VLA TECHNICAL REPORT NO. 40

R.F. TO I.F. CONVERSION SUBSYSTEM:
Modules F4 (Frequency Converter),
F7 (Front End I.F. Filters) and
F8 (I.F. Offset)

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October 1979

Blue Binder - Yellow, Silver, Gray Tape

Printing History:

Revision 0:

Issued October 1, 1979

Modules covered are designed F4-C, F7-A, F8-A

FOREWORD

The original VLA Front End included a single frequency conversion from R.F. to I.F. for each channel. This was accomplished in the Frequency Converter module (F4), series A, designed by S. Weinreb and described in VLA Technical Report No. 7, July 1975. However, it was recognized that this arrangement had a possible spurious response (see Section 3 of the above referenced report, and Section 3.2.1 of the present report), and that the selectivity might not be sufficient to reject strong interfering signals near the observing frequency. Furthermore, the response could not be restricted to the protected radio astronomy bands except by filters far downstream at the Control Building.

It was thus decided, in 1976, to implement the present scheme, starting from a preliminary design study by A. R. Thompson (VLA Electronics Memorandum No. 137, April 1976). Spurious responses were greatly reduced, and additional selectivity with user-selectable bandwidths was added. In the process, other advantages were gained: only two 2-4 GHz synthesized L.O. signals are needed for the four channels; the selective filters were specified to be particularly phase stable; and the use of a common first I.F. for the four channels enabled the ALC attenuator to introduce less phase variation.

The detailed design effort was not undertaken until early 1978, when D. S. Bagri and J. Campbell constructed prototype F7 and F8 modules. I took over the project in late 1978, eventually evolving a design which meets the specifications of Section 2.

Thus, the efforts of S. Weinreb, A. R. Thompson, D. S. Bagri, and J. Campbell are gratefully acknowledged. Much of S. Weinreb's design of the F4 module has been carried over to the present version.

This design effort also uncovered the need to tighten the gain specifications for the Front End subsystem. Discussions with P. Napier and P. Lilie have been helpful in this regard.

Finally, I want to acknowledge the administrative, budgetary and moral support given by P. Napier throughout this project; it would have been less successful without this.

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FIGURES

1. FUNCTIONAL DESCRIPTION

Refer to the subsystem block diagram, Figure 1.1.

The R.F. to I.F. conversion subsystem accepts broadband noise signals in the 4.5 to 5.0 GHz (R.F.) band from the receivers and delivers a composite I.F. signal, containing four frequency-multiplexed channels in the 1.3 to 1.7 GHz band, to the waveguide communication channel for transmission to the Control Building. There are four input signals, two from the AB receiver and two from the CD receiver, delivered by the R.F. Splitter module (F6). From each of these 500 MHz bandwidth signals, a band of width 55, 25 or 12 MHz is selected and converted to one of the output channel frequencies.

The subsystem is implemented in 9 modules, with one Frequency Converter module (F4) and one I.F. Filter module (F7) for each I.F. channel, and a single I.F. Offset module (F8) containing circuitry for all channels. Figure 1.1 shows the complete block diagram only for channel A, since all channels are similar. The modules are mounted in Bin G (F4's) and Bin F (F7's and F8) of Rack A, which also contains the cooled front ends.

Double conversion is used to suppress a possible spurious response (see Section 3.2.1). The first I.F. is centered at 1025 MHz for all channels, and is obtained by mixing the input with a 3490 to 3990 MHz L.O. from the 2-4 GHz Synthesizer module (L6) in Rack B. The latter L.O. is tunable in steps of 20 and 30 MHz, and this sets the channel frequency within the R.F. band. The channel bandwidth is determined by a filter at the first I.F.; three bandwidths are selectable via computer-generated commands (transmitted through the Data Set, M1, and Control Interface, F5). Normally, the widest bandwidth (55 MHz to -3 dB) should be used for best flatness and phase stability, but the narrower bandwidths may be useful for rejecting interference close to the observing frequency.

A second mixer upconverts the 1025 MHz first I.F. to one of the four I.F. channels, centered at 1325, 1425, 1575, and 1675 MHz, re-

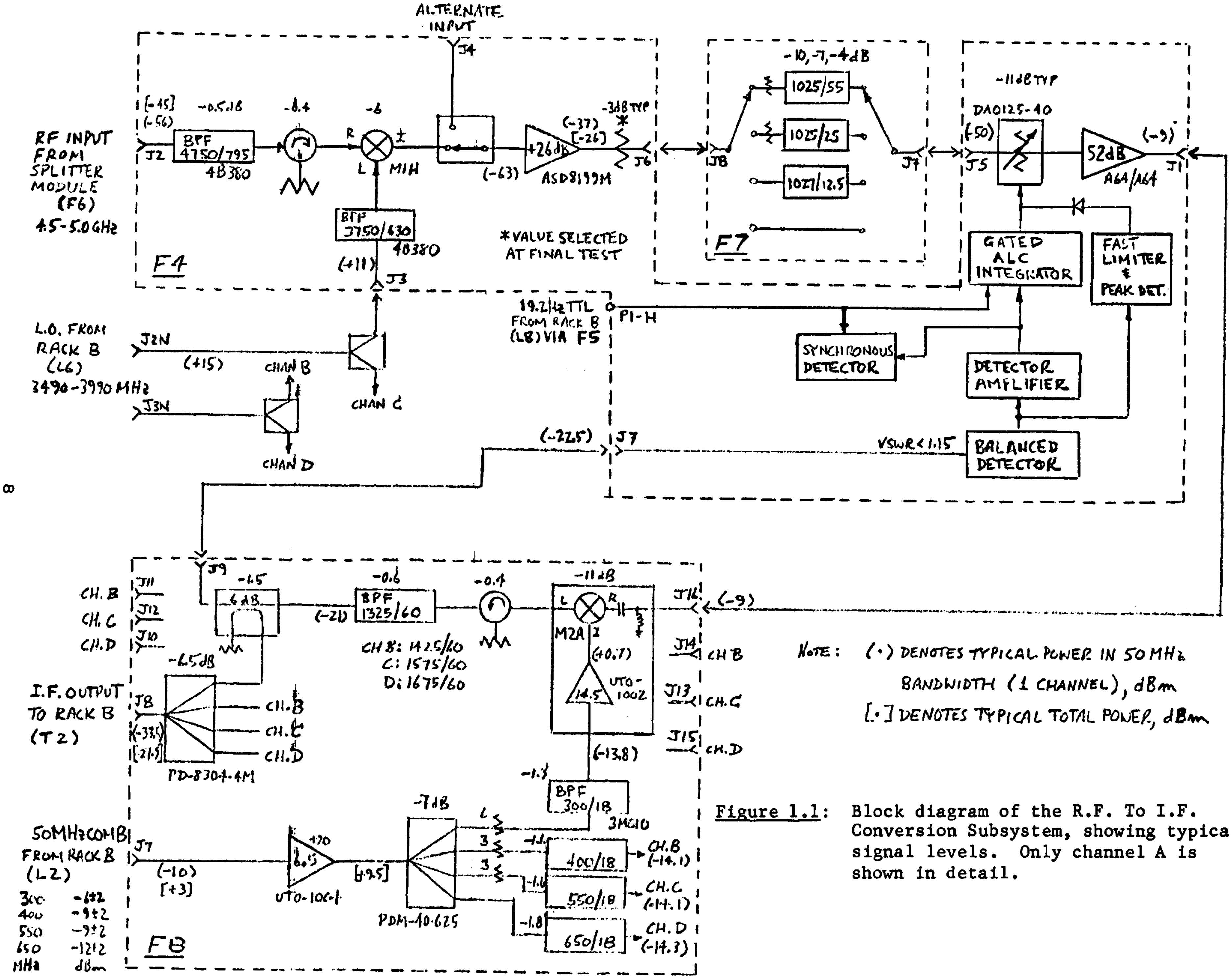


Figure 1.1: Block diagram of the R.F. To I.F. Conversion Subsystem, showing typical signal levels. Only channel A is shown in detail.

spectively. This mixer uses fixed-frequency L.O. signals derived from a comb spectrum supplied by the 50 MHz Harmonic Generator module (L2) in Rack B. Finally, the four channels are summed in a power combiner and the composite signal is delivered to the I.F. Combiner module (T2) in Rack B.

Before combining the I.F. signals, a portion of each is delivered to a square-law detector, whose output is used for several purposes. First, it closes an ALC loop by adjusting the gain at the first I.F. This loop is gated in synchronism with the switching of a noise source at the receiver input, so the loop does not respond to this deliberately-imposed level change. Second, the portion of the detector output due to the noise source switching is synchronously detected, providing a measure of the gain and noise temperature to this point in the signal processing. Third, a threshold limiter rapidly reduces the gain if the signal gets about 3 dB above its normal level; this is intended to gate out strong interference which has a short duty cycle.

2. SPECIFICATIONS

The subsystem is designed to meet the specifications of Table I. The most difficult of these have been the phase variation with temperature (maximum 0.3°/C; see also Section 3.5) and the gain variation with frequency (maximum 0.5 dB peak-to-peak; see also Section 3.6).

The input power spectral density range is that for which all specifications are expected to be met. Lower levels will result in wide-open ALC loop operation and hence low output power. Higher levels can be accommodated by the ALC loop, but the phase variation with input power will be larger (due to the ALC attenuator); also, at about -32 dBm/50 MHz (-22 dBm/500 MHz) significant gain compression can occur in the first amplifier of F4. The specified range should be sufficient to accommodate the present four-band VLA front ends, with reasonable gain tolerances and with system temperatures up to twice nominal.

The input noise figure specification ensures that the subsystem adds less than 1% to the system temperature at 6 cm. About 10 dB better than this is typically being achieved.

The L.O. input levels and tolerances are based on measurements of levels actually produced at antennas 1 through 17. All L2 and L6 modules must now meet these requirements; however, the tolerances are wide enough so that this should cause no difficulty.

TABLE I: SUBSYSTEM SPECIFICATIONS

Input power spectral density (4.5-5.0 GHz)		-58 to -48 dBm/50 MHz
Input noise figure; noise temperature		<21.4 dB; <4x10^{4} K
Output power, each I.F. channel (at F8-J8)		-33.5±1 dBm
Phase variation with temperature at 55 MHz bandwidth		<0.3°/C
Phase variation with input power		<1°/dB
Gain variation with frequency, each channel		<0.5 dB peak-to-peak
First L.O. (3.5-4.0 GHz) input		+11±3 dBm
Second L.O. (50MHz comb) input	300 MHz	-6±2 dBm
	400	-9±2
	550	-9±2
	650	-12±2

3. THEORY OF OPERATION

3.1 SIGNAL LEVELS AND REQUIRED GAINS

Figure 3.1 is a block diagram of the major R.F. components in Rack A, showing the gain of each and the signal levels at certain points. Only one of the two front end subsystems, and one of the four R.F.-to-I.F. conversion channels, is shown. When operating on the 6-cm band, the system temperature referred to the 6-cm input is expected to be near 50 K. This corresponds to a power spectral density of -104.2 dBm/55 MHz. Since we must supply -34.0 dBm per channel to module T2, a net gain of 70.2 dB is required. However, the signal processing involves the losses of two frequency conversions, power dividing and combining, level-setting and ALC attenuators, and filtering; it is thus necessary to provide about 145 dB of amplification.

Determining the gain requirements of the subsystem is complicated by the need to operate on four bands and over a range of system temperatures, and by the nonzero tolerances on the component gains. At 2 cm and 1.3 cm, the conversion losses of the mixers are not accurately known because they are tuned for minimum receiver temperature without regard to conversion loss, and the diodes show considerable variation in the conversion loss at which this occurs.

We can discuss the gain requirements in terms of the attenuation needed in the variable attenuator in F4, which is controlled by the ALC loop. Using the gains and tolerances of Figure 3.1, one can calculate the necessary range of attenuation as a function of T_s', the system temperature referred to the band switch input; this is plotted in Figure 3.2.

At 6 cm, T_s' is essentially the input system temperature, T_s. At the other bands, T_s' is higher than T_s by the upconverter's or downconverter's gain and its intrinsic noise. The range of T_s' indicated in Figure 3.1 for each band is based on the results in Table II. In the table, the maximum usable receiver temperatures T_R are some-

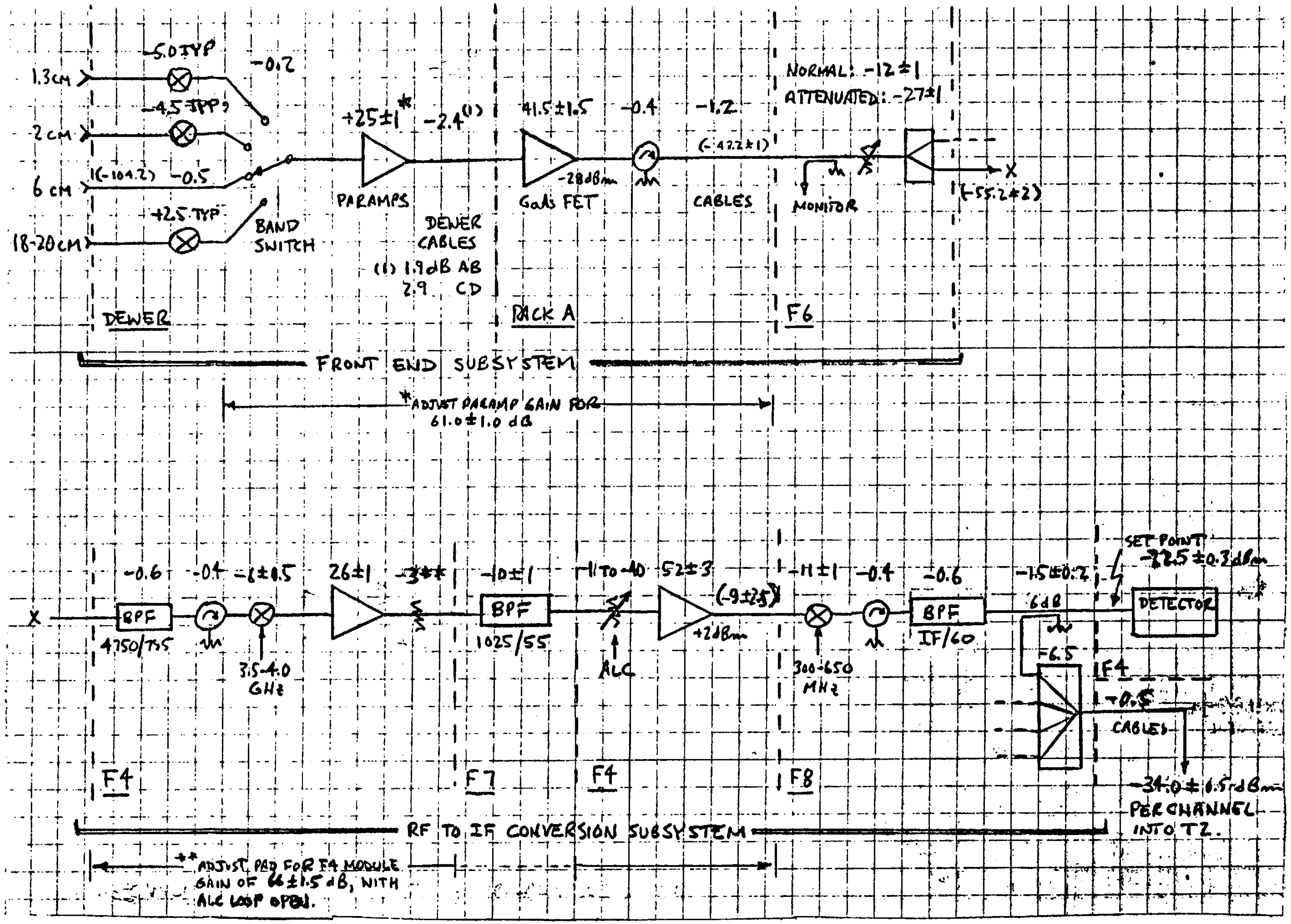


Figure 3.1: Simplified block diagram of Rack A, with gains and signal levels. Numbers in parentheses are power spectral densities in dBm/55MHz at 6 cm band with system temperature of 50K.

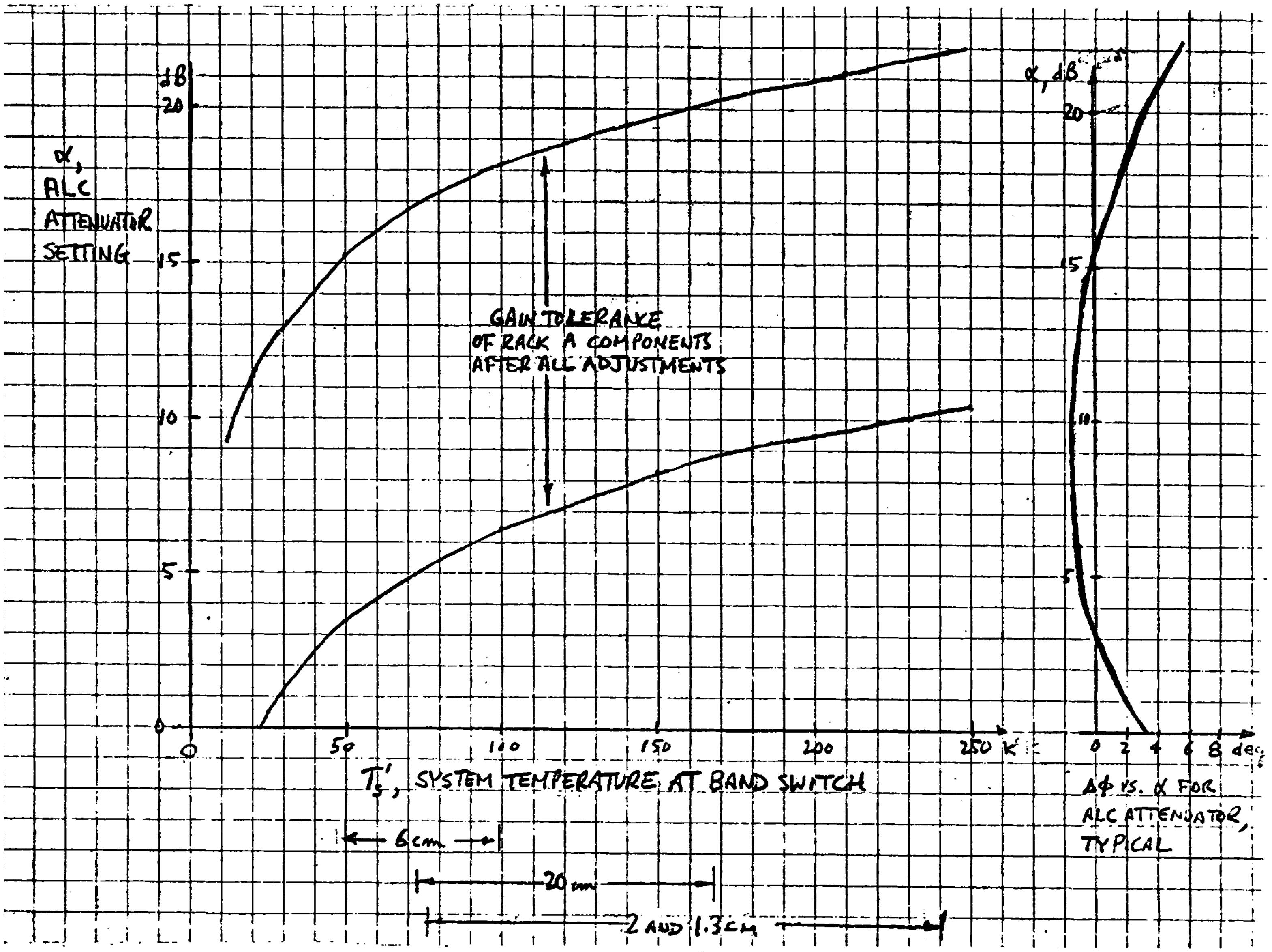


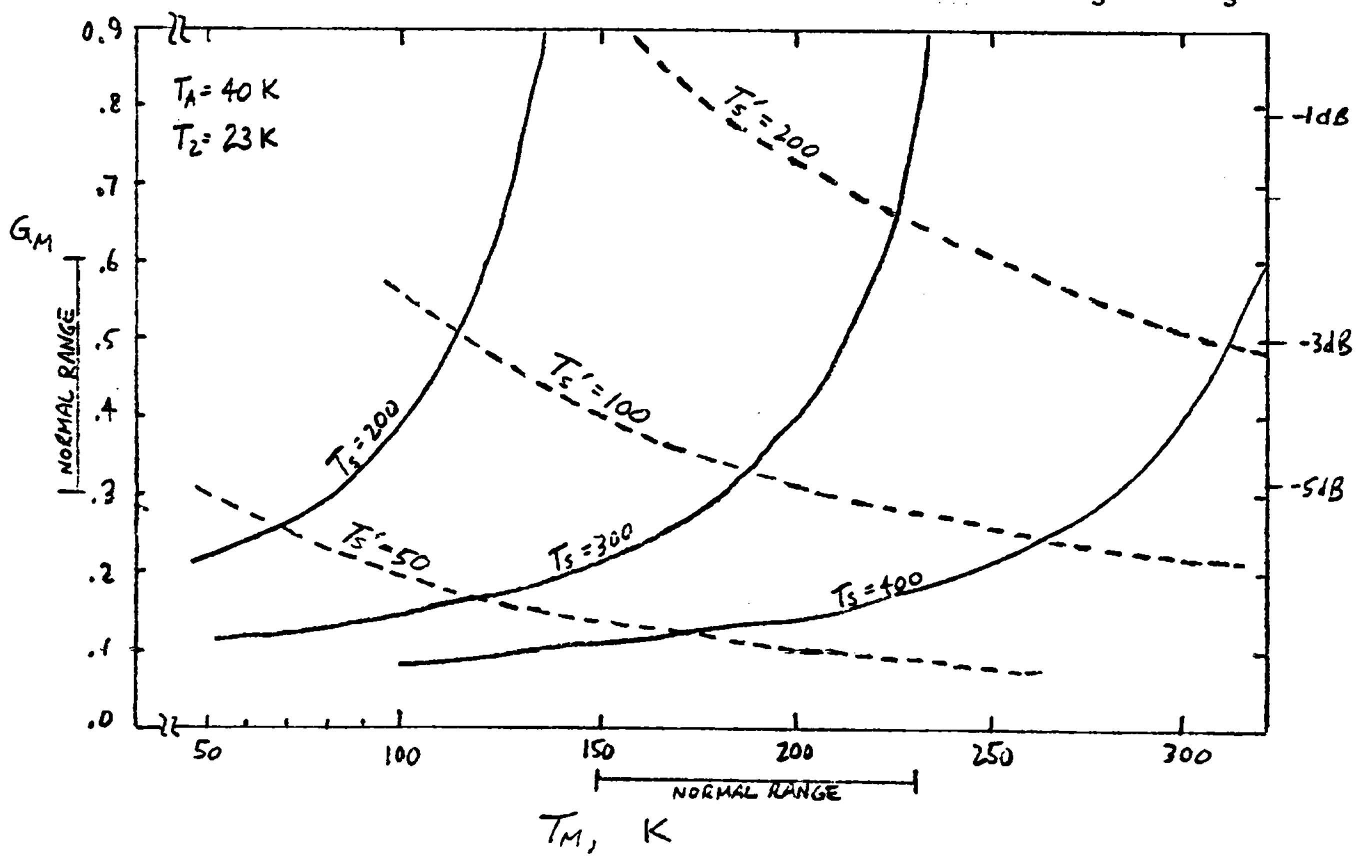
Figure 3.2: Range of attenuation as a function of T_s'.

