

Packaged within an RFI shielded metal enclosure and hermetically sealed header, these high performance units have their pins oriented on a 0.2 inch grid.

Ruggedness and durability are built into the SRA series. Only well matched hot-carrier diodes and ruggedly constructed transmission line transformers are used. Internally every component is bonded to the header and case with silicone rubber to provide super reliable protection against shock, vibration, and acceleration.

The model SRA-1 has become an industry standard throughout the world and is believed to be the number one volume leader. Used by all branches of the Department of Defense, NASA, FAA, and every major communications company, the SRA-1 has proven to be an industry work horse. Used in over 250 different military contracts, and over a period of years, enable sufficient history to establish the SRA-1 as one of the most reliable mixers obtainable, even when considering high priced models.

High reliability is associated with every SRA series mixer. Every production run is 100% tested and every unit must pass our rigid inspection and high quality standards. Naturally, our 1 year guarantee applies to these units.

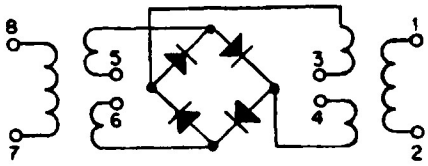


Note: Numbers are for reference only, use blue bead or letter M for determining orientation.

WEIGHT 5.2 grams .18 ounces

PIN CONNECTIONS

	SRA-1 SRA-1-1 SRA-1W* SRA-3	SRA-2 SRA-4	SRA-6
LO	8	8	8
RF	1	3,4	1
IF	3,4	1	3,4
Ground	2,5,6,7	2,5,6,7	2,5,6,7
Case Ground	2	*2,5,6,7	—



ABSOLUTE MAXIMUM RATINGS

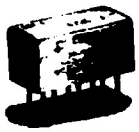
Total Input Power	50mW
Total Input, Current Peak	40mA
Operating & Storage Temperature	-55° C to +100° C

Pin Temperature (10 seconds) 510° F

DOUBLE BALANCED MIXERS

STANDARD LEVEL (+7dBmLO)