TABLE II: EXPECTED SYSTEM TEMPERATURES

Band	T_R(normal) [1]	T_R(max.usable)	T_A(zenith) [1]	T_A(el=10°) [2]	T_s	T_s'	$\Delta T_s/S$ [1]
18-21 cm	18 K	40 K	30 K	44 K	48-94 K	74-170 K	.09 K/Jy
6	25	60	24	38	49-98	49-98	.12
2	200	350	40	59	240-410	75-210	.09
1.3	240	350	50	120	290-470	75-240	.08

Refs: [1] Weinreb, S. et al., IEEE Trans. on Microwave Thy. & Tech., MTT-25, 243 (1977).
[2] Based on measurements by Vandenberg, N., VLA Test Memorandum No. 122 (1977).

what arbitrary estimates of the highest values that will be tolerated before an antenna is taken down for maintenance. The antenna temperatures T_A should be fairly reliable, and are based on having only weak sources in the field. Combining T_R and T_A gives the indicated range of T_s; for bands other than 6 cm, this has been converted to T_s' by assuming a gain of 2 to 3 dB for the upconverter, and -3 to -5 dB for each mixer, and a 25 K second-stage contribution. Figure 3.3 shows the relationship of T_s and T_s' with



Curves of constant T_s and T_s', where $T_s = \frac{T_2}{G_M} + T_M + T_A$ and $T_s' = G_M T_s$,

and T_M is the mixer temperature, referred to input;

G_M is the conversion gain of the mixer;

T_A is the antenna temperature at the mixer input (here 40 K); and

T_2 is the second stage noise temperature (here 23 K).

Figure 3.3: Performance of 2 and 1.3 cm mixers.

parameters appropriate to the 2- and 1.3-cm bands.

From Figure 3.2, then, we see that the range required in the variable attenuator is about 3.5 to 22 dB, although most of the time we expect to operate with $T_s' < 100$ K on all bands, in which case the range is 3.5 to 18 dB. This does not take into account the possibility of a very strong source in the beam; one can do so using the data in the last column of Table II. Figure 3.2 also shows a typical curve of phase shift vs attenuation for the variable attenuator used (Vectronics model DA0125-40, purchased to Specification A13180N3).

3.2 FREQUENCY CONVERTER MODULE, F4

3.2.1 R.F. Components

Refer again to the subsystem block diagram, Figure 1.1. The 500 MHz bandwidth R.F. input is passed through a band-pass filter, which is designed to isolate the 3.5 to 4.0 GHz L.O. from the input (otherwise, it could be coupled to the adjacent channel's input through the finite isolation of the R.F. Splitter module). This is followed by an isolator to improve the match into the double-balanced mixer. The L.O. input is also passed through a band-pass filter in order to prevent possible crosstalk between channels A and C or B and D (which have common L.O. signals), and hence possible cross-polarization, by way of the finite R-to-L and L-to-R isolations of the mixers and the finite isolation of the L.O. power dividers outside the modules. The R.F. and L.O. band-pass filters are chosen to have the same fractional bandwidth, number of poles and type of construction and so their temperature coefficients of phase should be nearly the same. They are mounted close to each other so that phase variations with temperature should cancel.

The double-balanced mixer responds to signals such that

$$nf_R + mf_L = f_I$$

where f_R, f_L and f_I are the R-, L- and I-port frequencies, respectively; and n,m are any (small) integers. The desired response is

$(n,m) = (1,-1)$. Higher-order responses are weaker, with even harmonics better rejected by the mixer balance than odd harmonics. The strongest undesired response is $(-1,2)$; f_I has been chosen as 1000 to 1050 MHz in order that this response have f_R well outside the 4.5 to 5.0 GHz band for all values of f_L being used. The lowest-order response falling in the band is then $(-2,3)$, although $(2,-2)$ approaches the lower band edge; this is illustrated in Figure 3.4.

The mixer is followed by an amplifier with 26 dB gain. This amplifier has a nominal frequency range of 1000 to 2000 MHz, but its 3 dB bandwidth is actually about 700 to 2500 MHz. It was chosen because a large number was available from earlier designs. At most L.O. settings, this amplifier responds to the entire R.F. band, and will be the first component to saturate if the input level is increased excessively (next would be the GaAs FET amplifier, followed by the paramp; see Figure 3.1). The saturation point of this amplifier might

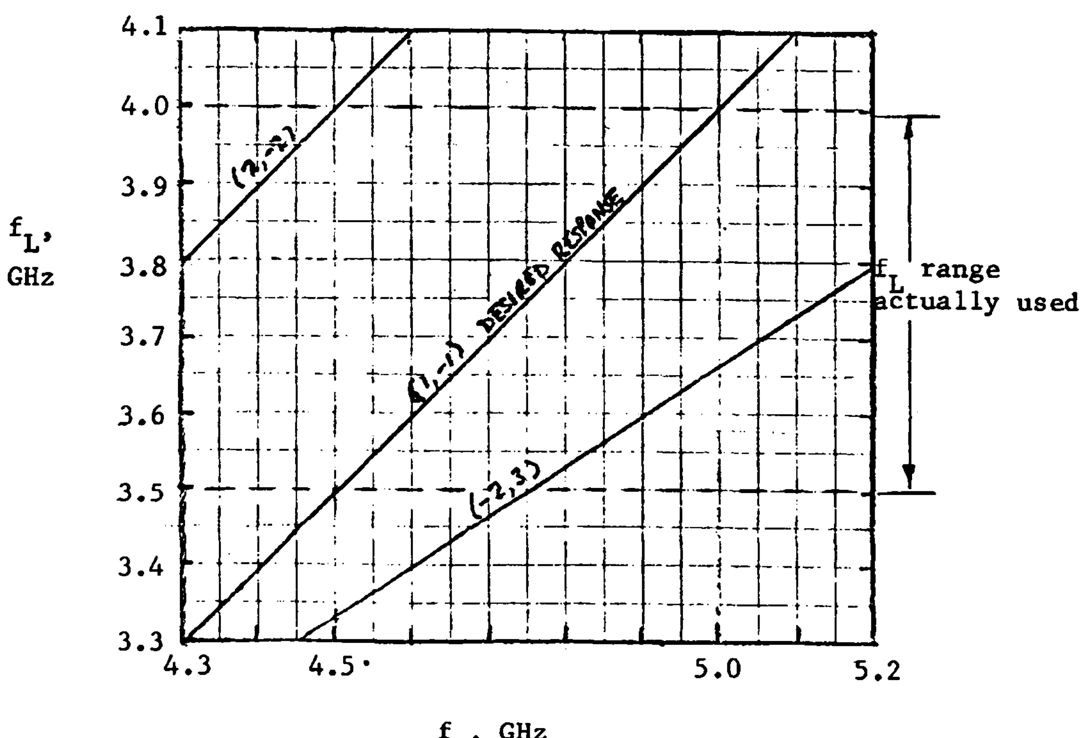


Figure 3.4: Lines of $nf_R + mf_L = 1025$ MHz, for various (n,m).

have been raised to a much higher input power level by placing it after the band-pass filter (in F7); but that filter is required to have a rather high insertion loss of up to 10 dB, and this would have made it difficult to meet the subsystem noise figure specification.

The 26 dB amplifier is followed by a selected pad, used to establish the overall gain of the F4 module at 66.0 dB, compensating for variations in other components. This location was chosen for the gain-setting pad because it also helps to improve the match seen by the following component, the band-pass filter in F7. The amplifier output has a VSWR of nearly 2.0, which can cause excessive ripple in the filter response. (Further discussion is given in Section 3.6.)

The signal is next passed through the bandwidth-determining filter in F7, and then returned to the F4 module for further amplification. A current-controlled attenuator closes the ALC loop at this point. The attenuator is an absorbtive design using 90° hybrids to maintain a good match. It is specified to have low phase shift with attenuation over the normally-used portion of its range (specification A13180N3, see Appendix D). This is made feasible by the fact that the signal occupies at most a 5% bandwidth at this point, with the same center frequency for all channels.

The attenuator is followed by a high-gain (52 dB) amplifier, bringing the final output of the module to about -8.5 dBm.

The 1000 to 1050 MHz output of F4 is passed to F8, where it is upconverted to one of the four I.F. channels and combined with the other three channels. A portion of the upconverted signals is returned to F4 to close the ALC loop. The returned signal, at -22.5 dBm, feeds a balanced detector consisting of a 90° hybrid and two tunnel diode detectors. To the extent that the detectors have equal reflection coefficients, reflected power appears at the terminated port of the hybrid, and the input is well matched. Tests using all pairs from six randomly-selected detectors gave better than 20 dB return loss at the input for all frequencies of interest.

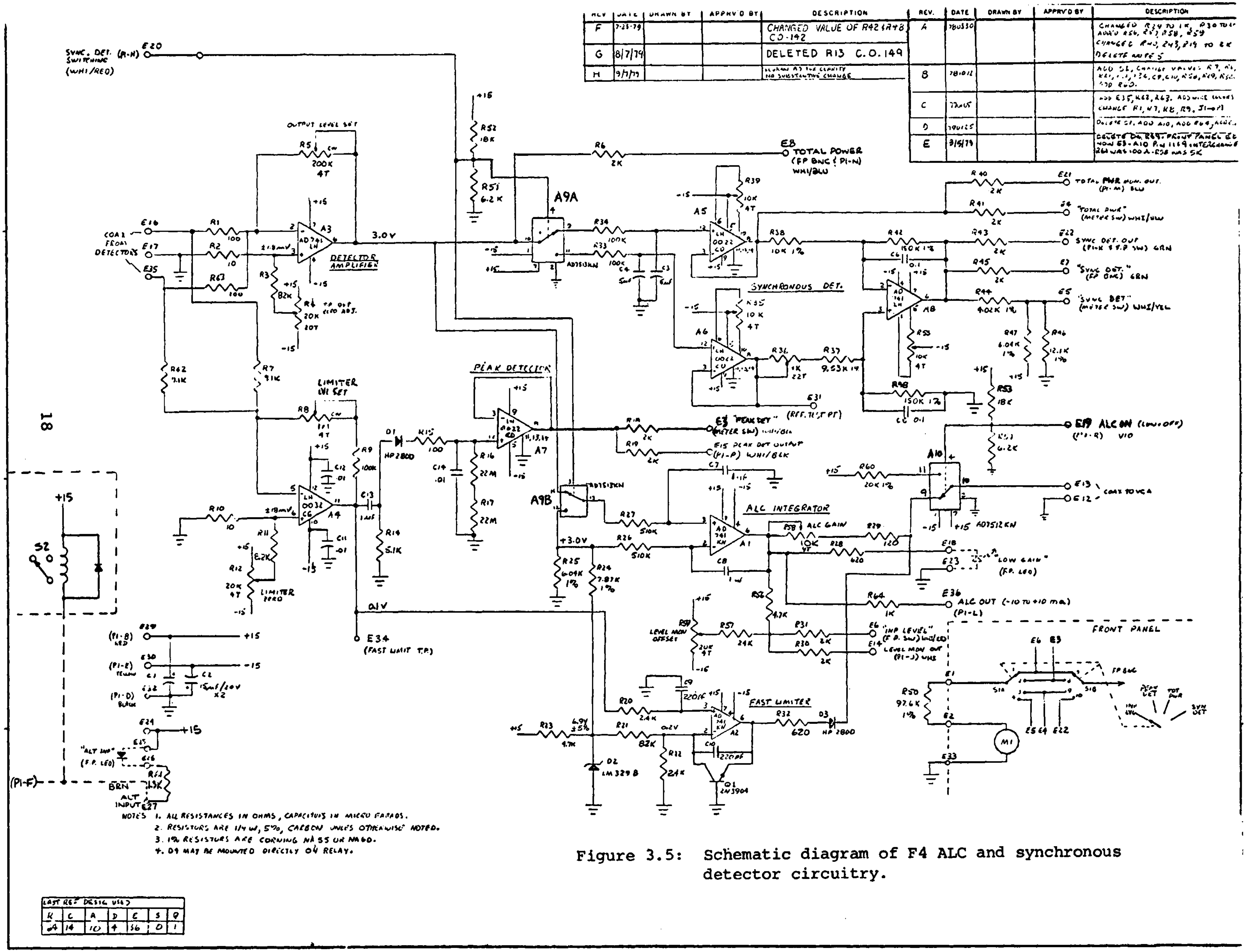


Figure 3.5: Schematic diagram of F4 ALC and synchronous detector circuitry.

3.2.2 Gated ALC Loop

Refer to the schematic diagram, Figure 3.5.

Signals from the two detectors are each terminated in a 100 Ω resistor and added in an operational amplifier, A3. This terminating impedance should provide good square-law accuracy to at least -20 dBm per detector (see Appendix D); with the ALC loop closed, the level will be held to -25 dBm per detector.

An AD741LH is chosen for the detector amplifier because of its low input offset drift (<5 μV/°C). Since each detector will provide about 1 mV across 100 Ω at -25 dBm, 1% error occurs for an offset of about 20 μV. If this circuitry is used to derive gain corrections for the astronomical data, then <<1% error is desired. In that case, it may be desirable to substitute an even more stable amplifier, especially if we consider that the offset compensation adjustment must be made in the laboratory where the temperature may be up to 10°C different from that at the antenna.

The output of A3 will be held at 3.0 V by the ALC loop; thus, a voltage gain of about 1,500 is required. At this gain, the bandwidth is about 700 Hz, which is sufficient to avoid significant attenuation of a 9.6 Hz square-wave which modulates the R.F. input, as discussed below. The exact gain is set by R5, which compensates for deviations from nominal detector sensitivity. Input offset is nulled by R4 (which must be particularly stable and smoothly settable), R3, and R2, which give a ±1.8 mV adjustment range.

The output of A3 is connected through FET switch A9B to the ALC integrator, A1. The switch provides gating of the loop in synchronism with the switching of a noise source connected at the receiver input. This noise source is turned on and off at a 9.6 Hz rate by the Control Interface module (F5), which also provides the switching signal to F4 as TTL logic at rear panel connector P1, pin H. When the noise source is on, broadband noise power equal to 10% of the nominal system noise for the band being used is added to the receiver input. The FET switch connects the detector amplifier to the integrator when the noise source is off (P1-H is HIGH), and shorts the integrator input when the noise source is on; thus the loop responds only to the "off" signal level, and the gain is held constant during the "on" time.

The integrator input is offset by 3.0 V, derived from a sharp-knee, low drift voltage reference, D2, and 1% voltage divider R24-R25.

The integrator has a time constant of τ = 0.5 sec, selected to be long enough that drift during the "on" time will be negligible. It drives the current-controlled attenuator through gain-setting resistors R58 and R29, and FET switch A10. R58 is adjusted to give a 2 V change in the output of A1 over the specified input level range of 10 dB (cf. Table I). We can assume that the gain varies approximately exponentially with attenuator current over this range, so that the power into the detector is

$$P_d = G_o P_i e^{-kV_I}$$

where G_o is a constant gain, P_i is the input power, k is a constant depending on the attenuator characteristics and R58 + R29, and V_I is the integrator output voltage. Since V_I changes by 2 V when P_i changes by 10 dB, with P_d held constant, it is easy to show that k = -(log 0.1)/2 V. The open loop gain from integrator output to integrator input, when the latter is in the vicinity of 3 V, is -(3 V) x k = 3/2 log 0.1 = -3.45. The total open loop gain, including the integrator, is

$$H_{o\ell}(s) = -\frac{3/2 \log 0.1}{\tau s} = +\frac{6.90 \text{ sec}^{-1}}{s},$$

from which one can calculate the close-loop transfer function:

$$H_{c\ell}(s) = -\frac{H_{o\ell}(s)}{1 - H_{o\ell}(s)} = \frac{1}{1 - \tau' s}$$

where $\tau' = (6.90 \text{ sec}^{-1})^{-1} = 0.14$ sec is the closed-loop time constant. It should be emphasized that this transfer function applies only to small disturbances of the loop; transients in which the integrator input departs greatly from 3 V, or during which the integrator output saturates, can have much different responses (usually slower). Also, note that since the loop is closed only half the time, the effective time constant is $2\tau'$.

The ALC loop may be disabled by applying a TTL low level to P1-R. This causes FET switch A10 to disconnect the integrator output from the attenuator and instead to apply a constant current of about 0.7 mA. This sets the attenuator near its nominal attenuation of about 12 dB.

Open circuits at P1-H and P1-R will cause the loop to be closed and enabled, respectively, by virtue of voltage dividers R51-R52 and R53-R54.

The integrator output voltage can be monitored at the front panel meter and BNC jack and at P1-J on the rear panel. The connections are via R56, R31 and R30; a high-impedance load ($\gtrsim$ 100 K) is required. The monitor outputs can be offset by up to ±2.4 V by adjusting R59; this allows their absolute calibration in terms of the module input power. R59 and R58 are normally adjusted to obtain +2.0 V at minimum specified input level (-58 dBm) and +4.0 V at 10 dB higher. In addition, the integrator output is connected, with no offset, to P1-L through a 1 K resistor, R64; this is intended for possible future use, in case it becomes desirable to close the loop through an external attenuator placed earlier in the signal path. Finally, the integrator output also connects through R28 to a front panel LED, whose polarity is such that it is on when the integrator output is negative; it thus indicates insufficient input power or gain and is labeled "low gain".

3.2.3 Fast Limiter and Peak Detector

There is some concern that the VLA may occasionally experience interference of large amplitude but short duty cycle, as in pulsed radar. It may be possible to operate in the presence of such interference if the receiver gain can be rapidly reduced when it is on (in order to prevent saturation of the waveguide channel), and rapidly returned to normal when it is off. The gated ALC loop does not accomplish this because, first, it is open half the time, and, second, its response is too slow to handle the ~1 μsec pulse widths expected. Therefore, a separate, ungated, high-speed limiter has been included.

A small portion of each of the detector output currents is fed to the summing junction of a high-slew-rate operational amplifier, A4, through R7 and R62. This amplifier has relatively poor offset drift (25 μV/°C), but it has high input impedance and a large gain-bandwidth product (70 MHz). The gain is adjusted by R8 for 0.1 V out when the gated ALC loop is holding the detector input at -22.5 dBm. This will normally require a voltage gain of 50, giving a bandwidth of 1.4 MHz. The input offset is nulled by R12, R11 and R10 (±18 mV range). Note that a portion of the offset of A4 can appear across A3's input through the voltage dividers R7, (R1 || detector) and R62, (R2 || detector); thus, the offset adjustments R4 and R12 interact slightly. This effect is minimized by making R7 and R62 large.