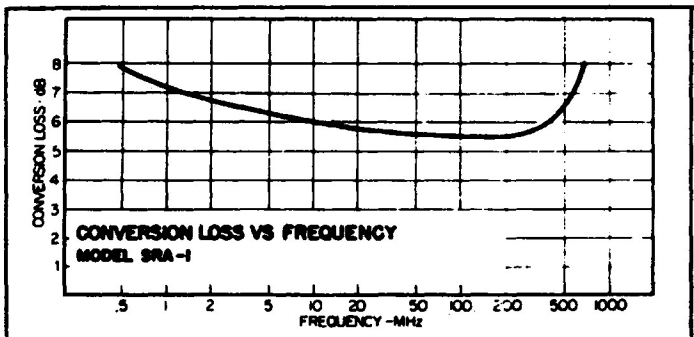
MODEL SRA-1 .5-500MHz

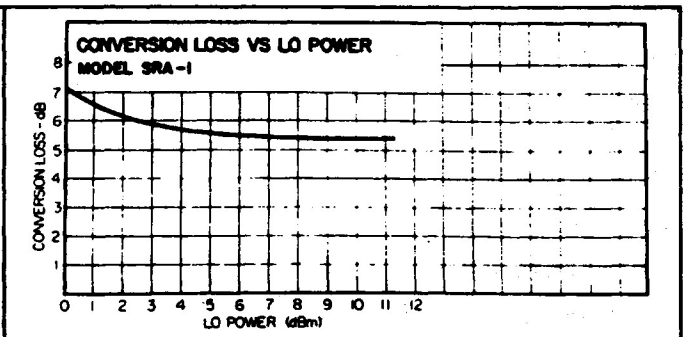


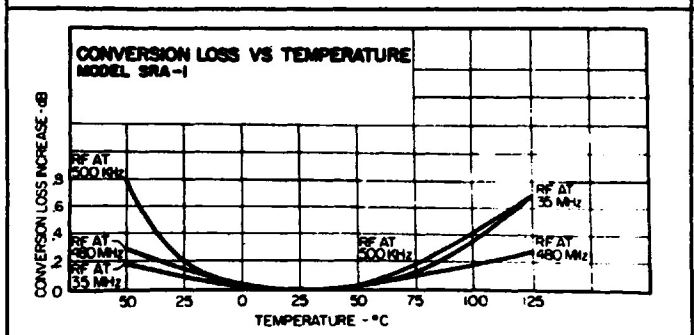
FOR CONNECTOR VERSION SEE ZAD SERIES

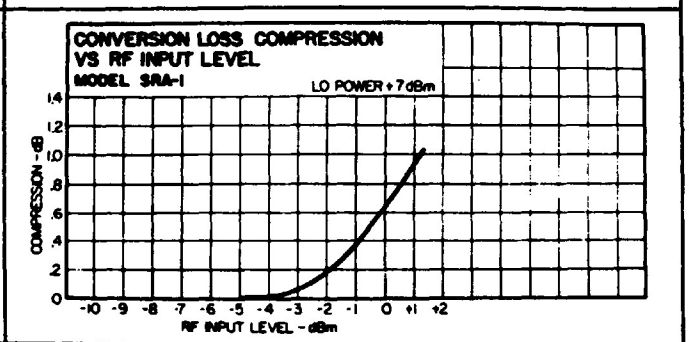
SPECIFICATIONS

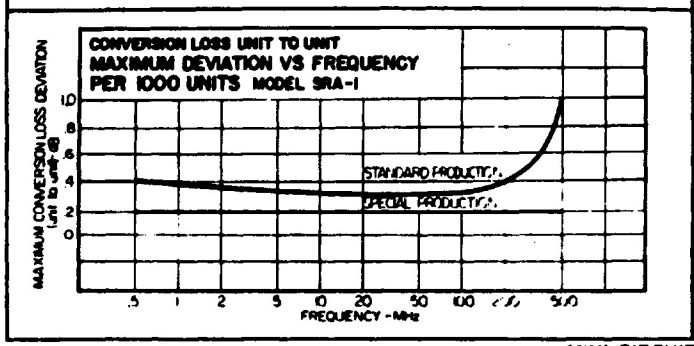
		MODEL SRA-1	
Frequency Range, MHz	LO	.5-500	
	RF	.5-500	
	IF	DC-500	
Conversion Loss, dB		Typical	Maximum
One Octave from Band Edge		5.5	7.5
Total Range		6.5	8.5
Signal, 1dB Compression Level	+1dBm		
Isolation, dB		Typical	Minimum
Lower Band Edge to One Decade Higher	LO-RF	50	35
	LO-IF	45	30
Mid Range	LO-RF	45	30
	LO-IF	40	25
Upper Band Edge to One Octave Lower	LO-RF	35	25
	LO-IF	30	20
Impedance, All Ports		50 ohms	
Phase Detection			
DC Offset		1mV typical	
DC Polarity		Negative	
Electronic Attenuation			
Minimum Attenuation (20mA)		3dB	
Price		$9.95 (6-49)	
Delivery		From Stock, One week maximum	

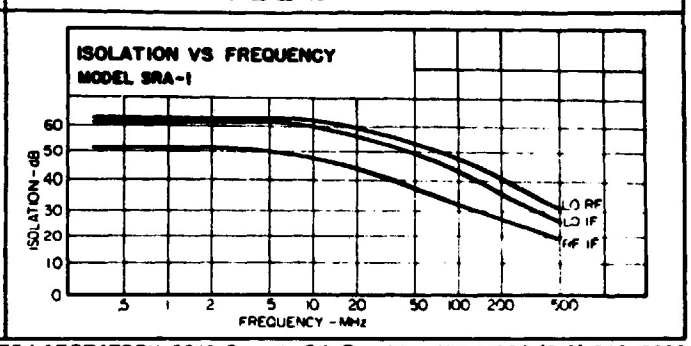


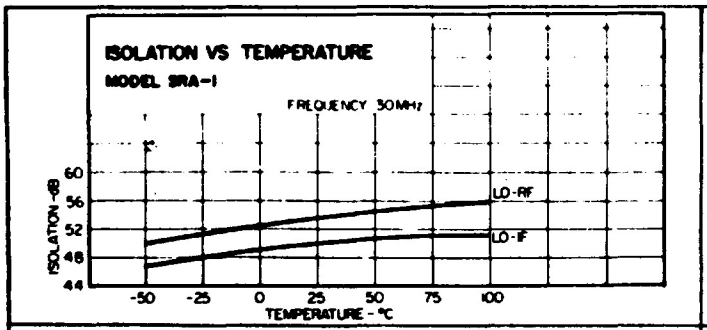


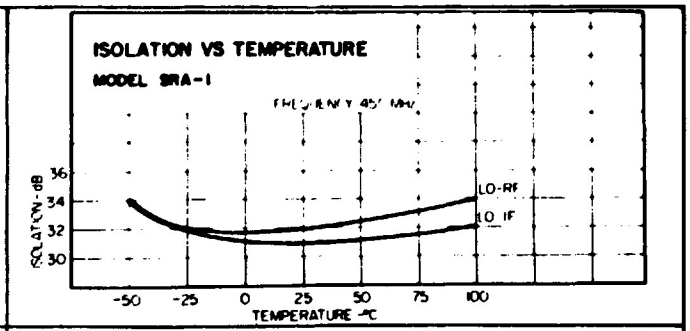


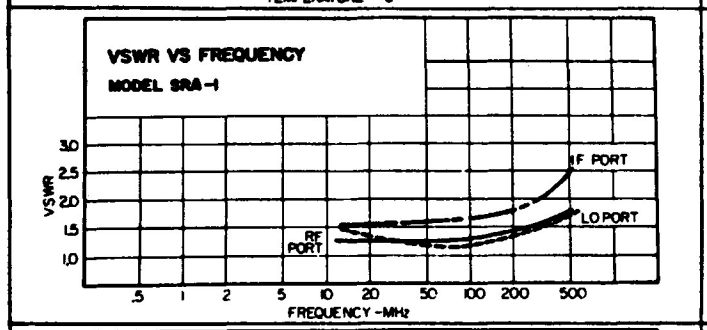


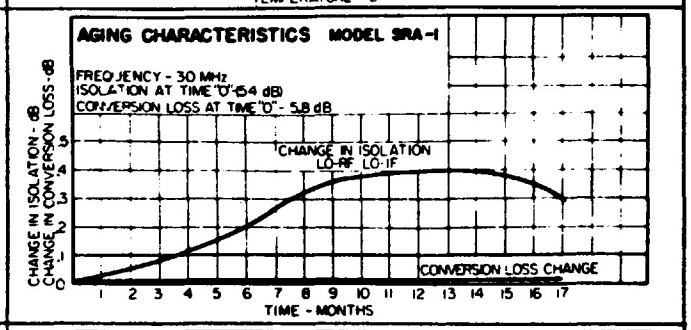


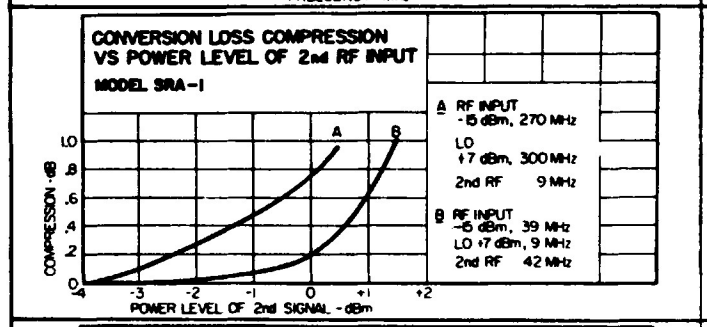


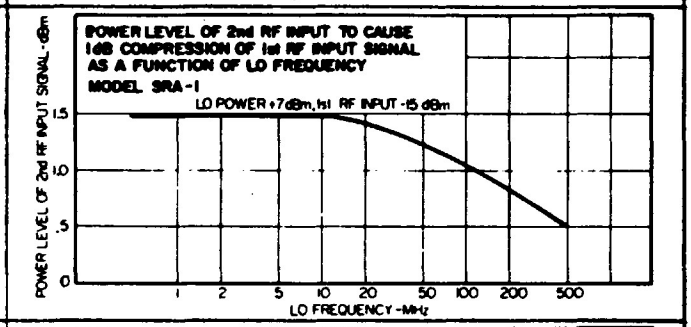

ISOLATION VS TEMPERATURE
MODEL SRA-1
FREQUENCY 30 MHz
LO-RF
LO-IF
ISOLATION - dB
TEMPERATURE - °C

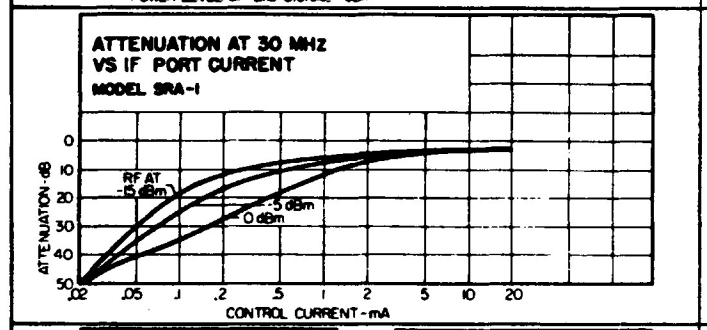

ISOLATION VS TEMPERATURE
MODEL SRA-1
LO-RF
LO-IF
ISOLATION - dB
TEMPERATURE - °C

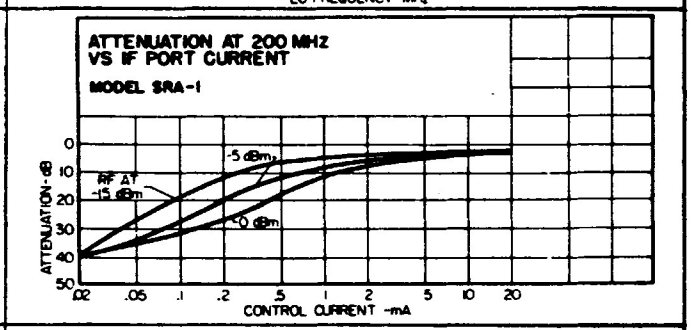

VSWR VS FREQUENCY
MODEL SRA-1
IF PORT
LO PORT
RF PORT
VSWR
FREQUENCY - MHz

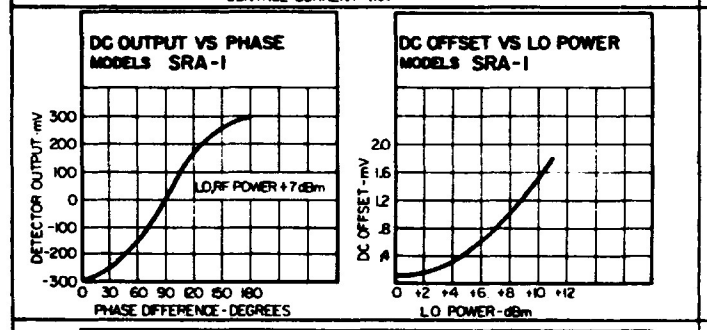

AGING CHARACTERISTICS MODEL SRA-1
FREQUENCY - 30 MHz
ISOLATION AT TIME "0" - 54 dB
CONVERSION LOSS AT TIME "0" - 5.8 dB
CHANGE IN ISOLATION LO-RF, LO-IF
CONVERSION LOSS CHANGE
CHANGE IN ISOLATION - dB
CHANGE IN CONVERSION LOSS - dB
TIME - MONTHS

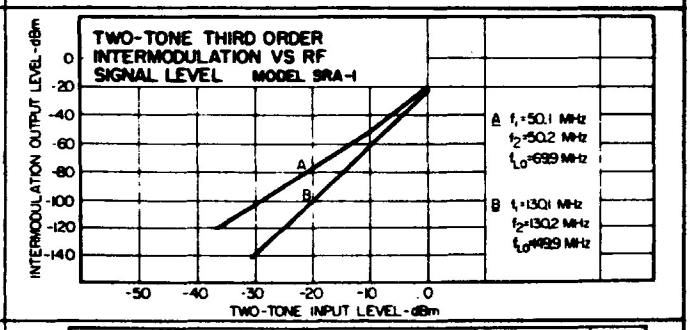

CONVERSION LOSS COMPRESSION VS POWER LEVEL OF 2nd RF INPUT
MODEL SRA-1
A RF INPUT -15 dBm, 270 MHz
LO +7 dBm, 300 MHz
2nd RF 9 MHz
B RF INPUT -15 dBm, 39 MHz
LO +7 dBm, 9 MHz
2nd RF 42 MHz
COMPRESSION - dB
POWER LEVEL OF 2nd SIGNAL - dBm