The output of A4 drives integrator A2, which has a time constant of 0.5 μsec and whose input is offset by 0.2 V (D2, R21, R24). At normal input level, this produces a net offset of 0.1 - 0.2 = -0.1 V, which would quickly drive A2 to its negative rail if it were not for transistor Q1, which clamps it at -0.7 V. This clamping keeps A2 unsaturated, allowing it to respond quickly to a sudden change in input level. The output of A2 connects through R32, diode D3 and switch A10 to the current-controlled attenuator; any output current from A2 is thus added to that from the gated integrator, A1.

Normally D3 is reverse biased by 1.7 V (about 1 V appears across the attenuator, which looks like a forward-biased diode) so the fast limiter has no effect. But if the input power suddenly increases so that the output of A4 exceeds 0.2 V, Q1 will turn off and the output of A2 will rapidly increase. When the latter exceeds about 1 V, D3 will conduct and additional current will be supplied to the attenuator, reducing the gain. The input level change at which this occurs is set by R8; if set for 0.1 V normal output from A4, a 3 dB increase will activate the limiter. Slightly tighter limiting is possible, but a margin must be allowed for noise (in view of the short integrating time of A2) and for the offset drift of A4.

In order to provide a warning that pulse-type interference is being experienced, A4 also drives an ac-coupled peak detector, consisting of C13, R14, D1, R15, C14, R16, R17, and A7. The coupling C13 x R14 limits the detector's response to transients with rise times $\lesssim$ 10 μsec, while R15 x C14 sets the minimum pulse width at ~1 μsec, closely matching the response speed of A4. The hold time is determined by C14 x (R16 + R17), ~0.5 sec. A7 provides a very high-input impedance, unity gain buffer. Outputs connect to the front panel meter and BNC jack, and to the rear panel at P1-P.

3.2.4 Synchronous Detector

The output of detector amplifier A3 contains a small, square-wave modulation due to the calibration noise source switching, as described in Section 3.2.2, above. Letting E_1 be the mean output voltage of A3 when the noise source is off, and E_2 the voltage when it is on, the synchronous detector is designed to allow accurate measurement of E_2-E_1.

The synchronous detection is accomplished by applying a 9.6 Hz TTL reference square-wave to FET SPDT switch A9A. The top switch contact is closed when calibration noise is off, so C3 charges toward E_1; the R34 x C3 time constant is 0.5 seconds, so many cycles are required to reach E_1. During the alternate half-cycle, the top contact is open, C3 holds its previous value, the bottom contact is closed, and C4 charges toward E_2.

The voltages on C3 and C4 are buffered by A5 and A6 so that in the steady-state E_1 and E_2 are available at their outputs. E_1 can be monitored by the front-panel switch (TOT PWR) and E_2 is available only on internal test point, E31. A differential amplifier, A8, is used to provide an output of 15 x (E_2 - E_1). Adjustment R36 is used to balance this amplifier.

The synchronous detector output is available at the rear panel (P1-K) and at the front-panel monitor switch. Note that the meter is offset to read mid-scale for zero output but the BNC jack directly connects to the synchronous-detector output; i.e., the jack voltage is zero for $E_2 = E_1$.

3.3 FRONT END I.F. FILTERS MODULE, F7

3.3.1 Choice of Filter Parameters

The first I.F. band of the subsystem was selected as 1000 to 1050 MHz for the reason given in Section 3.2.1. Filtering at the first I.F. is required in order to reject the image of the second mixer (in F8), and also to reduce the power which the 52 dB amplifier (in F4) must handle. It was decided to put here the most selective filter of the antenna signal processing, for two reasons: to reject out-of-band interference as early as possible, and to allow the filters to be identical for all channels. The F7 filter determines the bandwidth which will be transmitted through the waveguide (since the filter in F8 is wider), but a narrower filter should always be selected at baseband (in the Control Building) so that the latter controls the system bandwidth.

Maximum rejection of out-of-band interference requires the sharpest possible cutoff and the narrowest possible bandwidth. However, improving these parameters necessarily increases the temperature coefficient of phase of a filter. By specifying especially stable, temperature-compensated filters (see Section 3.5), six-section filters can be used, giving a 60 dB bandwidth about 3 times the 3 dB bandwidth (Specification A13190N1-3; see Appendix D). In order to keep the ultimate stopband attenuation as large as possible, the filters are of Chebyshev rather than elliptic function design.

In each F7, three filters are available for selection using PIN diode switches, and a fourth set of switches is provided for a possible future filter. The switches and three filters are integrated into a single assembly, purchased from RLC Electronics under Specification A13190N9.

The 25 MHz and 12 MHz bandwidths are available for use when smaller system bandwidths are selected at baseband and near-frequency interference is not adequately rejected by the 55 MHz bandwidth filter. These F7 bandwidths should be used only if needed for interference rejection, since they exact a phase-stability penalty (see Section 3.5).

The center frequency of the 12 MHz bandwidth filter is set at 1027 MHz in order to include the 1421 MHz line of atomic hydrogen within the band at an available setting of the 2-4 GHz Synthesizer, L6. (With the latter at 3589.9 MHz, the 1027/12 I.F. band translates to 1416.9/12.)

The filters are specified to contain resistive padding so that the total output power remains nearly constant as the bandwidth is changed when the input is white noise. Although not specified directly, each filter-switch assembly contains a tubular low-pass structure with a cutoff around 2 GHz in the common path on one end; this attenuates high-frequency spurious responses, especially odd harmonics of the passband. Both the low-pass structure and the padding are on the end used for input, connected to F7-J8. The padding helps to improve the match seen by the filter, which is driven by the 26 dB amplifier in F4; the latter has a VSWR near 2.0.

3.3.2 Switch Drivers

Refer to the F7 module schematic, Figure 3.6.

Four TTL signals are supplied to the module from the Control Interface module (F5) via rear-panel connector P1; all are HIGH = TRUE. Three of these are a binary-coded filter select command, allowing for 8 different commands even though only 4 switch positions are available (the MSB, bit 2, is ignored). The fourth is TRUE if the F5 front panel is set to manual mode (or if the line is open-circuited, as in bench testing).

The filter select bits connect to one set of inputs of digital multiplexer U3 (74157). If MANUAL is FALSE, they are connected to the inputs of decoder U2 (8250); if MANUAL is TRUE, the filter

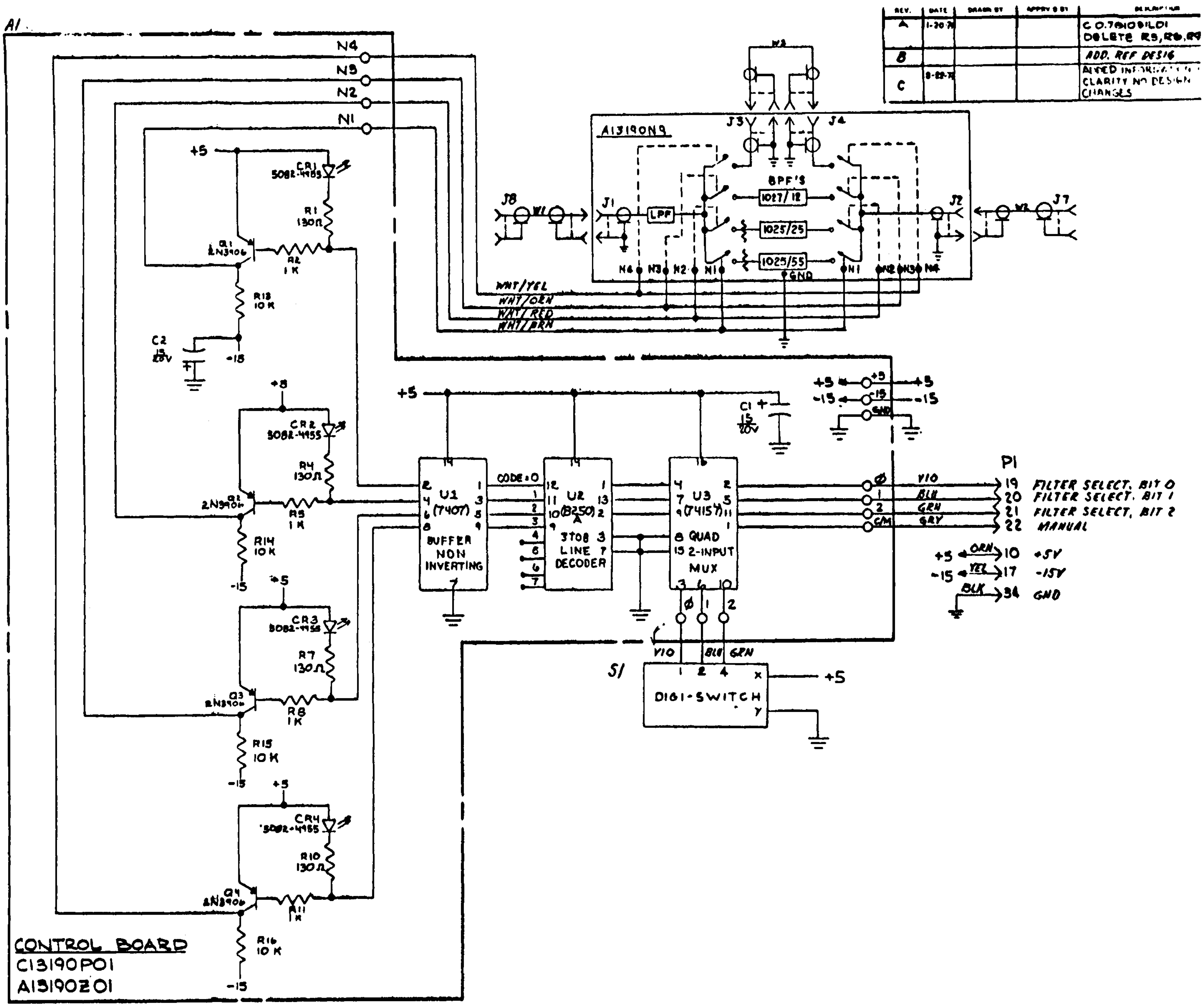


Figure 3.6: Schematic diagram of the F7 module.

select bits are not used and the decoder inputs are connected to the thumbwheel switch on the F7 front panel, which then controls the filter selection. The decoder has 8 output lines; line N is held low when the input code is N, and all others are held high.

The decoder outputs for codes 0 to 3 are connected through noninverting buffers in U1 (7407) to transistor switch drivers, Q1 through Q4. When the input to any switch driver is HIGH (>4.3 V), the transistor is cut off and the output line, connected to the collector, is at -15 V through 10 k ohms. The output line is connected to two control terminals of switch-filter assembly A13190N9, namely the input and output switch controls of one filter. A negative potential applied to any of these terminals opens the corresponding PIN diode switch; very little current is required since the diodes are reverse biased, and the 10 k resistor provides current limiting in case of a short or other failure. When code 0, 1, 2, or 3 is selected, one switch driver input is held LOW, causing sufficient base current to flow to saturate the transistor. This applies about +4.7 V to the output line and turns on the corresponding pair of PIN diode switches. Also, the LOW input allows current to flow through an LED (CR1, 2, 3, or 4) and 130 ohm resistor, providing a front-panel monitor of the selected filter.

3.3.3 Auxiliary Filter Selection

Notice from Figure 3.6 that when the fourth switch position (code = 3) is selected, the signal is connected straight through by way of a cable, with no filtering. This may sometimes be useful for testing. The cable can be replaced by another filter, mounted inside the module, if such a need should arise in the future. It should be noted that when one of the present three filters is selected, rejection at frequencies far from the passband may be limited by the isolation of the switches and transmission through the auxiliary cable. If this proves troublesome, the cable can be removed; but then J3 and J4 of the switch-filter assembly must be terminated to prevent RFI problems.

3.4 I.F. OFFSET MODULE, F8

3.4.1 Amplifier-Mixer Assembly

The F8 mixer is required to upconvert the 1000-1050 MHz band to one of the four I.F. bands centered at 1325, 1425, 1575, and 1675 MHz. However, most commercially available mixers suitable for operation in this frequency range are intended for dewar-conversion, and their I-port frequency response does not extend much above 1000 MHz. Consequently, the mixer is configured with the L.O. (the lowest frequency in our case) connected to the I-port and the output taken from the L-port.

Various mixers were evaluated for this application. Design requirements included good rejection of L.O. harmonics (hence only double-balanced mixers were considered); flat conversion loss across the 50 MHz channel; nearly equal conversion loss in the four channels, so that the subassemblies would be interchangeable; and low reflection at the R-port, since the input connection is through a relatively long cable. The mixers evaluated included the Watkins-Johnson M2G and M2A; the Anzac MD152; and the Vari-L DBM-177. The M2A was chosen because tests showed it to have better odd harmonic of L.O. rejection than the others (although the M2G was better for even harmonics), had better flatness across the 50 MHz channel, and because it is supplied in a conveniently-sized package (TO-8).

The L.O. harmonics which can appear at the mixer output for each of the four channels are illustrated in Figure 3.7. A few frequencies are troublesome: 1200 MHz (which is 4 $f_{L.O.}$ for the channel A mixer and 3 $f_{L.O.}$ for channel B), because it is one of the main L.O. reference frequencies to be transmitted to the Control Building along with the composite I.F. signal; 1300 MHz (2 $f_{L.O.}$ for D), because it is at the low end of channel A; 1600 MHz (4 $f_{L.O.}$ for B), at the high end of channel C; and 1650 MHz (3 $f_{L.O.}$ for C), low end of channel D. Each of these is subject to considerable attenuation in the 60 MHz band-pass filter which follows the mixer. We can estimate the acceptable levels and the required degree of filtering as follows.

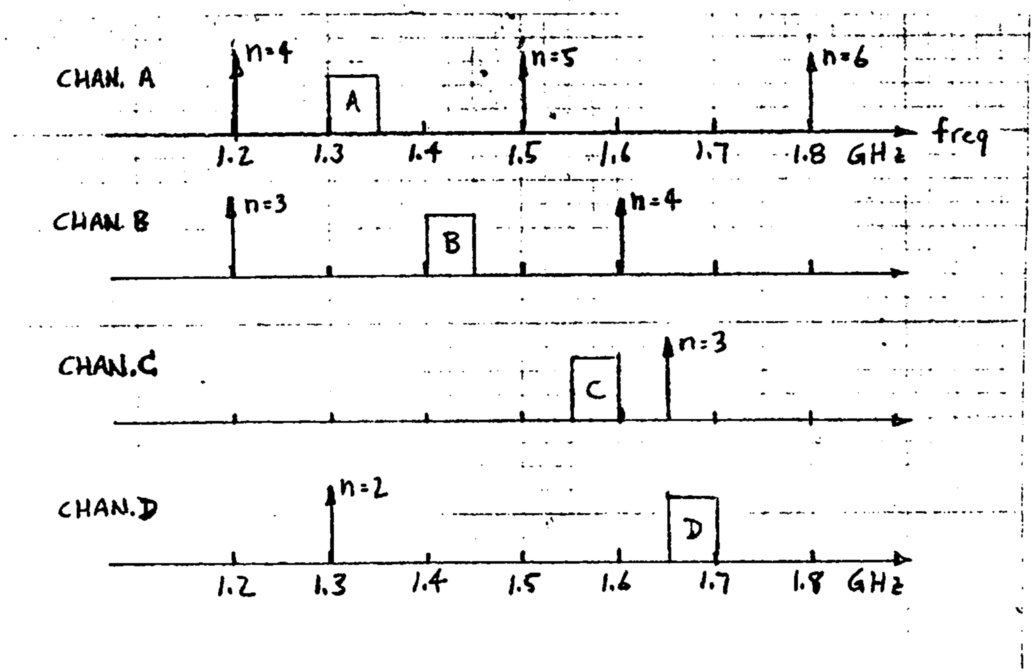


Figure 3.7: Undesired L.O. responses of F8 mixers.

For the 1200 MHz signal, it should be <-60 dB with respect to the desired 1200 MHz L.O. reference carrier in order to cause a phase shift of <.05°; the desired carrier would be -35 dBm referred to F8-J8, so the spur must be <-95 dBm there, or <-82 dBm plus the BPF rejection referred to the mixer output.

For signals appearing at the edges of the I.F. channels, we would like to make the spurs undetectable in 12 hours of integrating at any observing bandwidth. The worst case occurs with the narrowest bandwidths in spectrometer mode. Although spurs at the I.F. channel edges will never be in the analyzed band, they can enter by imaging or aliasing; we can count on a minimum of 30 dB rejection of such signals in the I.F.-to-baseband conversion subsystem. In addition, we can count on about 20 dB rejection due to the synchronous phase switching of the 2-4 GHz L.O. and the correlator. The allowable level at the F8 output is then

$$P_{spur} \lesssim P_{noise} \frac{W_{final}}{W_{noise}} \frac{1}{\sqrt{W_{final} T}} \qquad (+20\text{ dB})(+30\text{ dB})$$

where P_{noise} = -33.5 dBm, W_{noise} = 55 MHz, W_{final} = 381 Hz (smallest spectrometer channel width), T = 12 hours. Thus

$$P_{spur} \lesssim -71 \text{ dBm}$$

which becomes -58 dBm plus the BPF rejection at the mixer output.

The results of the calculations are summarized in Table III, which also shows the expected filter rejections. In order to keep the 4 $f_{L.O.}$ output close to the required level, it was necessary to reduce the L.O. drive below the recommended +7 dBm. At 0 dBm, the conversion loss increases by 1 to 1.5 dB, but the various L.O. harmonics are reduced to 7 to 10 dB. The R-port impedance also varies with L.O. power, but tests show little variation of this impedance or of the conversion loss for L.O. powers of -3 to +3 dBm.

The mixer assembly includes a 14.5 dB (typical) amplifier for the L.O. and an input matching network at the R-port. Tests of various M2A's showed very consistent reflection coefficients at 1025 MHz and 0 dBm L.O. for $f_{L.O.}$ = 300 to 650 MHz, namely a magnitude of -10 dB and phase of +120±10°. A simple matching network (shunt-L and series-C) gave better than 20 dB return loss from 1000 to 1050 MHz and P_L = -3 to +3 dBm on each of three prototypes, without selecting or adjusting network values. A good match here is necessary in order to avoid significant standing waves along the cable connecting the F8 inputs to the F4's.

3.4.2 L.O. Demultiplexing

The required L.O. signals at 300, 400, 550, and 650 MHz must be derived from the 50 MHz comb supplied to the module from the

TABLE III: F8 MIXER SPURIOUS OUTPUT REQUIREMENTS

Channel	Critical Requirement	Filter # Sections	Filter Rejection[1]	Max Allowable at Mixer Output	Test Results [2]
A	-82 dBm at 1200 (4 $f_{L.O.}$)	4	-40 dB	-42 dBm	-40 dBm
B	-82 at 1200 (3 $f_{L.O.}$)	4	-58	-24	-45
C	-58 at 1650 (3 $f_{L.O.}$)	6	-44	-14	-46
D	-58 at 1300 (2 $f_{L.O.}$)	4	-70	> 0	-43

[1] Calculated conservatively, at the critical frequency.
[2] For one M2A with 0 dBm at $f_{L.O.}$ into port I; power measured at port L at the critical frequency.

50 MHz Harmonic Generator (L2) in Rack B. The comb is not perfectly flat, and the spectrum varies somewhat from unit to unit. A typical spectrum at the output of Rack B is shown in Figure 3.8. This is transmitted through 5.5 feet of .250-inch spline-dielectric cable and 2.1 feet of .141-inch solid TFE dielectric cable, producing a loss of 0.25 to 0.4 dB. The arrangement of components shown in the block diagram is chosen to deliver -14.5±2 dBm to each of the four amplifier-mixers over the range of variations observed in L2 modules so far built. This should result in 0±2.5 dBm at the mixer's I-port.

The available L.O. power was another consideration in setting the mixer drive level at 0 dBm. Most of the required amplification must be placed after the filters in order to avoid using expensive, high-power amplifiers. The 6.5 dB amplifier operates at about +10 dBm output (including all 50 MHz harmonics to 1 GHz), which is

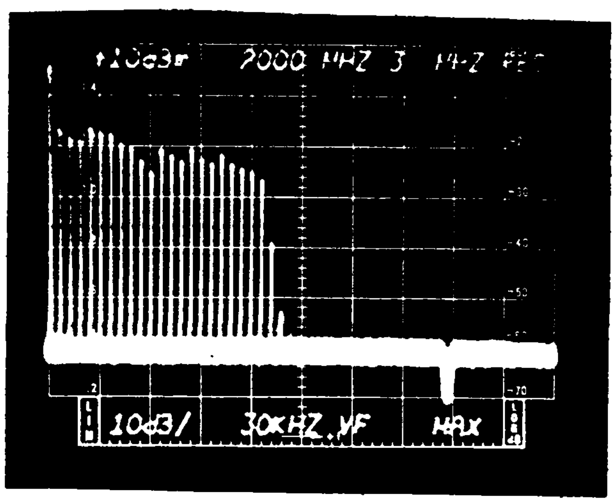


Figure 3.8: Typical second L.O. (50 MHz comb) spectrum at F8-J7.

about its 1 dB gain compression point for broadband signals (even though its CW compression point is specified as $\gtrsim$+20 dBm). This amplifier also buffers the long input cable from L2, so that it sees a reasonably good match; the return loss looking into the power divider is only about 4 dB at almost all frequencies.

For each channel, the required comb line is selected by a band-pass filter. These filters need sufficient selectivity to reject the adjacent comb lines by at least 30 dB, to keep spurious responses less than 0.1% for spectroscopy. (Since the channel bandwidth here can be slightly greater than 50 MHz, signals near one band edge can show up at the opposite band edge when converted by a comb line adjacent to the desired one.) But the filters must not be so selective that they have high temperature coefficients of phase. Three-section, 18 MHz bandwidth filters seemed the best compromise. To save space in the module, helical resonator filters were selected. The manufacturer of these filters (K & L Microwave) had considerable difficulty in meeting our temperature coefficient specification of $\lesssim$10 ppm/C; they had to employ chip capacitors with carefully chosen temperature coefficients to compensate the inductance variations. Without such special efforts, filters of this type seem to perform no better than tubular filters, i.e., with temperature coefficients ~-50 ppm/C.

The L.O. demultiplexing network in F8 could be made much more efficient and simpler if implemented with channel-dropping filters in a true demultiplexer, rather than wasting most of the power of the desired lines in a power divider. If directional filters were used, the unused comb lines could all be terminated in a matched load (see, e.g. G. L. Matthaei *et al.*, *Microwave Filters, Impedance Matching Networks, and Coupling Structures*, McGraw-Hill 1964). The module design effort did not include enough time to pursue this approach, but it should be considered if any redesign is required later.

3.4.3 Other R.F. Components

The mixer output is connected through an isolator to a band-pass filter covering the I.F. channel. The selectivity required in this filter is determined mainly by the need to reject harmonics of the L.O., as discussed in Section 3.4.1. The isolator is needed to ensure a good match into the filter, since the mixer output is poorly matched and a mismatch here will cause the filter to produce large passband ripples (see Section 3.6.2). Isolators from several manufacturers were tested for phase/temperature coefficient before the present ones were selected; the latter gave <.03 deg/°C.

The 6 dB directional coupler ensures that the filter output is well matched; it sees mainly the low-VSWR balanced detector in F4. The coupler also keeps the four-way power combiner reasonably well matched, so that at the module output the return loss is at least 15 dB. Note that the power delivered to each F4 detector is controlled by the ALC loops, so the module output power is determined only by the coupling difference between the detector output and the composite I.F. output (J8) ports, namely 11 dB. Allowing 0.5 dB for cable losses, the subsystem delivers -34.0 dBm per channel to T2, or -28.0 dBm total.

3.5 TEMPERATURE STABILITY CONSIDERATIONS

As mentioned in Section 2, maintaining a low temperature coefficient of phase through the subsystem was a difficult design objective. The approach taken was simply to use broadband, nonresonant components wherever possible; to pay careful attention to component layout so that cable lengths would be short and the use of connectors would be minimized; and to specify carefully the band-pass filters which contain most of the selectivity. The specification of <0.3°/C is based on an analysis of the phase error budget of the entire telescope with the objective of achieving <1.4° peak phase error at an observing frequency of 1.4 GHz; of this, 1.1° is allocated to the L.O. and waveguide subsystems, and 0.1° to the front end, leaving 0.2° for our subsystem. We then assume that the peak temperature variation of the subsystem can be held to <0.7 C (1.4 C P-P), giving the specified temperature coefficient. Controlling the temperature to this precision is possible, but not easy (see, for example, VLA Electronics Memorandum No. 184); nevertheless, even tighter temperature control is highly desirable.

All signal-processing components of the subsystem have at least octave bandwidths except the band-pass filters and the isolators in F8; the latter had to be 15-20% bandwidth to fit in the available space, but were carefully tested for low $d\phi/dT$. For band-pass filters, the temperature coefficient of phase at the center of the passband is given fairly accurately by the formula

$$\frac{d\phi}{dT} = \frac{\pi N f_o}{2\Delta f} k$$

where N is the number of sections (upper-half-plane poles), f_o is the center frequency, Δf is the 3 dB bandwidth, and $k = f_o^{-1}\, df_o/dT$ is the fractional temperature coefficient of center frequency. Normally, k is a constant for a particular type of filter construction; for a cavity filter constructed of a single material, -k equals the expansion coefficient of the material used. For tubular filters, $k \approx -50 \times 10^{-6}/C$.

In F4, the R.F. and L.O. tubular filters have N = 4 and are expected to have $d\phi/dT \approx -.11°/C$, but their effects should cancel in the first mixer and we neglect them here.

The first I.F. filter in F7, the second I.F. filter in F8 and the L.O. filter in F8 are of necessity arranged such that their phase shifts add at the output frequency. These are also the filters with the narrowest fractional bandwidths. Assuming that their k-values all have the same sign (usually negative), they must be held to unusually small values in order to achieve the required stability at the output. Table IV lists the maximum total temperature coefficient of phase of the three filters for each channel and bandwidth; it also gives the number of sections and specified maximum value of k for each filter. It is apparent that most of the allowed subsystem temperature coefficient is taken up in these filters, especially for channels C and D, and that the coefficient is expected to be much worse when the narrow bandwidths are selected.

TABLE IV: COMBINED $d\phi/dT$ FOR BPF'S

		Combined $d\phi/dT$, degrees/C				1st I.F. Filter		
Band-width		Channel A	B	C	D	$d\phi/dT$	N	$\lvert k \rvert_{max}$
55		.195	.216	.248	.269	.070	6	7
25		.280	.301	.333	.354	.155	6	7
12.5		.436	.457	.489	.510	.311	6	7
2nd I.F. Filter	$d\phi/dT$	.080	.086	.095	.101	^{o}/C		ppm/C
	N	4	4	5	4			
	$\lvert k \rvert_{max}$	10	10	8	10	ppm/C		
L.O. Filter	$d\phi/dT$	.045	.060	.083	.098	^{o}/C		
	N	3	3	3	3			
	$\lvert k \rvert_{max}$	10	10	10	10	ppm/C		

Tests have been made of the temperature coefficient of the whole subsystem, using early prototype modules. These tests involved placing one each F4, F7 and F8 module in a temperature-controlled chamber with the modules properly interconnected (using short runs of semi-rigid coax) so as to make one channel operative. A similar set of modules was operated outside the chamber, at constant temperature; and the phase difference of the output signals from the two sets was monitored, using a network analyzer, while the chamber temperature was varied. Identical L.O. and R.F. signals were fed to the two module sets, with the cables into and out of the chamber kept as short as possible (a few inches). Similar tests were performed on portions of the subsystem. The results are summarized in Table V. Note that during these tests the L.O. filters in F8 were not the final ones, which are required to have $|k| < 10$ ppm/C; the filters used

Table V: SUBSYSTEM TEST RESULTS; $d\phi/dT$, EARLY PROTOTYPES

Note: During these tests, the F8 L.O. filters had k ≈ -50 ppm°/C; spec requires |k| <10 in production units.

Subsystem		Run 1	Run 2	Run 3	Average	F8 L.O. Filter (calculated)
ALC off:	Ch. B	-0.18°/C	-	-	-0.18	-0.30
	Ch. D	-0.25	-0.35	-	-0.30	-0.49
ALC on:	Ch. B	-0.19	-0.15	-	-0.17	-0.30
	Ch. D	-	-0.40	-0.39	-0.40	-0.49
Input to F4-J6		+.03	+.03		+.03	
F4 alt. inp. to F4 out including F7		+.058	+.031		+.045	
F8 only	Ch. B	-0.21			-0.21	-0.30
(ALC off)	Ch. D	-0.36			-0.36	-0.49

had k ≈ -50 ppm/C. Correcting for this, the tests indicate acceptable performance. As of this writing, temperature coefficient tests of the final-design subsystem have not been completed.

3.6 IMPEDANCE MATCHING CONSIDERATIONS

Another difficult specification was the gain variation with frequency, which should be held to <0.5 dB P-P across each 50 MHz channel. Because most of the components have bandwidths much greater than 50 MHz, their intrinsic gain variations across the channel are expected to be very small (however, the WJ-M2A mixer was selected for F8 partly because it offered better flatness than others). Departures from flatness across 50 MHz result mainly from reflections between mismatched components separated by a significant length of transmission line, and from the band-pass filters at the first and second I.F.'s, where bandwidths are near 50 MHz.

3.6.1 Ripple Due to Reflections

If a source with reflection coefficient Γ_1 and a load with reflection coefficient Γ_2 are separated by a lossless transmission line of length ℓ, then the transfer function is

$$H(\omega) = \frac{V_2}{V_1} = 1 + \Gamma_1\Gamma_2 e^{-j2\ell\omega/v} + \text{(higher order terms)},$$

where $\omega = 2\pi f$ is the angular frequency and v is the phase velocity, assumed dispersionless. The maximum slope of $|H|^2$ is easily shown to be (neglecting higher order terms)

$$\left.\frac{d|H|^2}{d\omega}\right|_{max} = 4\ \Gamma_1\Gamma_2/v.$$

Over a small bandwidth $\Delta\omega = 2\pi\Delta f << v/2\ell$, we have

$$\Delta|H|^2 \equiv \Delta P = 8\ \pi\ \Gamma_1\Gamma_2\Delta f/v.$$

Taking $\Delta f = 50$ MHz and $v = 0.7c$, the above inequality is satisfied for most of the cables in our subsystem (the longest, connecting F8 to F4, is about 0.4 m).

Figure 3.9 is a plot of ΔP vs ℓ and $\Gamma_1 = \Gamma_2$ for our case. The results indicate that even fairly poor matches are tolerable for short line lengths, but that special care must be taken at the interfaces between modules where lines are long. It is for this reason that the balanced detector was required in F4, and the matching network was required at the mixer R-port in F8. Also, the internal layouts of F4 and F8 are designed to keep cable lengths short.

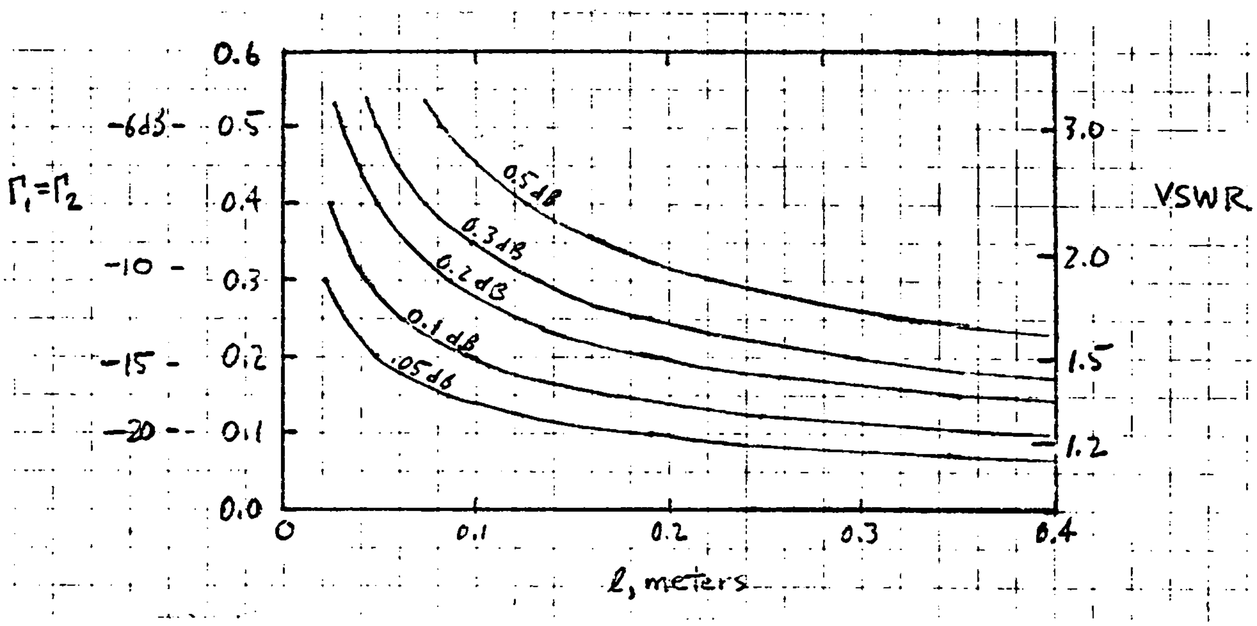


Figure 3.9: Gain variation across 50 MHz due to two equal reflections separated by a line of length ℓ.

3.6.2 Behavior of Filters with Mismatched Source or Load

The filter specifications (see Appendix D) allow a passband ripple of up to 0.5 dB P-P, but they also require a passband VSWR of ≤ 1.5. For a lossless filter, the latter implies a passband ripple of <0.18 dB when the filter is connected to exactly nominal (50 ohm) source and load impedances. (A slightly lossy filter, in practice, is a bit flatter.) However, we cannot guarantee that the source and load impedances will be 50 ohms, and this can have a large effect on the flatness of the filter's transfer function. To illustrate this effect, consider a lossless filter designed for input and output impedances of Z_o and terminated in a resistive load $R_L = Z_o$ but driven with resistive source impedance $R_s \neq Z_o$. If the filter is of Chebyshev (equal-ripple) design, its input impedance will vary across the passband but will remain inside a circle centered on the real axis in the complex impedance plane, as shown in Figure 3.10. The circle's radius is related to V_{max}, the maximum allowed VSWR in the passband. If R_s is outside the circle one can show that the ratio of the largest and smallest reflection coefficients is

$$r = \frac{R_s V_{max} + Z_o}{R_s + V_{max} Z_o} ,$$

and if R_s is inside the circle the ratio is

$$r = \frac{1}{4 R_s V_{max} Z_o} \max[(R_s V_{max} + Z_o)^2, (R_s + V_{max} Z_o)^2].$$

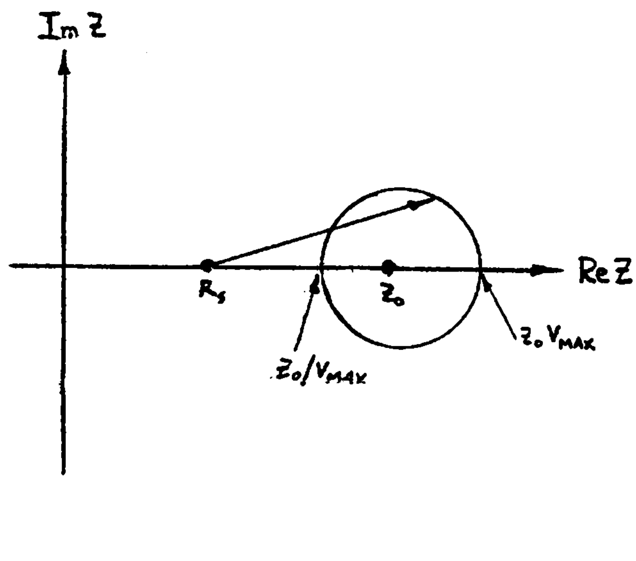


Figure 3.10: Input impedance of a Chebyshev filter with matched termination.

These formulas are plotted in Figure 3.11 for two values of V_{max}, corresponding to Chebyshev filters with design ripples of .18 dB and .01 dB. It is apparent that a filter's design ripple can be greatly exceeded when it is mismatched.

Because of this, care has been taken to ensure that the I.F. filters in F7 and F8 are well matched. In F8, an isolator was required at each filter's input because the mixer may have an output reflection coefficient as large as -6 dB. The filter's output sees mainly the balanced detector in F4. In F7, there can be a problem at the filter's input because the amplifier in F4 which drives it (an Avantek ASD8199M) has a reflection coefficient around -10 dB; but this is improved through padding, with typically 3 dB in F4 (but possibly 0 dB in low-gain modules) and 0 to 6 dB in F7, depending on the bandwidth selected. It may be necessary in the future to add

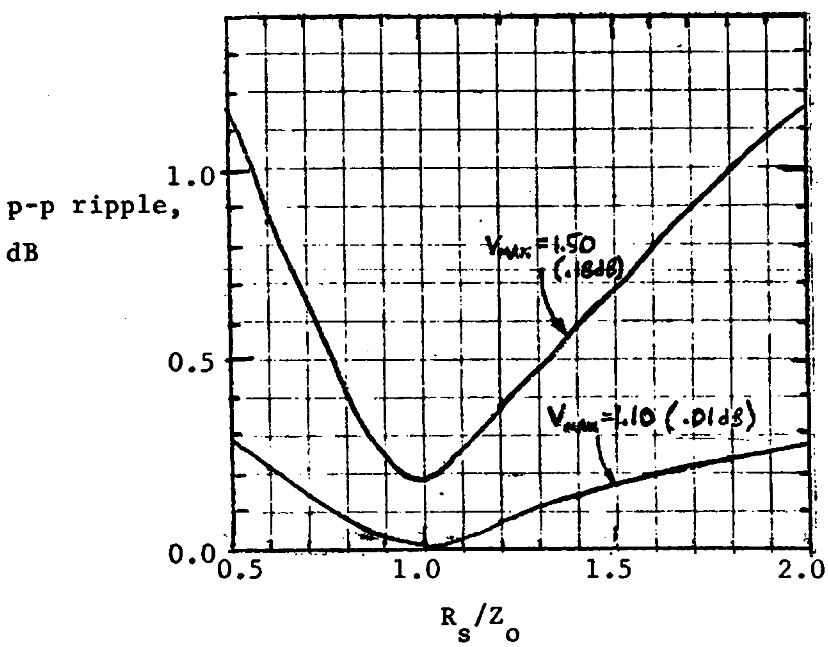


Figure 3.11: Calculated peak-to-peak ripple in lossless Chebyshev filters with matched load but mismatched source, for design (matched) ripples of .18 and .01 dB.

an isolator at this point if maximum flatness is required at the narrow bandwidths. At the output of F7, the filter sees the variable attenuator in F4, whose reflection coefficient is <-14 dB (typically <-20 dB).

4. TEST, ADJUSTMENT AND MAINTENANCE PROCEDURES

4.1 FREQUENCY CONVERTER, F4

4.1.1 R.F. Gain Check and Adjustment

Set up the test equipment as shown in Figure 4.1. Slight variations in the equipment are permissible, but the following precautions should be observed in order to obtain accurate results:

a. Use no unncessary adapters. Cables should be fabricated with appropriate connectors.

b. Keep all cables as short as is practical. Use no unnecessary cables in the signal path.

c. The power meter must be capable of better than 5% accuracy at -20 dBm and 5 GHz. Normally, this will require that the most sensitive range be $\leq$-30 dBm full scale.

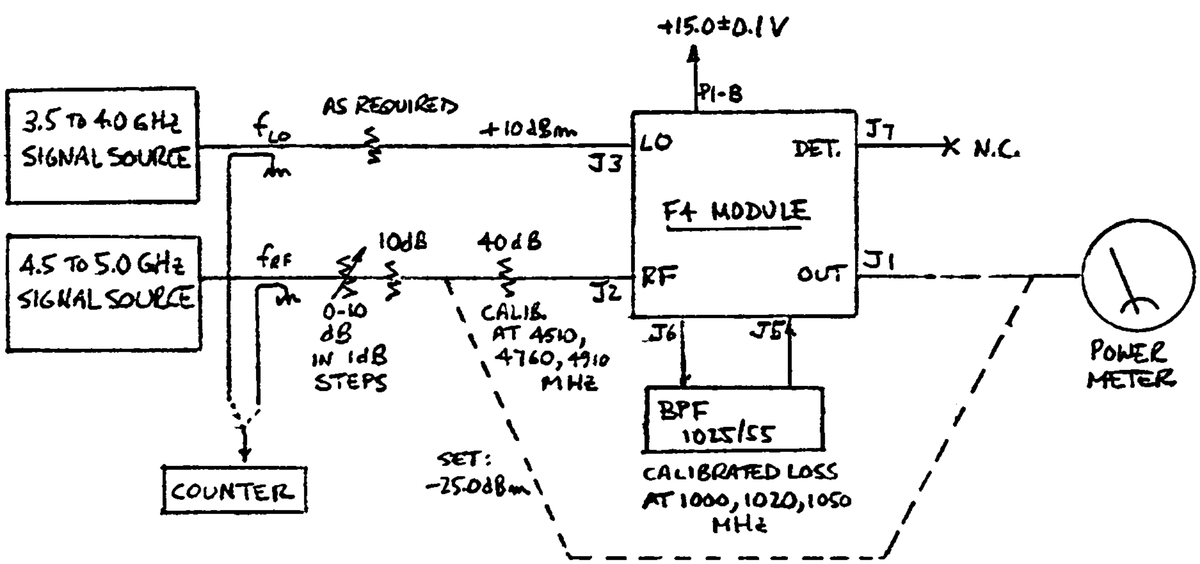


Figure 4.1: Equipment setup for F4 gain measurement.

d. The 40 dB attenuator must be well matched (VSWR <1.15 at 5 GHz) and its actual attenuation must be known to ±0.2 dB at 4.51, 4.76 and 4.91 GHz.

e. The 1025 MHz BPF should have <2 dB insertion loss, and the insertion loss must be known to ±0.2 dB at 1000, 1020 and 1050 MHz.

f. A means must be provided for setting the frequencies of the signal sources to ±2 MHz.