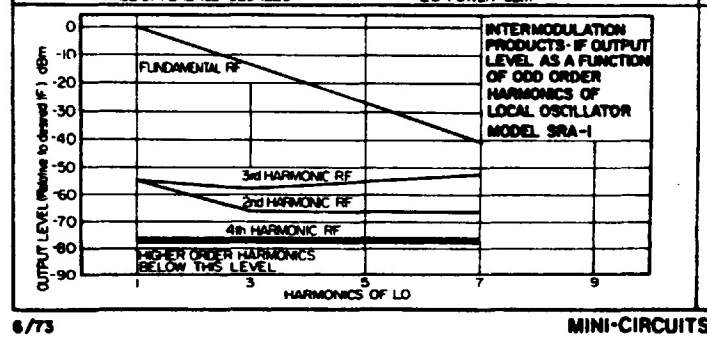

POWER LEVEL OF 2nd RF INPUT TO CAUSE 1dB COMPRESSION OF 1st RF INPUT SIGNAL AS A FUNCTION OF LO FREQUENCY
MODEL SRA-1
LO POWER +7dBm, 1st RF INPUT -15 dBm
POWER LEVEL OF 2nd RF INPUT SIGNAL - dBm
LO FREQUENCY - MHz

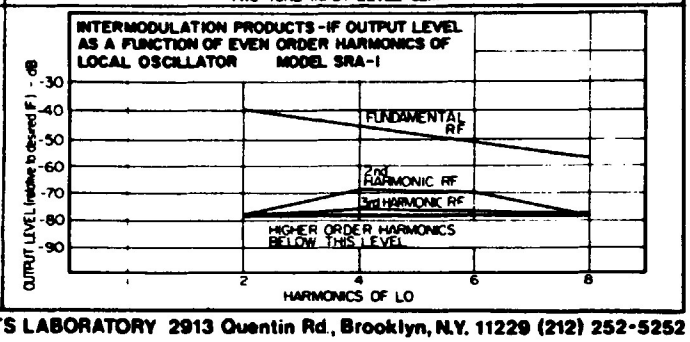

ATTENUATION AT 30 MHz VS IF PORT CURRENT
MODEL SRA-1
RF AT -15 dBm
-5 dBm
0 dBm
ATTENUATION - dB
CONTROL CURRENT - mA


ATTENUATION AT 200 MHz VS IF PORT CURRENT
MODEL SRA-1
RF AT -15 dBm
-5 dBm
0 dBm
ATTENUATION - dB
CONTROL CURRENT - mA


DC OUTPUT VS PHASE
MODELS SRA-1
LO/RF POWER +7 dBm
DETECTOR OUTPUT - mV
PHASE DIFFERENCE - DEGREES
DC OFFSET VS LO POWER
MODELS SRA-1
DC OFFSET - mV
LO POWER - dBm

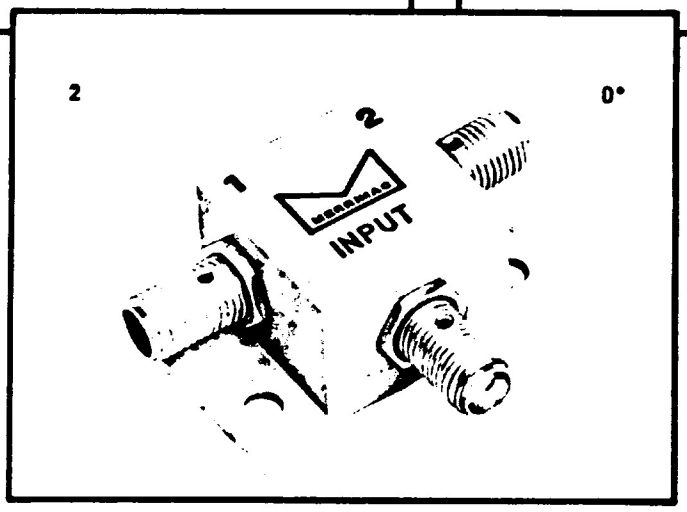

TWO-TONE THIRD ORDER INTERMODULATION VS RF SIGNAL LEVEL MODEL SRA-1
A f1=50.1 MHz f2=50.2 MHz fLO=69.9 MHz
B f1=130.1 MHz f2=130.2 MHz fLO=149.9 MHz
INTERMODULATION OUTPUT LEVEL - dBm
TWO-TONE INPUT LEVEL - dBm


INTERMODULATION PRODUCTS - IF OUTPUT LEVEL AS A FUNCTION OF ODD ORDER HARMONICS OF LOCAL OSCILLATOR
MODEL SRA-1
FUNDAMENTAL RF
3rd HARMONIC RF
2nd HARMONIC RF
4th HARMONIC RF
HIGHER ORDER HARMONICS BELOW THIS LEVEL
OUTPUT LEVEL (relative to desired IF) - dBm
HARMONICS OF LO


INTERMODULATION PRODUCTS - IF OUTPUT LEVEL AS A FUNCTION OF EVEN ORDER HARMONICS OF LOCAL OSCILLATOR MODEL SRA-1
FUNDAMENTAL RF
2nd HARMONIC RF
3rd HARMONIC RF
HIGHER ORDER HARMONICS BELOW THIS LEVEL
OUTPUT LEVEL (relative to desired IF) - dB
HARMONICS OF LO