To measure the module gain, proceed as follows. Set the 3.5 to 4.0 GHz source to $f_{L.O.}$ = 3.740±.002 GHz and adjust its power for +10.0±0.5 dBm at J3. Set the 4.5 to 5.0 GHz source to $f_{R.F.}$ = 4.760 ±.002 GHz, the step attenuator to 10 dB, and adjust the power for an indication of -25.0 dBm exactly when the power meter is connected to the output of the 10 dB pad. Be sure to set the power meter efficiency control for 4.8 GHz. Now connect the 10 dB pad's output through the calibrated 40 dB pad to J2, and connect the power meter to J1. Reset the power meter efficiency for 1 GHz. The module gain is then given by

$$G = P - (-25 \text{ dBm}) + L_P + L_F$$

where P is the power meter reading in dBm, L_P is the calibrated pad loss in dB at frequency f_R, and L_F is the calibrated filter loss in dB at frequency $f_{I.F.} = f_{R.F.} - f_{L.O.}$.

Now repeat the gain measurement at $f_{I.F.}$ = 1.000, 1.020 and 1.050 GHz for each of several values of $f_{R.F.}$, namely 4.510, 4.760 and 4.910 GHz. If necessary, replace attenuator AT2 in the module with a value selected to produce <u>G = 66±1 dB</u> at all test frequencies. Selection in steps of 1 dB may be necessary. Typically, AT2 is expected to be 3 dB, but values of 0 to 7 dB are possible. If the gain specification cannot be met with an attenuator in this range, then some component is defective and must be repaired or replaced before proceeding.

At this point, it is useful to check the module's compression point and noise figure. Decrease the setting of the step attenuator until 1 dB of gain compression occurs, and note the power meter reading; it must be $\geq$+3 dBm. Next, disconnect the R.F. input from J2 and install a 50 Ω termination; note that the output power is <-18 dBm. Then terminate J5; note that the output power is <-28 dBm.

4.1.2 Detector and ALC Alignment

Set up the test equipment as shown in Figure 4.2. Observe precautions a, b, c, and f of Section 4.1.1. Refer to Figure 4.3 for the locations of adjustments.

1. Set $f_{L.O.}$ to 3.740 GHz and adjust power for +10 dBm at J3.
2. Set $f_{R.F.}$ to 4.760 GHz, set the step attenuators to 10 dB, and adjust power for -20.0 dBm at J2.

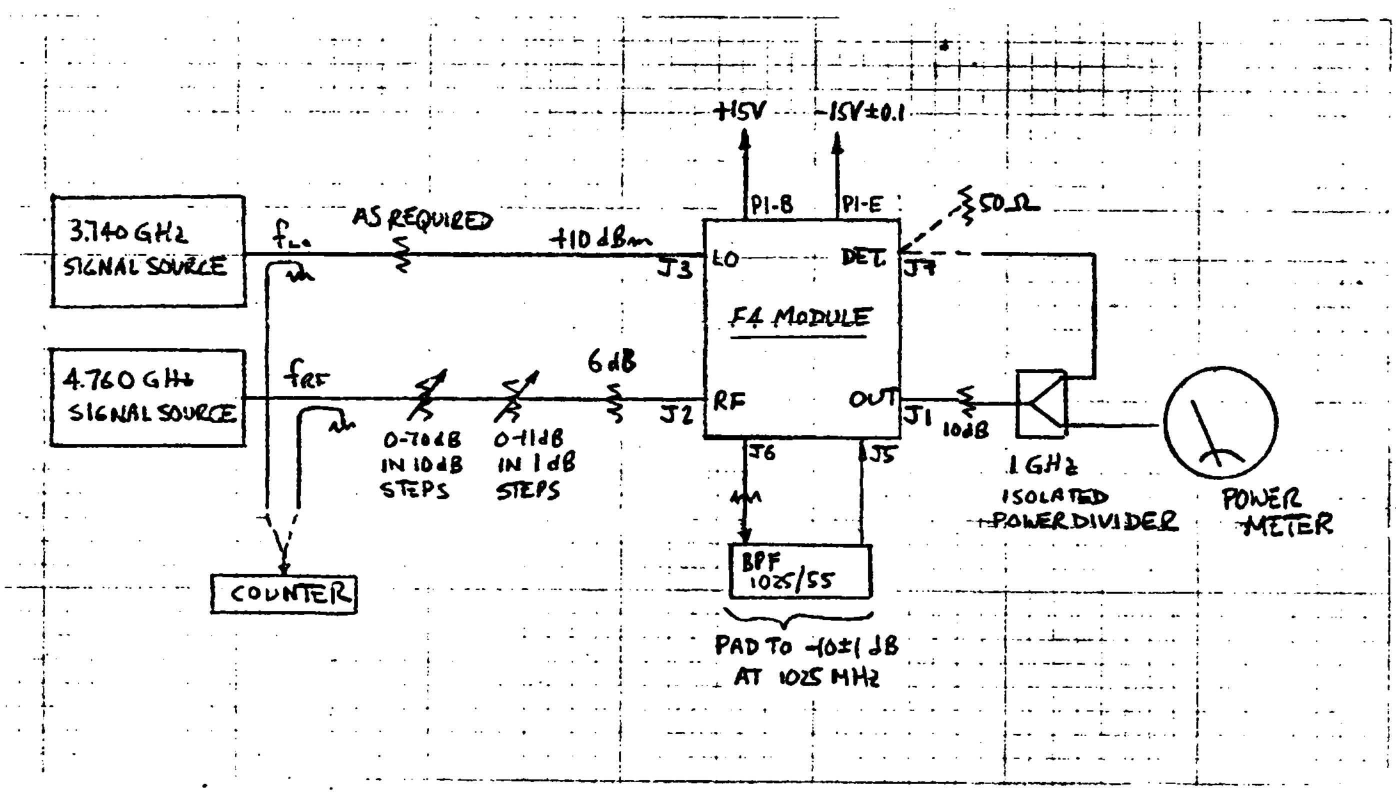


Figure 4.2: Equipment setup for F4 detector and ALC alignment.

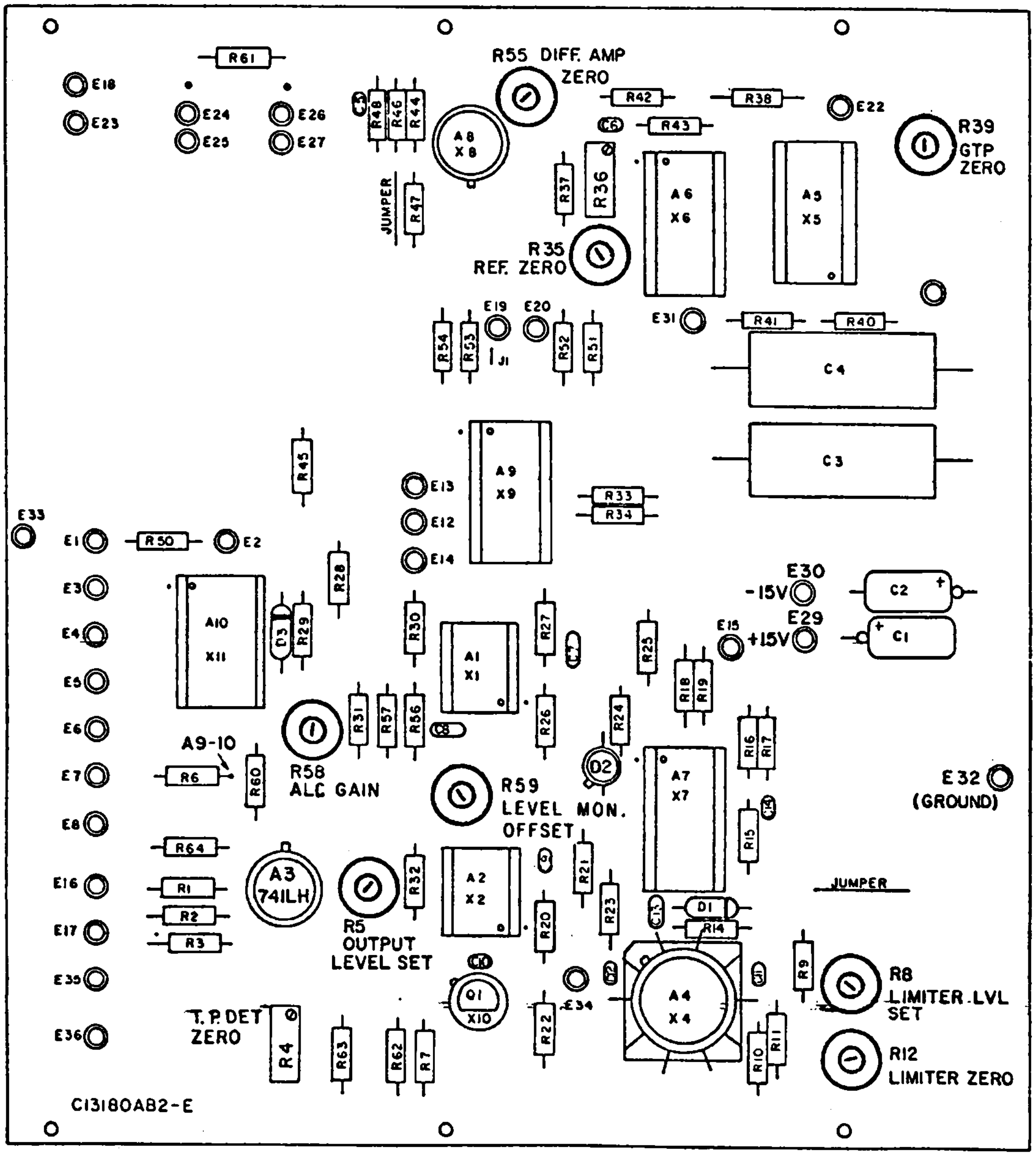


Figure 4.3: F4 printed circuit board, showing locations of adjustments.

3. Set step attenuators to 47 dB (-57 dBm to J2).
4. Temporarily remove signal from J7 and connect a 50 Ω termination. NOTE: All voltages are to be measured with respect to terminal E32 (ground) on F4 pc board.
5. Adjust R4 for 0.000±.001 volt at E8, and adjust R12 for 0.000±.005 volt at E34. Repeat until both conditions are achieved, since these adjustments interact slightly.
6. Reconnect signal to J7.
7. Adjust R5 for -22.5±0.1 dBm on power meter. Verify that the "LOW GAIN" LED on the front panel is not on. (If "LOW GAIN" stays on, try adjusting R58.)
8. Adjust R8 for 0.100±.005 volt at E34.
9. Repeat steps 4 through 8.
10. Before proceeding, verify proper operation of ALC loop as follows: slowly reduce R.F. input level in 1 dB steps until power meter reading drops by 1 dB. Verify that this occurs at -60 to -70 dBm (50 to 60 dB on step attenuator), and that the "LOW GAIN" LED comes on.
11. Reset the step attenuator to 48 dB (-58 dBm input) and adjust R59 for +2.00±.01 volts at E14 (or P1-J). If 2.00 volts cannot be obtained, try adjusting R58.
12. Change the step attenuator to 38 dB (-48 dBm input) and adjust R58 for +4.00±.01 volts at E14 (or P1-J).
13. Repeat steps 11 and 12 until -58 dBm gives 2.00 volts and -48 dBm gives +4.00 volts at E14.

4.1.3 Synchronous Detector Alignment

This procedure does not require the setups of Sections 4.1.1 and 4.1.2, and may be performed independently. Refer to Figure 4.3 for the locations of adjustments.

1. Remove IC A3 (AD741LH, detector amplifier).
2. Apply +15.0±.1 volts to P1-B, -15.0±0.1 V to P1-E, and a 9.6 Hz TTL square-wave to P1-H. NOTE: The square-wave must be symmetric to 1% or better.

3. Connect a clip lead from IC A9, pin 10, to E32 (ground).
4. Adjust R39 for .0000±.0001 volt at E21, and adjust R35 for .0000±.0001 volt at E31.
5. Adjust R55 for .000±.001 volt at E22.
6. Remove clip lead from E32 (ground) and connect to junction of D2, R21, R23, R24 (+6.9 volts). Verify that +6.9±0.1 volts is found at E21 and E31, and that the two differ by less than .001 volt. (If not, check A9, A5 and A6 for possible fault.)
7. Adjust R36 for .000±.001 volt at E22.
8. Alternately connect clip lead to ground and +6.9 volts adjusting R55 and R36 respectively until .000±.001 volt is obtained at E22 for both connections. (Allow 30 sec settling time after each connection change.)
9. Reinstall IC A3.

4.1.4 Data Sheet

When an F4 is first constructed and when a major realignment is undertaken because of maintenance work, the measurements made during alignment should be recorded on a standard data sheet. A sample data sheet, properly filled out and showing normal performance, is given in Figure 4.4.

4.2 FRONT END I.F. FILTERS, F7

This module contains no adjustments.

The switch-filter assemblies should all have been tested prior to installation in the module. Thereafter, any failures will probably be detectable with a simple insertion loss test at 1027 MHz; the loss should be 10±1 dB, 7±1 dB, 4±1 dB, and 1.5±0.5 dB for bandwidth selection codes of 0, 1, 2, and 3 respectively. If these losses are obtained both with the selection code applied through the front-panel switch and with it applied through the rear connector, and if the front-panel lights indicate properly, then both the R.F. and control circuitry can be assumed to be operating correctly.

F4, FREQUENCY CONVERTER MODULE: TEST AND ALIGNMENT DATA

Serial No C41
By LRD
Date 790910

1.0 RF Performance (setup: see manual, Fig. 4.1)

1.1 Value of selected attenuator, AT2 [3] dB

1.2 Measured gain (66±1 dB)

gain= P_{out} + 25dBm + L_p + L_f

where L_p is calibrated pad

L_f is calibrated filter

f_{RF}=	4510	4760	4910	
f_{IF}=1000	66.5	66.3	66.1	dB
1020	66.6	66.4	66.2	dB
1050	66.4	66.2	66.0	dB

1.3 P_{out} at 1.0 dB gain compression (+3 dBm min.) [>+10] dB

1.4 P_{out} with J2 terminated (-18 dBm max.) [-23] dBm

P_{out} with J5 terminated (-28 dBm max.) [-32] dBm

2.0 Detector and ALC Alignment (setup: Fig. 4.2)

2.1 Detector zero (±.005 V) [-.002] V

2.2 Deviation from square law: open ALC loop, vary RF input power and monitor on power meter.

Power meter reading	det. output	
-19.0 dBm	6.12	V
-21.5	3.33	V
-22.0	2.97	V
-22.4	2.71	V
-25.0	1.44	V

2.3 Detector flatness: disconnect cable from J1 and connect to 1 to 2 GHz sweep generator. Set to -22.0 dBm on power meter.

Detector output at 1.025 GHz [4.31] V

Maximum output over 1.3 to 1.7 GHz [4.70] V

Minimum output over 1.3 to 1.7 GHz [4.18] V

(Detector output over 1.3 to 1.7 GHz must be within 10% of the value at 1.025 GHz.)

3.0 Synchronous Detector Alignment

Sync. detector output, no signal (±.005 V) [+.003] V

constant signal at -22 dBm, ALC loop closed [+.01] V

constant signal at -19 dBm, ALC loop open [+.01] V

Figure 4.4: Sample F4 Data Sheet, filled in.

A more detailed test involves a swept-frequency measurement of the response for each selected bandwidth. Care should be taken that the source and load are well matched (<-20 dB reflection coefficient preferred). Performance should be compared with the filter specifications given in Appendix D.

If marginal operation of the PIN diode switches is suspected, their isolation should be checked. At the frequencies corresponding to the -60 dB points of each filter, at least 60 dB of attenuation should be obtained when that filter is selected. If the auxiliary filter jumper cable is removed and 50 Ω terminations installed in its place, then >60 dB of attenuation should be obtained for selection code 3 at 1025 MHz.

CAUTION: Do not exceed +10 dBm R.F. input during any of these tests; distortion caused by the PIN diodes may then lead to spurious results, and burnout of the diodes is possible.

4.3 I.F. OFFSET, F8

This module also contains no adjustments.

The basic performance test involves a CW measurement of conversion loss, which may be performed separately for each channel. The first I.F. input should be about -9 dBm at 1025 MHz. The L.O. signal applied to J8 should meet the specifications of Table I; if a comb is unavailable, a CW signal with frequency and level appropriate to the channel being tested may be used. The conversion loss from the input (J16, J14, J13, or J15) to the corresponding detector output (J9, J11, J12, or J10, respectively) should be 13.5±1.5 dB, with J8 terminated. From the input to J8, with the detector output terminated, it should be 24.5±1.5 dB. The difference between the two outputs should be -11.0±0.3 dB.

More detailed tests include the following. A swept-frequency measurement of conversion loss should show variation less than 0.3 dB over 1000 to 1050 MHz input for any channel at nominal L.O. level. The -1 dB compression point for CW signals should be $\geq$-2 dBm referred to the input (typically 0 dBm). The total current drawn from the +15 V supply should be 202±10 mA (110 mA for the L.O. amplifier and 23 mA for each of the others).

APPENDIX A: MONITOR AND CONTROL DATA

All connections between this subsystem and the Monitor and Control subsystem (or DCS) are via the Control Interface module, F5. For reference, data on these connections are summarized here.

A.1 COMMANDS

Command Name		DCS Address[1]	Front Panel of F5	Rear Connectors[2]
Chan. A	Alternate Input	322_8, bit 8	ALT INP	F4(A)P1-F; F5P1-d
	ALC Off	322_8, bit 7	ALC OFF	F4(A)P1-R; F5P1-e
	Filter Select	322_8, b.1,2,3	-	F7(A)P1-19,20,21; F5P1-t,u,v
Chan. B	Alternate Input	322_8, bit 5	ALT INP	F4(B)P1-F; F5P1-f
	ALC Off	322_8, bit 4	ALC OFF	F4(BOP1-R; F5P1-h
	Filter Select	322_8, b.15,16,12	-	F7(B)P1-19,20,21; F5P1-w,x,y
Chan. C	Alternate Input	323_8, bit 8	ALT INP	F4(C)P1-F; F5P1-j
	ALC Off	323_8, bit 7	ALC OFF	F4(C)P1-R; F5P1-k
	Filter Select	323_8, b.1,2,3	-	F7(C)P1-19,20,21; F5P1-z,AA,BB
Chan. D	Alternate Input	323_8, bit 5	ALT INP	F4(D)P1-F; F5P1-m
	ALC Off	323_8, bit 4	ALC OFF	F4(D)P1-R; F5P1-n
	Filter Select	323_8, b.14,15,12	-	F7(C)P1-19,20,21; F5P1-CC,DD,EE
Manual Operation		none	MANUAL	F7(all)P1-22; F5P1-Z

[1]Multiplex address in Data Set 1; LSB is bit 1.

[2]F5 has nonstandard rear-panel arrangement. Viewed from rear, the connectors are: P1, top left; P2, top right; P3, bottom left; P4, bottom right.

A.2 MONITOR DATA

Signal Name		DCS Addess	Rear Connectors[2]
Chan. A	Sync. Detector	0	F4(A) P1-K; F5P2-B
	Total Power	1	F4(A) P1-M; F5P2-D
	Input Level	2	F4(A) P1-J; F5P2-A
	Peak Detector	3	F4(A) P1-P; F5P2-E
	Filter Select Readback	222_8,b.9,10,11	([3])
Chan. B	Sync. Detector	4	F4(B) P1-K; F5P2-H
	Total Power	5	F4(B) P1-M; F5P2-K
	Input Level	6	F4(B) P1-J; F5P2-F
	Peak Detector	7	F4(B) P1-P; F5P2-L
	Filter Select Readback	222_8,b.22,24,20	([3])
Chan. C	Sync. Detector	20_8	F4(C) P1-K; F5P2-N
	Total Power	21_8	F4(C) P1-M; F5P2-R
	Input Level	22_8	F4(C) P1-J; F5P2-M
	Peak Detector	23_8	F4(D) P1-P; F5P2-S
	Filter Select Readback	223_8,b.9,10,11	([3])
Chan. D	Sync. Detector	24_8	F4(D) P1-K; F5P2-V
	Total Power	25_8	F4(D) P1-M; F5P2-W
	Input Level	26_8	F4(D) P1-J; F5P2-T
	Peak Detector	27_8	F4(D) P1-P; F5P2-X
	Filter Select Readback	223_8,b.23,24,20	([3])

[3]Command readback internal to F5. Not meaningful in manual mode.

APPENDIX B: DRAWING LISTS

On the following pages are reproduced the Configuration Control Lists for modules F4, F7 and F8 as of the date of publication of this report. These lists give the numbers and current revision levels of all drawings associated with the module. A complete set of drawings fully specifies the construction of the modules.

B.1 F4: Configuration Control Drawing No. A13180C1E (2 pages).

B.2 F7: Configuration Control Drawing No. A13190C28 (2 pages).

B.3 F8: Configuration Control Drawing No. A13190C1 (2 pages).

ASSEMBLY NAME FREQUENCY CONVERTER MODULE F4 | SERIES/MODEL C | USED ON RACK A

DRAWING NO.	REV	TITLE	NOTES
A13180ZØ1	F	F4 TOP ASSY - BOM	
D13180PØ1	C	F4 TOP ASSY	
D13180BØ1	A	F4 MODULE BLOCK DIAGRAM	
A13180WØ1	B	F4 MODULE WIRE LIST	
A13180WØ2	-	F4 REAR PANEL CONNECTIONS	
A13180ZØ2	F	ALC LOOP & SYNC DETECTOR PCB - BOM	
C13180PØ2	G	- ASSY	
C13180SØ2	H	- SCHEMATIC	
C13180MØ3	F	- DRILL DWG	
C13180ABØ2	E	- ARTWORK	
A13180ZØ3	-	AMPLIFIER ASSEMBLY PER A13180N4 - BOM	
A13180PØ3	—	- ASSY	
A13180NØ4	-	.8-1.2 GHZ AMPLIFIER - SPECIFICATION	
A13180ADØ5	-	AMPLIFIER ASSEMBLY SILKSCREEN-ARTWORK	
A13180NO3	-	CURRENT CONTROLLED ATTENUATOR - SPECIFICATION	
B13180MØ2	D	F4 FRONT PANEL	
B13180AAØ4	A	F4 FRONT PANEL SILKSCREEN - ARTWORK	
D13180MØ6	B	SUPPORT BARS TOP & BOTTOM	
C13180MØ8	-	F4 REAR PANEL	
C13180MØ9	B	SUPPORT PLATE	
C13050MØ4	B	GUIDE	

NOTES:

1. GENERAL USE ITEM

DWG. NO. A13180CØ1

SHEET 2 OF 3

RE[redacted]

ASSEMBLY NAME FREQUENCY CONVERTER MODULE F4 | SERIES/MODEL C | USED ON RACK A

DRAWING NO.	REV.	TITLE	NOTES
C13050M06	–	SIDE PLATE	1
C13050M07	–	PERFORATED COVER ASSEMBLY	1
A13050M33	C	MIXER MOUNT	1

NOTES:

1. GENERAL USE ITEM

DWG. NO. A13180C01

REV. E

ASSEMBLY NAME FRONT END IF FILTERS, F7 | SERIES/MODEL A | USED ON RACK "A"

DRAWING NO.	REV.	TITLE	NOTES
A13190EØ2	A	F7 MODULE ASSEMBLY - BOM	
D13190PØ2	—	F7 MODULE TOP ASSEMBLY	
C13190SØ1	C	F7 MODULE SCHEMATIC	
A13190WØ3	—	REAR PANEL CONNECTIONS	
A131902Ø1	A	F7 CONTROL BOARD BOM	
[illegible]13190FØ1	B	F7 CONTROL BOARD ASSY	
[illegible]13190MØ3	B	CONTROL BOARD	
B13190ABØ3	—	CONTROL BOARD ARTWORK	
A13190HØ1	C	BANDPASS FILTERS	
A13190HØ2	C	BANDPASS FILTERS	
A13190WØ3	C	BANDPASS FILTERS	
A13190NØ3	A	SP4T DIODE SWITCH	
A13190HØ[illegible]	A	SWITCH-FILTER ASSEMBLY	
C13190MØ1	B	FRONT PANEL	
[illegible]13190AAØ1	A	FRONT PANEL SILKSCREEN	
C13190MØ4	A	SUPPORT BARS	
B13050MØ4	D	GUIDE	
[illegible]13050M18	C	SIDE PLATE	
[illegible]13[illegible]M22	D	PERFORATED COVER	

NOTES

1 GENERAL USE ITEM

ASSEMBLY NAME	SERIES/MODEL	USED ON
FRONT END I.F FILTERS, F7	A	RACK "A"

DRAWING NO.	REV.	TITLE	NOTES
B13050W23	C	SUPPORT BAR	
F132[illegible]0M11	D	REAR PANEL	

NOTES:

1. GENERAL USE ITEM

DWG. NO. [illegible]

SHEET [illegible]

REV.

ASSEMBLY NAME F8 - IF OFFSET MODULE | SERIES/MODEL A | USED ON RACK A

DRAWING NO.	REV.	TITLE	NOTES
A1319OZØ5	A	IF OFFSET MODULE - BOM	
D1319OPØ5	–	- ASSY	
A1319OWØ2	–	- REAR PNL. CONN.	
A1319OZØ3	A	AMPLIFIER - MIXER - BOM	
C1319OPØ3	A	- ASS'Y	
C1319OM12	B	- PCB DRILL DWG.	
C1319OAFØ5	B	- PCB ARTWORK	
B1319OABØ6	–	- SILKSCREEN ARTWORK	
A1319OZO4	–	AMPLIFIER, 10-1000 MHz 6dB - BOM	
A1319OPØ4	–	- ASSY	
C1319OMØ2	A	PANEL, FRONT	
B1319OAAØ2	–	PANEL, FRONT - SILKSCREEN ARTWORK	
B1325OM11	D	PANEL, REAR	
D1319OMO9	A	SUPPORT BAR, TOP & BOTTOM	
D1319OMØ5	D	SUPPORT PLATE	
C1319OM11	D	MOUNTING PLATES FOR R.F. COMPONENTS	
B1319OM13	–	FILTER MTG PLATE	
B1305OMO4	D	GUIDE	1

NOTES:

1. GENERAL USE ITEM

DWG. NO. A13190C1

REV.

ASSEMBLY NAME F8 - IF OFFSET MODULE

SERIES/MODEL A

USED ON RACK A

DRAWING NO.	REV.	TITLE	NOTES
B13050M23	C	SUPPORT BAR	1
B13050M18	C	RIGHT & LEFT SIDE PLATES	1
C13050M22	-	PERFORATED COVER	1

NOTES:

1. GENERAL USE ITEM

DWG. NO. A13190C1

SHEET 3 of 3

REV.

APPENDIX C: BILLS OF MATERIALS

On the following pages are reproduced the Bills of Materials for modules F4, F7 and F8 as of the date of publication of this manual.

C.1 F4 BOM's.

A13180Z01F - F4 Top Assembly (5 pages).

A13180Z02F - ALC Loop and Synchronous Detector PC Board (5 pages).

A13180Z03 - Amplifier Assembly Per A13180N4 (1 page).

C.2 F7 BOM's

A13190Z02A - F7 Top Assembly (3 pages).

A13190Z01A - Control Board (2 pages).

C.3 F8 BOM's

A13190Z05A - F8 Top Assembly (6 pages).

A13190Z03A - Amplifier-Mixer Assembly (2 pages).

A13190Z04 - Amplifier, 10-1000 MHz, 6 dB (1 page).

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13180Z01 REV F DATE 790719

MODULE # F4 MODULE NAME FREQUENCY CONVERTER ASSEMBLY NAME F4 TOP ASSEMBLY DWG # D13180P01

PREPARED BY L. R. D'Addario APPROVED ______

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	1978 COST EA.
1		NRAO	D13180P01	F4 Top Assembly	0	-
2		NRAO	D13180B01	F4 Block Diagram	0	-
3		NRAO	A13180W01	F4 Wire List	0	-
4						
5	F1	K & L MICROWAVE	4B380-4750/795-0P	Filter, Tubular BP alternate P/N: 4B380-4750/795-0/0P	1	120.00
6	M1	WATKINS-JOHNSON	M1H	Mixer, Dbl Bal, 2-6 GHz	1	199.00
7	CIR1	WESTERN MICROWAVE	2JC-4080-5	Isolator	1	
8	F2	K & L MICROWAVE	4B380-3750/630-0	Filter, Tubular BP	1	120.00
9	S2	RLC	S-2580	Switch, Coax, 15 V	1	155.00
10	A1	AVANTEK	ASD8199M	Amplifier, 1-2 GHz, 26 dB	1	260.00
11	AT1	VECTRONICS	DA0125-40	Attenuator, Current Controlled, A13180N3	1	350.00
12	A2	NRAO	A13180Z03	Amplifier Assy. per A13180N4	1	308.00
13	HY1	MERRIMAC INDUSTRIES	QHM-2-1.5G	Hybrid, 90 Deg., 1-2 GHz	1	75.00
14	D1, D2	AERTECH	DO102B	Detector, 1-2 GHz	2	113.00
15		OMNI SPECTRA	20020P-1	Termination, SMA, 50 Ohm	1	16.32

[redacted] OF [redacted]ERI[redacted]

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13180Z01 REV F DATE 790626 PAGE 2 OF 5

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16		NRAO	A13180P2	ALC & Sync Det PCB Assy.	1	-
17			IN4007	Diode	1	
18	AT2	MIDWEST MICROWAVE	294	Attenuator (value selected at assembly)	1	29.00
19						
20		WESTON	111-5422100	Meter, Vertical Scale, 0-100UA	1	14.95
21		WESTON	1909-0256-258	Bezel	1	1.25
22	S1	GRAYHILL	510D3C-01-2AJN	Switch, Rotary	1	8.95
23		AMPHENOL	UG-625B/U	BNC Bulkhead Recept.	3	.56
24		OMNI SPECTRA	OMQ-3043-75	Jack, Bulkhead, 141SR	7	1.74
25		AMP SPEC IND	201347-4	Hood, 14 Pin	1	1.02
26		AMP SPEC IND	201355-3	Block, 14 Pin	1	1.55
27		AMP SPEC IND	202514-1	Guide Pin, GND	1	.94
28		AMP SPEC IND	203964-6	Guide Socket	1	.21
29		AMP SPEC IND	201578-1	Contact Pin	11	.23
30		MONSANTO	MV5024	LED, Red	2	.30
31						
32						

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13180Z01 REV F DATE 790626

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
33						
34						
35		NRAO	B13180M02	Panel, Front, F4	1	31.02
36		NRAO	B13180M08	Panel, Rear, F4	1	
37		NRAO	D13180M06-1	Bar, Support, Top	1	22.54
38		NRAO	D13180M06-2	Bar, Support, Bottom	1	22.54
39		NRAO	C13180M09	Plate, Support	1	15.35
40		NRAO	C13050M07	Perforated Cover Assembly	1	12.42
41						
42		NRAO	B13050M06	Side Plate	1	11.56
43		NRAO	B13050M04	Guide	2	.20
44		SOUTHCO	47-10-204-10	Fastener, Captive	2	.67
45		RAYTHEON	50-4-1G	Knob	1	.30
46		NRAO	A13050M33	Mixer Mount	2	1.87
47						
48						
49						

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13180Z01 REV F DATE 790626 PAGE 4 OF 5

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
50		OMNI SPECTRA	OSM-201-1	SMA Plug, 141SR	16	1.02
51		OMNI SPECTRA	OSM-202-1A	SMA Jack, 141SR	1	4.71
52		OMNI SPECTRA	OSM-511-3	SMA Plug, RG188	2	5.27
53		UNIFORM TUBES	UT-141A	Cable, Coax Semirigid	4 ft.	.45
54		ALPHA	RG188A/U	Cable, Coax	2 ft.	
55				Wire, Stranded Hookup, 24 AWG	AR	
56				Wire, Stranded Hookup, 18 AWG	AR	
57		K & L MICROWAVE	M38-A	Mounting Clip, Filter	1	
58						
59						
60			6-32 x 3/8	Screw, Flat Head, Cross Recessed	2	
61			6-32 x 1/4	Screw, Flat Head, Slotted	6	
62			6-32 x 3/8	Screw, Hex, Socket Hd	2	
63			6-32 x 1/4	Screw, Pan Hd, Slotted	4	
64			6-32 x 5/8	Screw, Pan Hd, Slotted	2	
65			6-32 x 7/8	Screw, Pan Hd, Slotted	2	
66						

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13180Z01 REV F DATE 790626 PAGE 5 OF 5

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
67						
68			2-56 x 1/4	Screw, Pan Hd, Slotted	12	
69			2-56 x 5/8	Screw, Pan Hd, Slotted	2	
70						
71			4-40 x 5/8	Screw, Pan Hd, Slotted	2	
72			4-40 x 1/4	Screw, Pan Hd, Slotted	8	
73			4-40 x 3/8	Screw, Pan Hd, Slotted	2	
74			4-40 x 3/4	Screw, Pan Hd, Slotted	4	
75			No. 2	Washer, Split Lock	14	
76			No. 4	Washer, Split Lock	12	
77			No. 6	Washer, Split Lock	16	
78			No. 6	Washer, Ext Tooth	2	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

[ ] ELECTRICAL [X] MECHANICAL BOM # A13180Z2 REV F DATE 790302 PAGE 1 OF 5

MODULE # F4 NAME Frequency Converter DWG # SUB ASMB ALC Loop amp & Sync. Det DWG # C13180P2

SCHEMATIC DWG # C13180S2 LOCATION QUA/SYSTEM PREPARED BY Oty APPROVED

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	C13180P02	ALC Loop amp & Sync. Det.	-	
2		NRAO	C 13180S2	ALC Loop amp & Sync. Det. Schematic	Ref.	
3						
4						
5						
6						
7		NRAO	C 13180AB2	P.C. Card	1	
8						
9		Keystone	1562-2	Terminal	32	
10		Wakefield	213-CB	Heat sink	1	
11	X4	Robinson Nugent	MP 12100S	12 Pin TO-8 Socket	1	
12	X3, X8	Robinson Nugeht	DP-5178-A	8 Pin TO-5 Socket	2	
13	X1, X2	Robinson Nugent	1CN-083-S3	8 Pin DIP Socket	2	
14	X5, X6 X7, X9, X10	Robinson Nugent	1CN-143-S3	14 Pin DIP Socket	5	
15	X10	Robinson Nugent	S08173	3 Pin Transistor Socket	1	

NATIONAL RADIO STRONOMY OBSERVATORY

x ELECTRICAL ☐ MECHANICAL BOM # A1318022 REV F DATE 790802 PAGE 2 OF 5

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16	R2, R10		RCR07100JS	10 ohm, ¼W, 5%, Carbon Resistor	2	
17	R61		RCR07132JS	1.3 k ohm, ¼W, 5%, Carbon Resistor	1	
18	R15, R1		RCR07101JS	100 ohm, ¼W, 5%, Carbon Resistor	2	
19	R29		RCR07121JS	120 ohm, ¼W, 5%, Carbon Resistor	1	
20	R28, R64		RCR07102JS	1 k ohm, ¼W, 5%, Carbon Resistor	2	
21	R6, 18, 19, 30, 31, 40, 41, 43, 45		RCR07202JS	2 k ohm, ¼W, 5%, Carbon Resistor	9	
22	R20, R22		RCR07242JS	2.4 k ohm, ¼W, 5%, Carbon Resistor	2	
23	R32		RCR0621JS	620 ohm, ¼W, 5% Carbon Resistor	1	
24						
25	R23, 56		RCR07472JS	4.7 k ohm, ¼W, 5%, Carbon Resistor	2	
26	R14		RCR07512JS	5.1 k ohm, ¼W, 5%, Carbon Resistor	1	
27	R51, R54		RCR07622JS	6.2 k ohm, ¼W, 5%, Carbon Resistor	2	
28	R62, R7		RCR07912JS	9.1 k ohm, ¼W, 5%, Carbon Resistor	2	
29						
30	R52,53		RCR07183JS	18k ohm, ¼W, 5%, Carbon Resistor	2	
31	R3		RCR07823JS	82 k ohm, ¼W, 5%, Carbon Resistor	1	
32	R33,34, 9		RCR07104JS	100 k ohm, ¼W, 5%, Carbon Resistor	3	

NATIONAL RADIO ASTRONOMY OBSERVATORY

[x] ELECTRICAL [ ] MECHANICAL BOM # A1318OZ2 REV F DATE 790802 PAGE 3 OF 5

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
33	R26,27		RCR07514JS	510 k ohm, ¼W, 5%, Carbon Resistor	2	
34	R16,17		RCR07225JS	22M ohm, ¼W, 5%, Carbon Resistor	2	
35	R11		RCR07822JS	8.2 k ohm, ¼W, 5%, Carbon Resistor	1	
36						
37						
38	R57		RCR07243JS	24 k ohm, ¼ W, 5%, Carbon Resistor	1	
39	R44	Corning	NA 55	4.02 k ohm, ¼W, 1% MF	1	
40	R25, R47	Corning	NA 55	6.04 k ohm, ¼W, 1% MF	2	
41	R24	Corning	NA 55	7.87 k ohm, ¼W, 1% MF	1	
42	R37	Corning	NA 55	9.53 k ohm, ¼W, 1% MF	1	
43	R46	Corning	NA 55	12.1 k ohm, ¼W, 1% MF	1	
44	R50	Corning	NA 55	97.6 k ohm, ¼W, 1% MF	1	
45	R42, 48	Corning	NA 60	402 k ohm, ¼W, 1% MF	2	
46	R60	Corning	NA 55	20.0 k ohm, ¼W, 1% MF	1	
47	R38	Corning	NA 55	10.0 k ohm, ¼W, 1% MF	1	
48	C9, C10	Erie	8101-100-X7R0-221K	220 pf, , 50V, Capacitor	2	
49	C11,12,14	Erie	8121-050-651-103M	0.01 MF, 50V, Capacitor	3	

NATIONAL RADIO ASTRONOMY OBSERVATORY

[X] ELECTRICAL [ ] MECHANICAL BOM # A1318022 REV F DATE 790323

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA.	
50	C5, C6	Erie	8121-050-651-104M	0.1 MF, 50V, Capacitor	2	
51	C7,8,13	Erie	8131-050-651-105M	1.0 MF, 50V, Capacitor	3	
52						
53	C1, C2	Kemet	CSR13E156KL	15 MF, 20V, Capacitor	2	
54	C3, C4	Electrocube	650D1A505M	5 MF, 50V, Capacitor	2	
55						
56	A1, A2	Analog Devices	AD741KN	OP amp	2	
57	A3, A8	Analog Devices	AD741LH	OP amp	2	
58	A7, 5, 6	National	LH0022CD	OP amp	3	
59	A4	National	LH0032CG	OP amp	1	
60	A9, A10	Analog Devices	AD7512KN	FET Switch	2	
61						
62	D1, D3	H-P	5082-2800	Diode	2	
63	D2	National	LM 329B	Diode	1	
64						
65						
66	Q1		2N3904	Transistor	1	

NATIONAL RADIO ASTRONOMY OBSERVATORY

[X] ELECTRICAL [ ] MECHANICAL BOM # A1318022 REV F DATE 790328

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
67	R35, 39, 55, 58	Bourns	3339P-1-103	10 k ohm, 4 turn, pot	4	
68	R12, 59	Bourns	3339P-1-203	20 k ohm, 4 turn, pot	2	
69	R5	Bourns	3339P-1-204	200 k ohm, 4 turn, pot	1	
70	R8	Bourns	3339P-1-105	1 M ohm, 4 turn, pot	1	
71						
72	R36	Beckman	63WR1K-M1	1 k ohm, 22 turn, pot	1	
73	R4	Beckman	63WR20K-M1	20 k ohm, 22 turn, pot	1	
74						
75						
76						
77						
78						
79						
80						
81						
82						
83						

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

[X] ELECTRICAL [ ] MECHANICAL BOM # A13180Z03 REV - DATE 781212 PAGE 1 OF 1

MODULE # F4 NAME Frequency Converter DWG # SUB ASMB Amplifier Assembly DWG # X13180P03

SCHEMATIC DWG # LOCATION QUA/SYSTEM PREPARED BY APPROVED

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	1978 COST EA.
1		NRAO	X13180P03	Amplifier Assembly per A13180N4	0	-
2		WATKINS-JOHNSON	WJ-A64	Amplifier, TO-8 Pkg., 26 dB, 10-1200 MHz	2	130.
3		AVANTEK	TC-2M	Case for TO-8 Amplifiers	1	40.
4		AVANTEK	TB-2	PC Board for TO-8 Amplifiers	1	8.
				TOTAL COST		308.