ULTRA-WIDEBAND POWER DIVIDER
MINIATURE TWO-WAY
5 MHz-1000 MHz

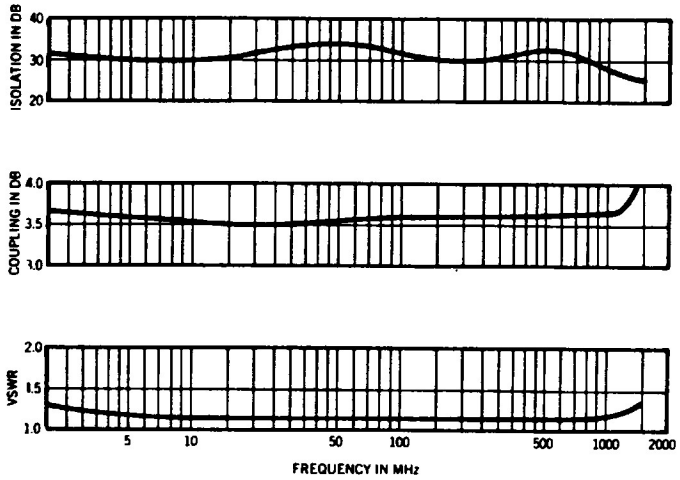
MODEL PDM-20-500



Merrimac's new miniature ultra-broadband power divider is extremely versatile for the following applications:

- **HF/VHF/UHF avionics**
- **LO power division**
- **VOR/glide slope systems**
- **Instrument landing systems**
- **Image reject mixers**
- **Antenna couplers**

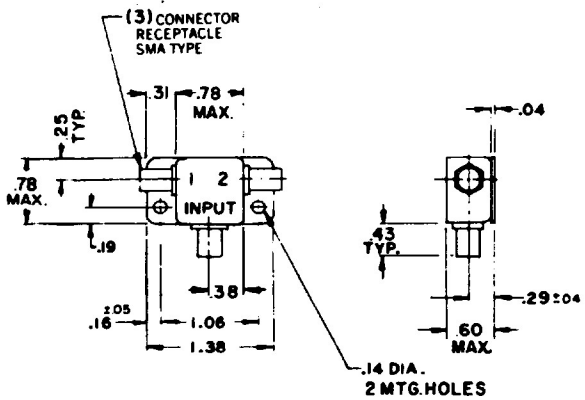
TYPICAL CHARACTERISTICS MODEL PDM-20-500



MINIMUM PERFORMANCE SPECIFICATIONS

MODEL:	**PDM-20-500**
Frequency Range:	5-1000 MHz
Coupling:	—3 db
Isolation:	25 db
Amplitude Balance:	0.2 db
Phase Balance:	2.0°
Insertion Loss:	0.7 db
Impedance:	50 ohms
VSWR:	1.3:1
Power (matched loads):	1 watt
Connectors (3):	SMA Female
Weight:	1 oz. (28 grams)
PRICE:	**$70.00**

OUTLINE OF PDM-20-500



For latest outline details, be sure to contact Merrimac.

Also available in other configurations, impedances, and with other connectors.

Prices and specifications subject to change without notice.

MERRIMAC INDUSTRIES, INCORPORATED
41 FAIRFIELD PLACE, WEST CALDWELL, N. J. 07006 • (201) 228-3890 • TWX 710-734-4314

SHIELDING BEADS AND CHOKES

FERROXCUBE Ferrite Shielding Beads and Chokes offer a convenient, simple, and inexpensive means for obtaining effective RF decoupling, shielding, and parasitic suppression, without an attendant sacrifice in DC or low-frequency power.

Supply leads and circuit conductors adjacent to a chassis or to other conductors, in radio, TV, and other electronic equipment, frequently offer convenient paths for the transfer of unwanted RF energy from one circuit to another; their distributed capacitance and inductance can also cause generation of spurious oscillations within the circuitry, particularly at the higher frequencies. The use of capacitive decoupling, and/or series inductance to minimize these phenomena is seldom completely successful, and may actually contribute to the problem in some cases. Ferrite beads and chokes avoid the weaknesses inherent in the technique, and contribute advantageous properties of their own, without introducing mechanical or electrical complexities into the system.

ELECTRICAL AND MAGNETIC PROPERTIES OF FERROXCUBE FERRITE MATERIAL FOR BEADS AND CHOKES
(Measurements Performed on Standard Pressed Toroids)

Materials	3B	4A	4B
Initial Permeability μ_0 at 20°C.	900 ±20%	600 ±20%	250 ±20%
Flux density in gauss, ballistically measured at a field intensity (in oersteds) of:	10	10	20
at 20°C approx.	3400	2900	3300
at 100°C approx.	2300	1800	2700
Saturation value (at H = 2000 Oe and T = 20°C):	4500	3600	4200
Temperature Factor $\Delta\mu/\mu^2\,\Delta T$ (between 20 and 50°C)	3×10^{-6}	6×10^{-6}	8×10^{-6}
Curie point (°C) min.	150	125	250
Minimum specific DC resistance at 20° C (ohm CM)	20	10^5	10^5
Linear expansion coefficient	Approximately 10^{-5}/°C.		
Specific weight (g/cm³)	4.7-4.9	4.6-5.0	4.4-4.8

SHIELDING BEADS

Ferroxcube Shielding Beads are made of medium-permeability ferrite, in a variety of material grades and sizes. By simply stringing these beads on power supply leads or circuit conductors, excellent high-frequency isolation between stages is readily obtained (see graph in Figure 1 below), and a continuous string of the beads constitutes a highly effective magnetic shield for the section of conductor that they cover, as well, the ferrite material acting as a lossy medium for high frequency fields existing in the circuitry of the conductor. One or more beads strung on a grid (or base) input lead presents an appreciable series impedance, and increases the loading and absorption loss, to the higher frequencies, effectively reducing the open loop gain and suppressing the tendency to parasitic oscillation in this region, without increasing the circuit impedance to DC and low frequencies.

The beads may be used in conjunction with small ceramic capacitors in "damping" circuits to provide additional rejection at the self-resonant frequency of the capacitor. (See Figure 2 below.)

$$20 \log_{10} \frac{V_1}{V_2} = 20 \log_{10} \omega C Z_\omega$$

where $Z_\omega \gg \frac{1}{\omega C}$ and $R_L \gg \frac{1}{\omega C}$

Note that where twin leads are accessible, double-bore beads may be utilized, to take advantage of mutual inductance, for additional isolation and suppression, without detriment of the DC and low-frequency circuit performance.

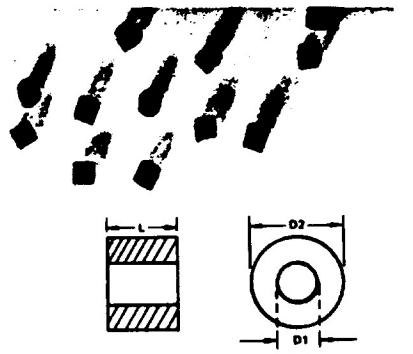


FIGURE A. SINGLE-HOLE BEAD

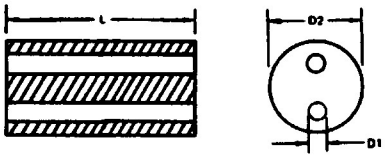


FIGURE B. DOUBLE-HOLE BEAD

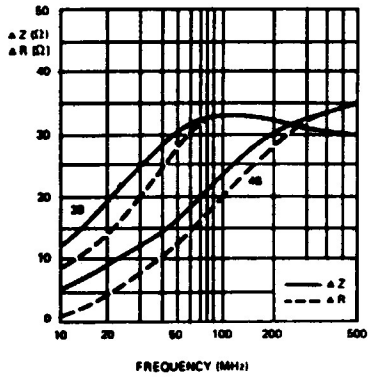


Figure 1. Performance of 56 590 65/3B and 56 590 65/4B beads. Note that the impedance of the 3B material is substantially resistive above 60 megahertz.

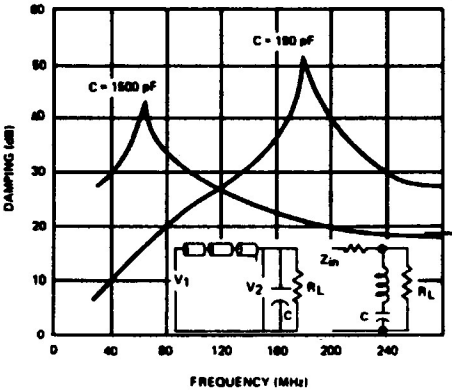


Figure 2. Typical damping curves for three 56 590 65/3B beads with additional parallel ceramic capacitor.

SHIELDING BEAD DIMENSIONS

FERROXCUBE PART NUMBER*	DIMENSIONS (INCHES) (See figures above)			
	D1	D2	L	FIG.
56 590 65/3B	.047 ± .008	.138 ± .008	.118 ± .008	A
56 590 65/4A	.047 ± .008	.138 ± .008	.118 ± .008	A
56 590 65/4B	.047 ± .008	.138 ± .008	.118 ± .008	A
K5 001 00/3B	.059 ± .008	.138 ± .008	.118 ± .008	A
56 390 31/4B**	.059 ± .008	.220 ± .012	.472 ± .016	B

*The core material is given in the part number: i.e., for 56 590 65/3B, the material designation is 3B.
**Has 2 Holes.