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13190Z02 REV A DATE ______ PAGE 1 OF 3

MODULE # F7 NAME FRONT END I.F. FILTER MODULE DWG # D13190P02 SUB ASMB ______ DWG # ______

SCHEMATIC DWG # C13190S01 A13190W03 LOCATION ______ QUA/SYSTEM ______ PREPARED BY ______ APPROVED ______

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1	F7	N.R.A.O.	D13190P02	FRONT END I.F. FILTER MODULE ASS'Y	-	
3	A1		A13190Z01	CONTROL BOARD ASSY - C13190P01	1	
5			B13050M04	GUIDE	4	
6			B13050M18	SIDE PLATE	2	
7			C13050M22-2	COVER, PERF.	2	
8			B13050M23	BAR, SUPPORT	2	
11			C13190M01	PANEL, FRONT	1	
12			C13190M04-1	BAR, SUPPORT	1	
13			C13190M04-2	BAR, SUPPORT	1	
15		N.R.A.O.	B13250M11	PANEL, REAR	1	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13190202 REV A DATE ______ PAGE 2 OF ______

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16						
18	FL1	RLC	M2272	SWITCH FILTER ASSY (N.R.A.O. SPEC. A13190N09)	1	
19	S1	DIGITRAN	23011-1	DIGISWITCH ASSY	1	
21	J7. J8	OMNI-SPECTRA	OMQ 3043-75	CONN., (BULKHEAD, OMQ - .141 SR)	2	
22		OMNI-SPECTRA	OSM 201-1A	CONN. (PLUG, SMA - .141 SR)	4	
24	P1	AMP SPEC INDUST.	204186-5	CONN. BLOCK - 42 PIN	1	
25			202394	PIN HOOD	1	
26			200833-4	GUIDE PIN	1	
27			202514-1	GUIDE PIN (GND)	1	
28			203964-6	GUIDE SOCKET	2	
29			201578-1	PIN CRIMP (24-20 AWG)	5	
30		AMP SPEC INDUST	202725-1	PIN CRIMP (2-#18 AWG)	2	
32		SOUTHCO	47-10-204-10	FASTNER, CAPTIVE	4	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☒ ELECTRICAL ☐ MECHANICAL BOM # A13190202 REV A DATE ______

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA
33			6-32 × 5/8 LG.	SCREW, SLOTTED BINDER HD. S.S.	4
34			6-32 × 3/4 LG	SCREW, SLOTTED BINDER HD. S.S.	4
35					
36			6-32 × 3/8 LG	SCREW, SLOTTED FLAT HD S.S.	14
37					
38			2-56 × 1/4 LG	SCREW, CROSS RECESSED FLAT HD S.S.	4
39			6-32 × 3/8 LG	SCREW, CROSS RECESSED FLAT HD S.S.	4
40					
41			6-32 × 3/8 LG	SCREW, SOCKET HD S.S.	6
42					
43			NO. 6	WASHER, FLAT S.S.	4
44			NO. 6	WASHER, SPLIT LOCK S.S.	4
45					
46			18 AWG (ASSORTED COLORS)	HOOK-UP WIRE TYPE MW PLASTIC	A/R
47			24 AWG (ASSORTED COLORS)	HOOK-UP WIRE TYPE MW PLASTIC	A/R
48					
49		UNIFORM TUBES	UT-141	SEMI-RIGID COAX. CABLE	A/R.

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190Z01 REV A DATE 790508

MODULE # F7 NAME Front End I.F. Filters DWG # ______ SUB ASMB ______ DWG # ______

SCHEMATIC DWG # ______ LOCATION ______ QUA/SYSTEM ______ PREPARED BY L. D'Addario APPROVED ______

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	C13190P01	F7 Module Control Board	-	
2		NRAO	B13190AB03	Control Board P.C. Artwork	Ref	
3		NRAO	C13190S01	Control Board Schematic	Ref	
4						
5		NRAO	C13190M03	Control Board P.C. Card	1	
6	CR1, 2, 3, 4	Hewlett-Packard	5082-4995	LED, green	4	.85
7						
8	U2	Texas Instruments	7407	Integrated Circuit, Hex Buffer/Driver	1	.75
9	U3	Texas Instruments	8250A	Integrated Circuit, Decoder	1	
10	U4	Texas Instruments	74157	Integrated Circuit, Quad 2-in mux	1	.49
11	Q1, 2, 3, 4	Motorola	2N3906	Transistor, pnp	4	.12
12						
13						
14						
15	R1, 4, 7, 10		RCR07131-5S	Resistor, ¼ W, 130 ohms	4	.06

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NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190Z01 REV A DATE 790508 PAGE 2 OF 2

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16	R2, 5, 8, 11		RCR07102-5S	Resistor, ¼ W, 1 k ohms	4	.06
17	R13, 14, 15, 16		RCR07103-5S	Resistor, ¼ W, 10 k ohms	4	.06
18						
19						
20	C1, C2	Sprague	CS13BE156K	Capacitor, Tantalum, 20 V, 15 µf	2	.24
21						
22		Cinch	3-LPS-B	Socket, Transistor	4	.12
23		Rob Nugent	ICN-143-S3	Socket, 14 pin DIP	2	.33
24		Rob Nugent	ICN-163-S3	Socket, 16 pin DIP	1	.40
25						
26		Keystone	1562-2	Terminal, Turret	16	.02
27		Amatom	9508B-SS-0256	Standoff, swage	4	.50
28						
29						
30						

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190B05 REV A DATE 9-5-79 PAGE 2 OF 7

MODULE # F3 NAME IF OFFSET DWG # D13190P05 SUB ASMB ______ DWG # ______

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

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	D13190PØ5	IF OFFSET MODULE ASSY	—	
2			C13190BØ1	IF OFFSET MODULE BLOCK DIAG.	—	
3						
4			B13190M13	MOUNTING PLATE, FILTER	1	
5			C13190M11-1	MOUNTING PLATE, CH A	1	
6			C13190M11-2	MOUNTING PLATE, CH B	1	
7			C13190M11-3	MOUNTING PLATE, CH C	1	
8			C13190M11-4	MOUNTING PLATE, CH D	1	
9			D13190MØ5	SUPPORT PLATE	1	
10			D13190MØ9-1	SUPPORT RAIL, BOTTOM	1	
11			D13190MØ9-2	SUPPORT RAIL, TOP	1	
12			C13190MØ2	PANEL, FRONT	1	
13			B13250M11	PANEL, REAR	1	
14			B13050M18	SIDE PLATE	2	
15		NRAO	C13050M22	COVER, PERFORATED	2	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190Z05 REV A DATE 9-5-79 PAGE 3 OF 7

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16		NRAO	B13050M04	GUIDE	4	
17		NRAO	B13050M23	SUPPORT BAR	2	
18		NRAO	A13190Z04	AMPLIFIER ASSY, 10-1000 MHZ, 6dB	1	
19		NRAO	A13190Z03	AMPLIFIER-MIXER ASSY	4	
20						
21						
22						
23						
24		AERTECH	AMF-6035	ISOLATOR, CH A	1	
25		AERTECH	AMF-6036	ISOLATOR, CH B	1	
26		AERTECH	AMF-6037	ISOLATOR, CH C	1	
27		AERTECH	AMF-6038	ISOLATOR, CH D	1	
28						
29		RLC	F-3685A	FILTER, BANDPASS, 1325/60	1	
30		RLC	F-3686A	FILTER, BANDPASS, 1425/60	1	
31		RLC	F-3687A	FILTER, BANDPASS, 1575/60	1	
32		RLC	F-3688	FILTER, BANDPASS 1675/60	1	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190Z05 REV A DATE 9-5-79

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
33		K&L MICROWAVE	3MC10-300/18-OP/O	BPF 300/18; TEMPCO < 10 PPM/C	1	
34		K&L MICROWAVE	3MC10-400/18-OP/O	BPF 400/18; TEMPCO < 10 PPM/C	1	
35		K&L MICROWAVE	3MC10-550/18-OP/O	BPF 550/18; TEMPCO < 10 PPM/C	1	
36		K&L MICROWAVE	3MC10-650/18-OP/O	BPF 650/18; TEMPCO < 10 PPM/C	1	
37						
38		MERRIMAC INDUSTRIES	PDM-40-625	POWER DIVIDER, 4 WAY, .1-1.0 GHZ	1	
39		VECTRONICS MICROWAVE CORP	PD8304-4M	POWER DIVIDER, 4 WAY .8-2.0 GHZ	1	
40						
41		OMNI-SPECTRA	20063-6	DIRECTIONAL COUPLER, 6dB, 1.0-2.0 GHZ	4	
42						
43		MIDWEST MICROWAVE	238-3DB	ATTENUATOR, 3dB, SMA, 1.21" LONG TO 4 GHZ	2	
44		MIDWEST MICROWAVE	238-6DB	ATTENUATOR, 6dB, SMA, 1.21" LONG TO 4 GHZ	1	
45		AMP SPECIAL INDUSTRIES	2008-33-4	GUIDE PIN	1	
46	P1	AMP SPECIAL INDUSTRIES	204186-5	42 PIN MOD CONN BLOCK	1	
47		AMP SPECIAL INDUSTRIES	203964-6	GUIDE SOCKET	2	
48		AMP SPECIAL INDUSTRIES	202394-2	CONN SHIELD	2	
49		AMP SPECIAL INDUSTRIES	202514-1	GROUND GUIDE PIN	1	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190205 REV A DATE 9-5-79 PAGE 5 OF 7

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
50		AMP SPECIAL INDUSTRIES	202725-1	PIN, CRIMP (2-#18 AWG)	2	
51						
52						
53		OMNI-SPECTRA	OSM-218	OSM ADAPTOR, STRAIGHT PLUG/PLUG	1	
54		OMNI-SPECTRA	OMQ-3043-75	OMQ JACK, BULKHEAD, 141 S.R.	10	
55		OMNI-SPECTRA	OSM-201-1	SMA PLUG, CABLE, .141 S.R.	36	
56		OMNI-SPECTRA	OSM-201-2A	SMA PLUG, .085 S.R	16	
57		OMNI-SPECTRA	OSM-202-1	SMA JACK, CABLE, .141 S.R.	2	
58						
59		UNIFORM TUBES	UT-141A	CABLE, COAX, .141" Semi-Rigid	17'	
60		UNIFORM TUBES	UT-085	CABLE, COAX, .085" Semi-Rigid	2'	
61						
62						
63			6-32	LUG, SOLDER	1	
64		CAMBION	4839-1	TERMINAL, INSULATED	1	
65						
66						

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190705 REV A DATE 9-5-79

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
67			2-56	WASHER, LOCK, SPLIT	8	
68			4-40	WASHER, LOCK, SPLIT	28	
69			6-32	WASHER, LOCK, SPLIT	8	
70						
71		AMATOM	9221 SS 115	SPACER, 3/16" ROUND x 1" L, SS	10	
72		AMATOM	9743-SS-0632	STANDOFF, 1/4" HEX, 1" L, MALE/FEMALE	6	
73						
74						
75			6-32 x 1/4"	SCREW, SOCKET HD. CAP, SS	10	
76			6-32 x 1/4"	SCREW, FLAT HD., CROSS RECESSED SS	16	
77			6-32 x 7/8"	SCREW, PAN HD., SLOTTED, SS	10	
78			6-32 x 1/4"	SCREW, PAN HD., SLOTTED, SS	1	
79						
80			4-40 x 1 1/4"	SCREW, PAN HD., SLOTTED, SS	6	
81			4-40 x 1"	SCREW, PAN HD., SLOTTED, SS	4	
82			4-40 x 1/4"	SCREW, PAN HD., SLOTTED, SS	36	
83						

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A131902Ø5 REV A DATE 9-5-79

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
84						
85						
86			2-56 x 1/2	SCREW, PAN HD., SLOTTED, SS	8	
87			2-56 x 1/4	SCREW, PAN HD., SLOTTED, SS	8	
88			2-56 x 1/4	SCREW, FLAT HD, CROSS RECESSED, SS	14	
89						
90						
91				WIRE, STRANDED, HOOKUP, 18 AWG, RED		
92				WIRE, STRANDED, HOOKUP, 18AWG, BLK		
93				WIRE, STRANDED, HOOKUP, 24 AWG, RED		
94				WIRE, STRANDED, HOOKUP, 24 AWG, BLK		

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190Z03 REV A DATE 7-31-79 PAGE 2 OF 3

MODULE # F8 NAME I.F. OFF SET DWG # D13190P05 SUB ASMB AMPLIFIER MIXER ASS'Y DWG # C13190P03

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

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	C13190P03	AMPLIFIER MIXER ASS'Y		
2			C13190AF05	AMPLIFIER MIXER ASS'Y P.C. BOARD ARTWORK	REF	
3			B13190AB06	AMPLIFIER MIXER SILKSCREEN ARTWORK	REF	
4		NRAO	C13190M12	P.C. BOARD	1	
5						
6		AVANTEK	TC-4	CASE FOR MODULAR AMPLIFIER	1	
7		AVANTEK	UTO-1002	MODULAR AMPLIFIER, 5-1000 MHz, 14dB	1	
8						
9		WATKINS-JOHNSON	WJ-M2A	MIXER, TO-8 PACKAGE	1	
10						
11		OMNI-SPECTRA	OSM-204	OSM JACK, FLANGE	1	
12						
13	C1	AMERICAN TECHICAL CERAMICS	100B-3R0-B-P-X-500	CHIP CAPACITOR, 3.0 pf	1	
14	R1		RCR07G680JS	RESISTOR, 6.8 Ω, 1/4 W, 5%	1	
15	H1		1N4001	DIODE	1	

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190Z03 REV A DATE 7-31-79 PAGE 3 OF 3

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
16	L1			WIRE, 22 AWG, SOLID COPPER TINNED	1 INCH	
17						
18			2-56 X 1/4	SCREW, PAN HD. S.S.	4	
19			2-56	LOCK WASHER, SPLIT.	4	
20						

BILL OF MATERIAL

NATIONAL RADIO ASTRONOMY OBSERVATORY

☐ ELECTRICAL ☐ MECHANICAL BOM # A13190Z04 REV ____ DATE 790905 PAGE 1 OF 1

MODULE # F8 NAME I.F. OFFSET DWG # ____ SUB ASMB Amplifier, 10-1000 MHz DWG # ____

SCHEMATIC DWG # ____ LOCATION ____ QUA/SYSTEM ____ PREPARED BY L. D'Addario APPROVED ____

ITEM #	REF DESIG	MANUFACTURER	MFG PART #	DESCRIPTION	TOTAL QUA	
1		NRAO	A13190P04	Amplifier Assembly, 10-1000 MHz, 6 dB	-	
2		Avantek	UTO-1004	Amplifier, TO-8 pkg, 10-1000 MHz, 6 dB	1	
3		Avantek	TB-1	PC board for one TO-8 amplifier	1	
4		Avantek	TC-2M	Case for TO-8 amplifiers, w/ SMA conn.	1	

APPENDIX D: NRAO SPECIFICATIONS

All NRAO specifications relevant to this subsystem are reproduced on the following pages. Most are used for the procurement of critical components.

A13180N3	Current-Controlled Attenuator
A13180N4	0.8-1.2 GHz Amplifier
A13190N1C	
thru N7C	Band-Pass Filters
A13190N8A	SP4T Diode Switch
A13190N9A	Switch-Filter Assembly

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROGRAM

SPECIFICATION: A13180N3 Date: March 27, 1978

TITLE: Current-Controlled Attenuator

PREPARED BY: ____________________ APPROVED BY: ______________________

1.0 GENERAL DESCRIPTION

An absorptive current-controlled RF attenuator for use with noise signals in a 990 to 1060 MHz band is required. The device will be used as part of an ALC loop in a sensitive radiotelescope receiver. Specifications which are of particular interest include phase *vs* attenuation (item 7.0) and flatness across the above band (item 8.0).

2.0 FREQUENCY RANGE

All specifications shall be met at any frequency in a 990 to 1060 MHz band.

3.0 ATTENUATION VS CONTROL CURRENT

3.1 Attenuation shall increase with positive control current into the device, and shall be minimum at zero control current.

3.2 At zero control current: $\leq$ 1.5 dB

3.3 At a control current I_1 specified by the manufacturer, but not exceeding +5 mA: 20 ± 5 dB

3.4 At a control current I_{MAX} specified by the manufacturer, but not exceeding +12 mA: $\geq$ 40 dB

3.5 The control currents I_1 and I_{MAX} shall be the same for all units.

3.6 It shall be possible to apply a control current of at least +20 mA or a (reverse) control voltage of -15 V without damage to the unit.

4.0 RF POWER

In normal operation, input power will not exceed 0 dBm. It shall be possible to apply +10 dBm without damage.

5.0 SWITCHING SPEED

With a step change in control current, the 0 to 90% switching time shall be $\leq$ 200 nsec.

6.0 VSWR

The design shall be absorptive, so that at any control current the VSWR at both input and output is $\leq$ 1.5.

7.0 PHASE VS ATTENUATION

The slope of the phase vs attenuation curve shall not exceed

7.1 for attenuation settings of 0 to 30 dB: 1.5°/dB;

7.2 for attenuation settings of 10 to 20 dB: 0.5°/dB.

8.0 FLATNESS

At any control current, the attenuation shall be constant across the specified frequency range to within ± 0.2 dB.

9.0 DISTORTION

The second-order harmonic intercept point and the third-order two-tone intercept point shall each be $\geq$ +20 dBm, referred to the input, at any control current. (Alternatively, with 0 dBm sinusoidal inputs, second-order products shall be $\leq$ -20 dB and third-order products shall be $\leq$ -40 dB from the desired signals.)

10.0 ENVIRONMENTAL

All specifications shall be met over an operating temperature range of 20 to 40 C. Phase shift and attenuation shall not be affected more than 1° or .05 dB respectively by change of orientation with respect to gravity or by light tapping on the case. The device shall survive storage temperatures of -40 to +60 C and a drop test from a height of one foot onto a wooden surface without degradation in performance.

11.0 PACKAGING AND CONNECTORS

Outside dimensions, excluding connectors, shall be less than or equal to 3.00 x 3.50 x 0.60 inches. Connectors shall not be mounted on the largest surfaces, which shall include provisions for mounting the device to a flat surface. RF connectors shall be SMA female, and the control current connector may be SMA female or solder lugs.

12.0 QUALITY CONTROL

Construction techniques shall be in accord with best commercial practices.

13.0 TESTING AND DOCUMENTATION

The manufacturer shall test each unit to the extent required to ensure that all specifications are met. Copies of the results of all such tests shall be supplied with each unit.

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROGRAM

SPECIFICATION: A13180N4 DATE: August 18, 1978

TITLE: 0.8 - 1.2 GHz AMPLIFIER

PREPARED BY: ____________________ APPROVED BY: ______________________

1.0 GENERAL DESCRIPTION

A solid state amplifier in an RF-tight package is required. All specifications shall be met at frequencies between 0.8 and 1.2 GHz, unless otherwise stated.

2.0 SMALL SIGNAL GAIN

2.1 Minimum	48 dB
2.2 Maximum	56 dB
2.3.1 Variation with frequency, 0.8 - 1.2 GHz	±1.0 dB
2.3.2 Variation with frequency, 0.95 - 1.1 GHz	±0.5 dB

2.4 Out-of-band gain (outside 0.8 - 1.2 GHz) shall not exceed in-band gain by more than 3 dB.

3.0 VSWR, input and output ports, in 50 ohms

3.1 0.8 - 1.2 GHz	≤2.0
3.2 0.95 - 1.1 GHz	≤1.7

4.0 NOISE FIGURE ≤5.0 dB

5.0 OUTPUT POWER AT 1.0 dB GAIN COMPRESSION ≥0 dBm

6.0 DISTORTION

6.1 Second harmonic intercept point	≥+30 dBm
6.2 Third order intercept point	≥+15 dBm

7.0 POWER REQUIREMENTS

7.1 Supply voltage at which all specifications shall be met — +15±1 Vdc

7.2 Supply current at +15.0 V — ≤80 mA

8.0 CONNECTORS

8.1 RF — SMA female

8.2 DC — solder terminals

9.0 CASE SIZE, excluding base plate and connectors, maximum — 3.0x1.0x0.75 inches

10.0 ENVIRONMENTAL

All specifications shall be met at any case temperature between 0 and 50°C, and in any orientation with respect to gravity.

No degradation shall occur after operation at temperatures of -30 to +80°C, or storage at -50 to +100°C, or dropping from a height of one foot onto a wooden surface.

11.0 TESTING

The manufacturer shall perform sufficient tests on each unit to ensure that all specifications are met, including measurements of at least the following: small signal gain, VSWR at each RF port, and power output at 1 dB compression. Each quantity shall be measured at 0.8, 0.9, 1.0, 1.1 and 1.2 GHz. The results of all tests shall be supplied with the unit.

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROGRAM

SPECIFICATION: A13190N1C thru A13190N7C DATE: November 16, 1978

TITLE: BAND-PASS FILTERS

PREPARED BY: ____________________ APPROVED BY: ______________________________

1.0 GENERAL DESCRIPTION

These specifications describe seven band-pass filters with different bandwidths and center frequencies in the 1-2 GHz range. The filters will be used in a radio astronomy antenna array and have a phase stability requirement which results in a center frequency vs temperature-coefficient specification which cannot be met with ordinary designs utilizing dielectric materials. Proposers shall state how they intend to meet the center-frequency temperature-coefficient requirement. Center frequencies, bandwidths, maximum temperature-coefficients, and insertion losses are specified in Table I. All specifications must be met in the $20^{\circ}C$ to $45^{\circ}C$ range.

2.0 SPURIOUS RESPONSES

Spurious responses shall be $\geq$ 60 dB down between 100 MHz and 10 GHz.

3.0 CENTER FREQUENCY STABILITY

Center frequency is defined as the average of upper and lower 3 dB frequencies. The temperature-coefficient of center frequency is the center frequency shift per $^{\circ}C$ divided by the center frequency. For example, filter A13190N1 of Table I has a maximum temperature-coefficient of 7×10^{-6} which is 7 kHz/$^{\circ}C$. The center frequency shall not vary by more than 0.1% of the 1 dB bandwidth due to light tapping upon the filter or change of orientation with respect to gravity. The center frequency vs temperature curve shall not have sharp jumps $\geq$ 0.1% of the 3 dB bandwidth as may be caused by "stick-slip" of materials with different temperature coefficients.