LIST OF FIGURES

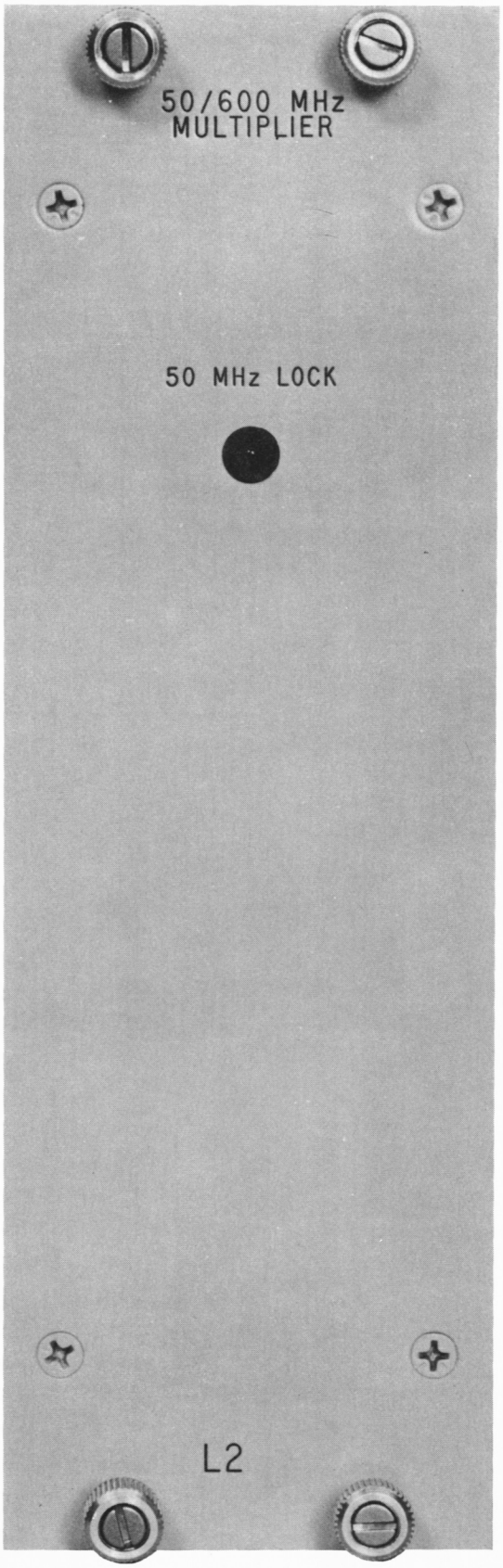


FIGURE 1 FRONT VIEW – 50/600 MHz MULTIPLIER

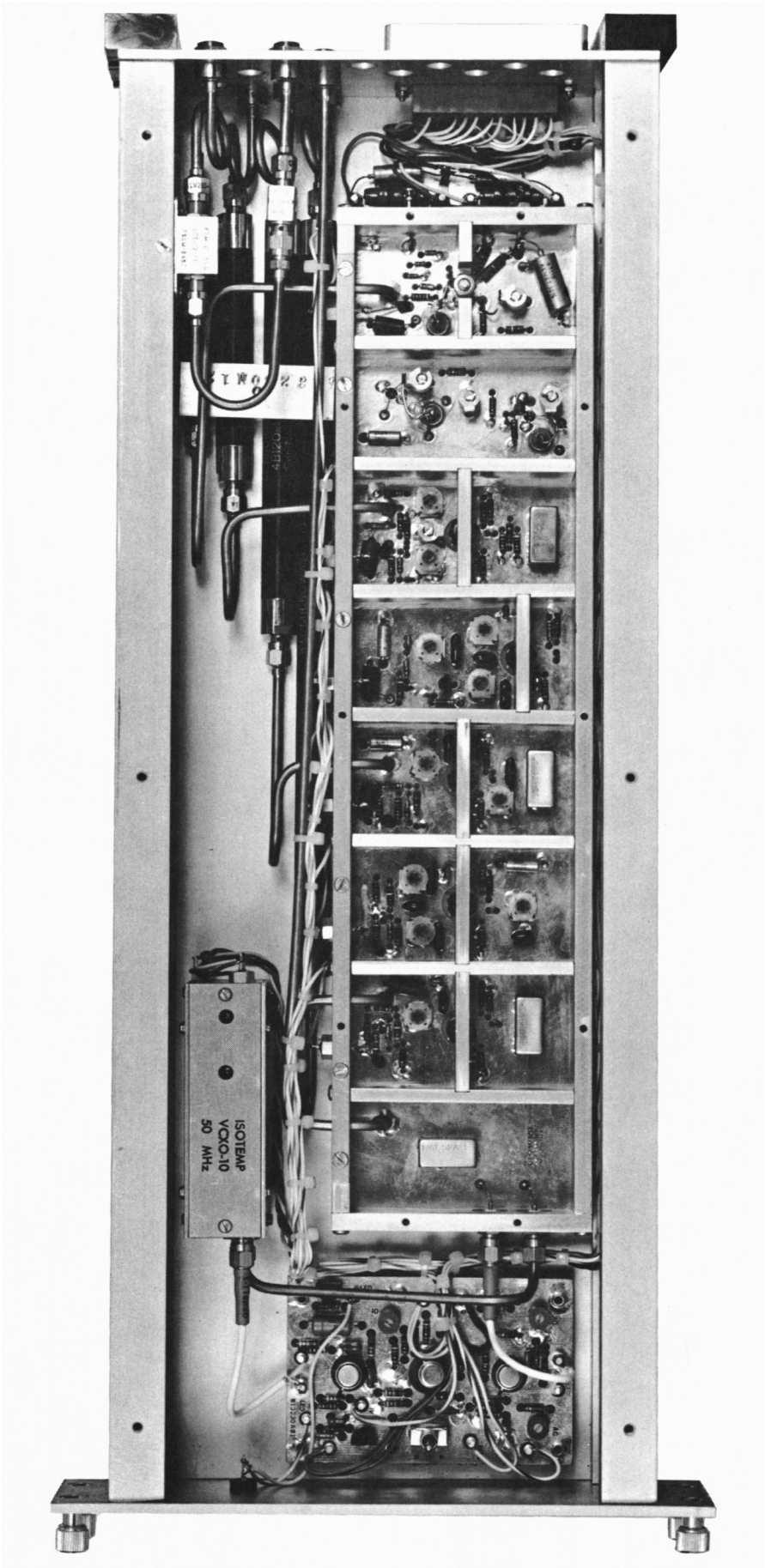


FIGURE 2 SIDE VIEW – 50/600 MHz MULTIPLIER

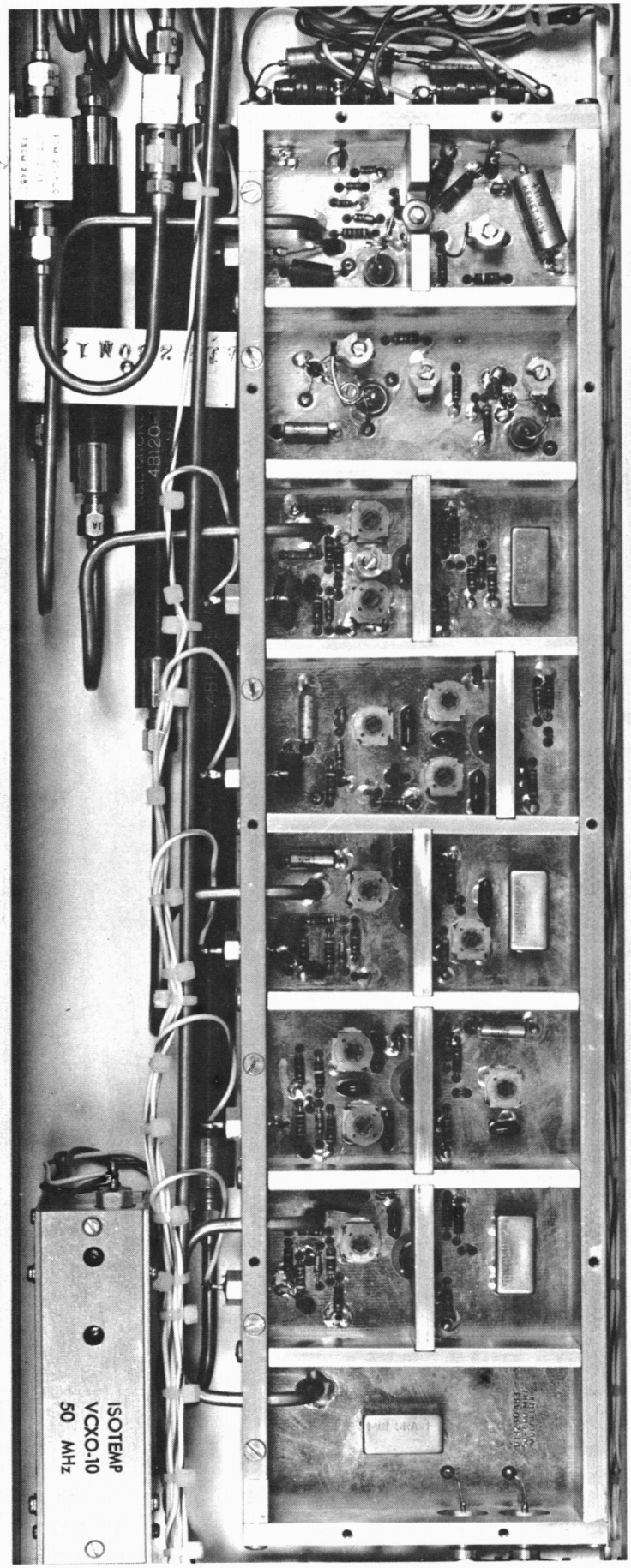
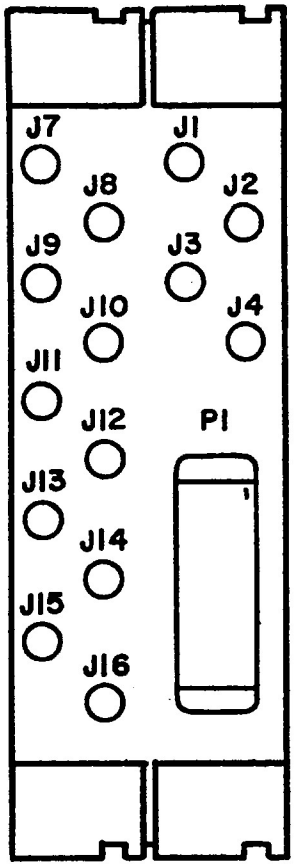
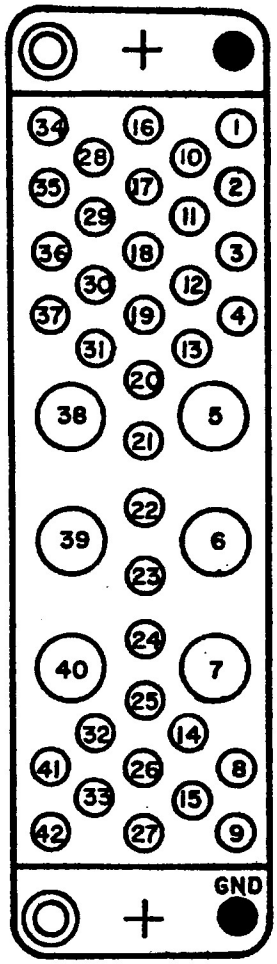


FIGURE 3 CLOSE-UP VIEW – X12 MULTIPLIER ASSY.



DOUBLE WIDE MODULE
(REAR VIEW)

CONN	FUNCTION
J1	
J2	200 MHz OUT
J3	100 MHz OUT
J4	50 MHz OUT
J7	+17600 MHz OUT
J8	
J9	+ 7600 MHz OUT
J10	50 MHz IN
J11	
J12	
J13	
J14	
J15	
J16	



P1 (REAR VIEW)

P1

PIN	FUNCTION	WIRE COLOR	PIN	FUNCTION	WIRE COLOR
1			22	ϕERROR IND	
2			23	LOOP MONITOR	
3			24	600 MHz MON.	
4			25	200 MHz MON.	
5			26	100 MHz MON.	
6			27	50 MHz MON.	
7			28	−28VDC	GREEN
8			29	+28VDC	GREY
9			30		
10	+5VDC	ORANGE	31		
11	−5VDC	BROWN	32		
12			33		
13			34	PWR. GROUND	BLACK
14			35		
15			36		
16	+15VDC	RED	37		
17	−15VDC	YELLOW	38		
18			39		
19	100 MHz MON.		40		
20	200 MHz MON.		41		
21	OPEN/CLOSE		42	HIGH QUAL. GROUND	

Fig. 4. Module rear connections and pin assignments, L2.