4.0 FREQUENCY RIPPLE

$\leq$ 0.5 dB peak-to-peak.

5.0 VSWR

$\leq$ 1.5 within 0.8 of the 3 dB bandwidth.

6.0 INSERTION LOSS

Resistive padding shall be built into each filter to provide insertion losses of 9±1, 6±1, and 3±1 dB for the 55, 25, and 12.5 bandwidth units respectively. The other filters have only a maximum insertion loss specification.

7.0 MECHANICAL CONFIGURATION

Each filter must fit within a 1.25" x 3.0" x 8.0" volume including connectors which are type SMA female.

8.0 TEST DATA

The following data must be supplied either graphically or in tabular form for each delivered unit:

a) Midband Insertion Loss
b) Maximum Return Loss (or VSWR) within 0.8 x 3 dB bandwidth
c) Upper and Lower 3 dB Frequencies
d) Upper and Lower 60 dB Frequencies for 1025 MHz filters; Upper and Lower 40 dB Frequencies for others.

TABLE I - FILTER SPECIFICATIONS

Part Number	Center Frequency MHz	3 dB Bandwidth MHz	60 dB Bandwidth MHz	Temperature Coefficient Specification $10^{-6}/^{\circ}C$	Temperature Coefficient Design Goal $10^{-6}/^{\circ}C$	Insertion Loss dB
A13190N1	1025±2	55±2	≤165	≤7	≤6	9±1
A13190N2	1025±1.2	25±1	≤80	≤7	≤3	6±1
A13190N3	1027±.6	12.5±.6	≤40	≤7	≤3	3±1
A13190N4	1325±3	60±3	≤250*	≤10	≤5	≤2
A13190N5	1425±3	60±3	≤250*	≤10	≤5	≤2
A13190N6	1575±3	60±3	≤250*	≤10	≤5	≤2
A13190N7	1675±3	60±3	≤250*	≤10	≤5	≤2

*40 dB Bandwidth

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROGRAM

SPECIFICATION: A13190N8A DATE: JULY 27, 1978

TITLE: SP4T DIODE SWITCH

PREPARED BY: ________________ APPROVED BY: ________________

1.0 GENERAL

A single-pole four-position diode switch having the mechanical configuration shown on the attached sketch is desired. All specifications must be met in the $20^{0}C$ to $45^{o}C$ range and at power levels $\leq + 10$ dBm.

2.0 FREQUENCY RANGE

975 to 1075 MHz

3.0 INSERTION LOSS

1 dB maximum

4.0 ISOLATION

30 dB minimum

5.0 VSWR

1.25 maximum

6.0 DRIVE REQUIREMENT

One arm of the switch shall be actuated when a voltage of $+5\pm0.5$ volts at $\leq$ 30 mA is applied to one of four feedthru terminals and -5 to -15 volts at $\leq$ 30 mA is applied to the other three terminals.

7.0 SWITCHING TIME

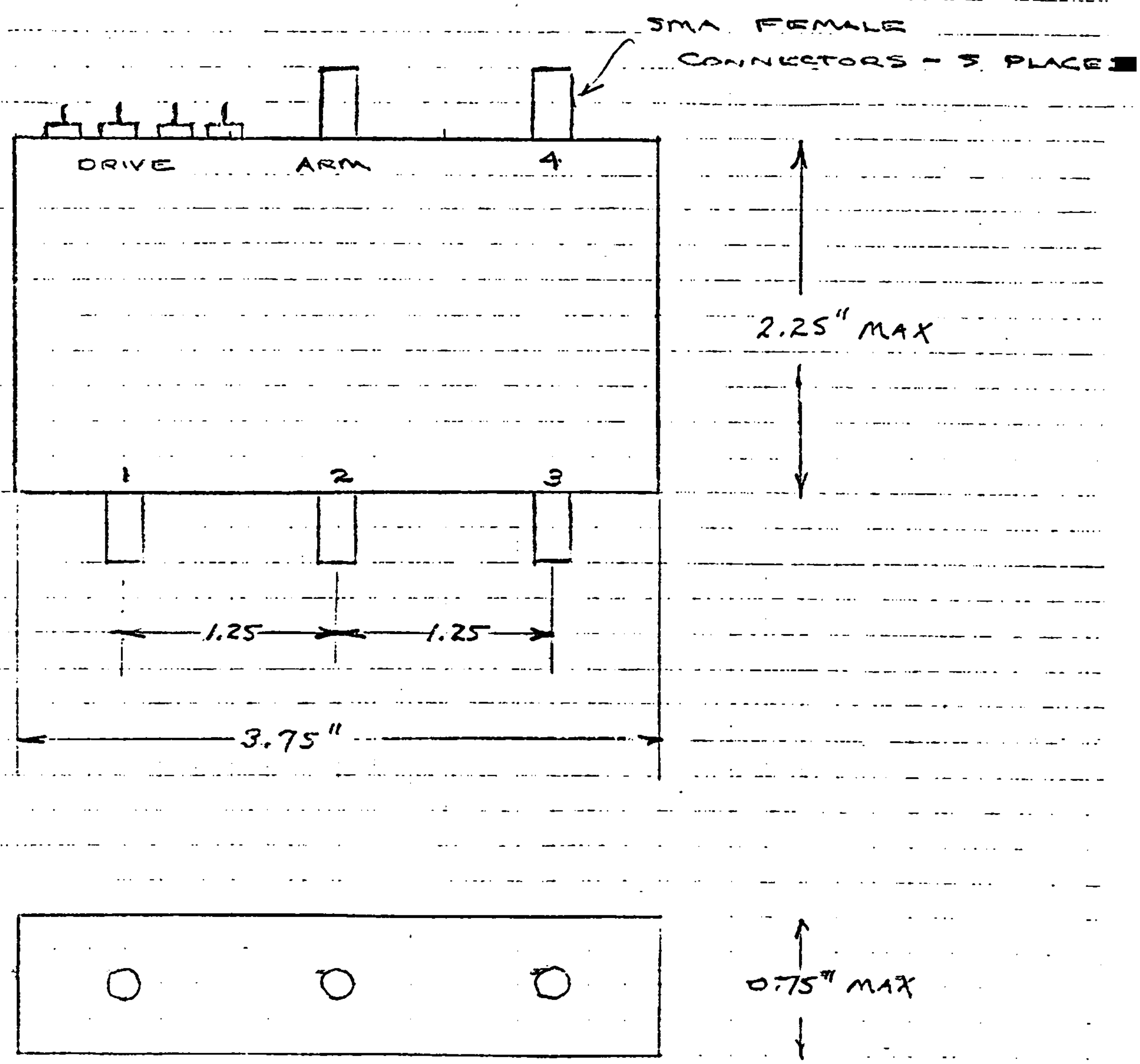
$\leq$ 100 μs

8.0 RFI SEALING

The switch shall be enclosed in an RFI-tight enclosure.

9.0 TEST DATA

Insertion loss and isolation for each port at a frequency of 1025 MHz.



MECHANICAL CONFIGURATI
SP4T SWITCH
SPECIFICATION A13170112
JULY 12, 1976

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROGRAM

SPECIFICATION: A13190N9A DATE: July 25, 1978

TITLE: SWITCH-FILTER ASSEMBLY

PREPARED BY: ____________________ APPROVED BY: ________________________

1.0 GENERAL DESCRIPTION

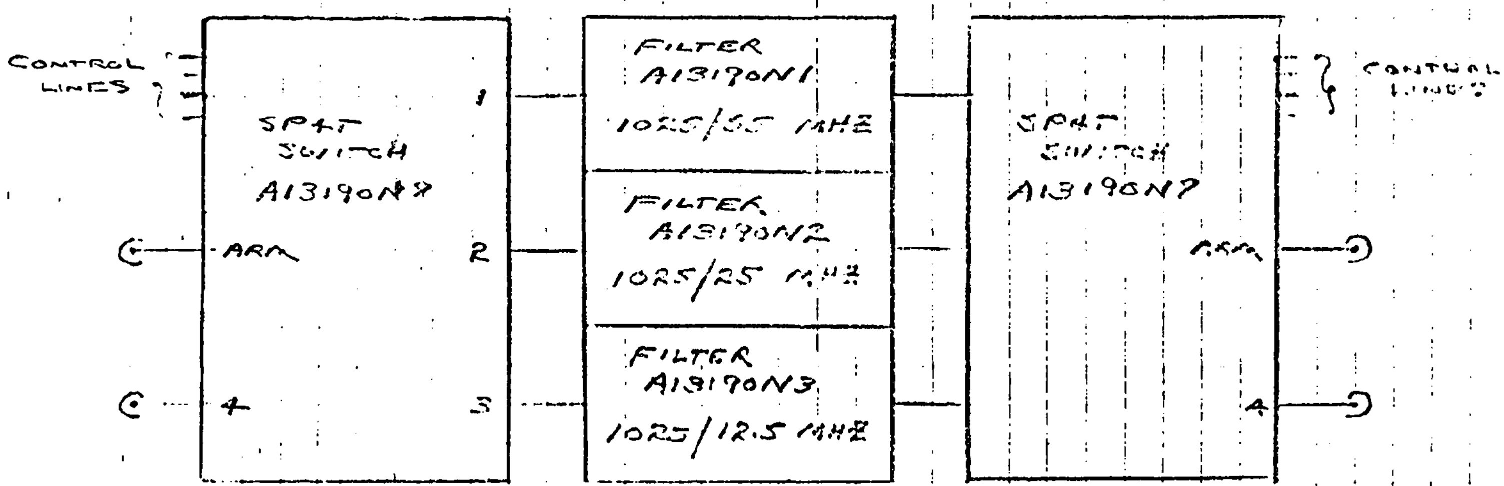
An assembly of two SP4T diode switches and three band-pass filters connected as shown in the attached figure is desired. Except as noted below, the switches shall conform to Specification A13190N8 and the filters shall conform to Specifications A13190N1 through A13190N3.

2.0 VSWR

In 50 Ω, at either port of the assembly, the VSWR shall be less than 1.6 over 80% of the 3 dB bandwidth of the selected filter.

3.0 INSERTION LOSS

The assembly shall include resistive padding to provide a total insertion loss of 10±1, 7±1, and 4±1 dB when the 55, 25, and 12.5 MHz bandwidth filters, respectively, are selected.



SWITCH - FILTER ASSEMBLY

A13190N9

JULY 12, 1976

APPENDIX E: MANUFACTURERS' DATA

On the following pages are reproduced selected manufacturers' data on components used in this subsystem. Not included are non-critical components and common items whose data are readily available in catalogs.

Watkins-Johnson

M1H Mixer

M2A Mixer

A64 Amplifier

Avantek

ASD8199M Amplifier (typical test data)

UTO-1002 Amplifier

UTO-1004 Amplifier

Analog Devices

AD741 Series Operational Amplifiers

Aertech

AMF-6035,6,7,8 Isolators

D0102B Detector, Tunnel Diode

K & L Microwave

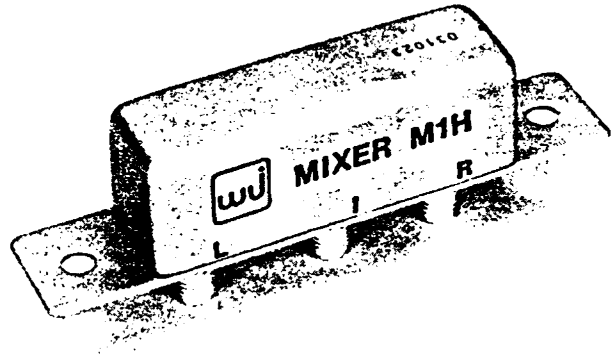
3MC10 Series Filters

WJ-M1H

DOUBLE-BALANCED MIXER

LO } 1.8 TO 6.2 GHz
RF }
IF DC TO 2 GHz

- HIGH ISOLATION: >35 dB (TYP.)
- LOW NOISE FIGURE: <6.0 dB (TYP.)
- LOW COST



Guaranteed Specifications*

Characteristics	Min.	Max.	Test Conditions
Conversion Loss		7.0 dB	f_L & f_R 1.8 to 4.2 GHz f_I DC to 2 GHz
			f_L & f_R 4.2 to 6.2 GHz
		8.0 dB	f_I DC to 500 MHz
		9.0 dB	f_I 500 MHz to 2 GHz
Noise Figure		7.0 dB	f_L & f_R 1.8 to 4.2 GHz f_I 30 MHz to 2 GHz
			f_L & f_R 4.2 to 6.2 GHz
		8.0 dB	f_I 30 MHz to 500 MHz
		9.0 dB	f_I 500 MHz to 2 GHz
Isolation			
f_L at R	25 dB		f_L 1.8 to 4.2 GHz
f_L at I	15 dB		
f_L at R	20 dB		f_L 4.2 to 6.2 GHz
f_L at I	15 dB		
Mixer Compression		1.0 dB	f_R = −2 dBm f_L at +13 dBm

*Measured in a 50-ohm system with f_L at +7 dBm. Downconverter application only unless other specified.

Weight 31 grams (1.1 oz.) maximum

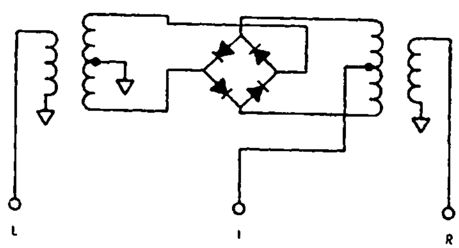
Connectors SMA Female

Price Each 1-9: $199

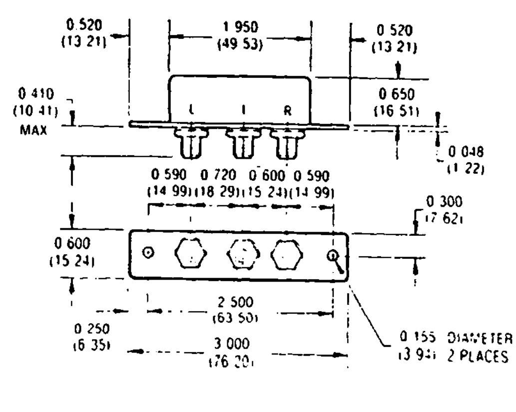
Absolute Maximum Ratings

Storage
Temperature .... −65°C to +100°C
Operating
Temperature .... −54°C to +100°C
Maximum RF Input
Power .... 50 mW peak
Maximum Input Current
at 25°C .... 50 mADC

Schematic Diagram



Outline Drawing



DIMENSIONS ARE IN INCHES (MILLIMETERS)

Avantek

CERTIFICATE OF COMPLIANCE
TEST DATA SHEET

MODEL ASD-8199M

FREQUENCY (MHz) 1000-2000

PART NO. ____________

SERIAL NO. 339-345

PROJECT NO. 24105

TESTED BY: 612 1454 DATE 3-25 1977

Q. A. FINAL A-11 ACCEPTANCE DATE 3-25 1977

Serial No.	Frequency (MHz)	Gain 23.5 dB min ± 1.0 dB	VSWR 2.0 max input	VSWR 2.0 max output	Noise Figure 5.5 dB max	Power Output at 1 dB Gain Compression 7 dBm, min	Current ___ mA typical +15VDC		
339	1000	27.4	<2.0	<2.0	4.1	7+10.0	72 ma		
	1500	27.5			4.5				
	2000	27.6			4.6				
340	1000	27.2			4.1		75		
	1500	27.5			4.5				
	2000	27.8			4.6				
341	1000	27.3			4.0		75		
	1500	27.5			4.5				
	2000	27.9			4.6				
342	1000	27.0			4.4		75		
	1500	27.5			4.7				
	2000	27.[illegible]			4.5				
343	1000	27.2			4.[illegible]		75		
	1500	27.7			4.4				
	2000	28.0			4.6				
344	1000	27.0			4.0		76		
	1500	27.5			4.4				
	2000	27.[illegible]			4.6				
345	1000	27.2			4.0	9.0			
	1500	27.6			4.5	7+10.0	72		
	2000	27.[illegible]			[illegible].5	7+10.0			

Additional Notes:

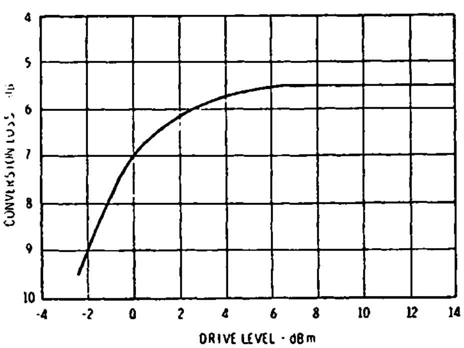
Cascadable Modular Amplifiers UTO Series, TO-8 Packaged

Guaranteed Specifications 0 to 50°C (A), −54° to +85°C (B)

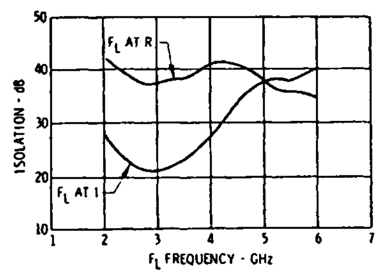
Model	Freq. Resp. (MHz) Min.	Gain (dB) Min. A	Gain (dB) Min. B	Noise Figure (dB) Max. A	Noise Figure (dB) Max. B	Power Output @ 1 dB Gain Comp. (dB) Min. A	Power Output @ 1 dB Gain Comp. (dB) Min. B	Gain Flatness (± dB) Max. A	Gain Flatness (± dB) Max. B	Typical Intercept Point for IM Prod. (dBm)	VSWR (50 ohms) Max. In	VSWR (50 ohms) Max. Out	Input Power (±1% Reg.) Volts DC	Input Power (±1% Reg.) Current mA Typ.	"R" Series Burn-In Case Temp. (°C)	Case Drawing
2 to 500 MHz, High Power Versions (Listed In Order Of Increasing Power Output, Decreasing Gain)																
UTO-516	5-500	14	13.5	5.5	5.5	+10	+9.5	1.0	1.0	+23	2.0	2.0	+15	35	100	TO-8U
UTO-523	5-500	23	23	7.0	7.0	+12	+12	1.0	1.0	+25[1] +36[2]	2.0	2.0	+15	80	100	TO-8U
UTO-503	5-500	9	8.5	7.0	7.0	+13	+13	1.0	1.0	+27	2.0	2.0	+24	50	100	TO-8U
UTO-515	2-500	12	11	7.0	7.5	+14	+13	0.5	0.7	+25	2.0	2.0	+15	65	100	TO-8U
UTO-533[4]	5-500	16	15	5.5	6.0	+14	+13	0.7	1.0	+28	2.0	2.0	+15	44	100	TO-8T
UTO-513	5-500	16	15.5	6.0	6.0	+14	+14	1.0	1.0	+27[1] +36[2]	2.0	2.0	+24	50	100	TO-8U
UTO-545	10-500	10	10	5.0	5.5	+17	+16	0.5	0.5	+36	2.0	2.0	+15	60	100	TO-8T
UTO-504	5-500	6	6	11.0	11.0	+17	+17	1.0	1.0	+31	2.0	2.0	+24	100	71	TO-8U
UTO-505	10-500	9	9	8.5	9.0	+18	+18	1.0	1.0	+30	2.0	2.0	+15	95	100	TO-8T
UTO-507[3]	10-500	14	14	8.5	9.0	+20	+20	1.0	1.0	+35	2.0	2.0	+15	110	71	TO-8T
UTO-508[3]	10-500	11.5	11	8.5	9.0	+20	+20	0.7	1.0	+35	2.0	2.0	+24	110	71	TO-8T
UTO-546[5]	10-500	10	10	8.0	8.5	+23	+22	0.5	0.5	+38	2.0	2.0	+15	110	71	TO-8T
UTO-561	10-500	11	10	9.0	9.5	+26	+25.5	0.7	1.0	+43	2.0	2.0	+15	190	71	TO-8T
2 to 1000 MHz, (Listed In Order Of Increasing Noise Figure, Decreasing Gain)																
UTO-1043[4]	10-1000	10	9	4.0	4.5	+6	+6	1.0	1.0	+22	2.0	2.0	+15	25	125	TO-8T
UTO-1011	2-1000	14	13.5	3.5	4.0	-5	-6	0.7	1.0	+10	2.0	2.2	+15	8	125	TO-8U
UTO-1044[4]	10-1000	10	9	4.5	5.0	+12	+12	1.0	1.0	+28	2.0	2.0	+15	35	125	TO-8T
UTO-1051	5-1000	10	9	5.0	5.7	-5	-6	1.0	1.0	+10	2.0	2.0	+5	7	125	TO-8U
UTO-1001	5-1000	14	13.5	5.0	5.5	-2	-3	1.0	1.0	+11	2.0	2.0	+15	10	125	TO-8U
UTO-1002	5-1000	14	13.5	6.5	7.0	+7	+7	1.0	1.0	+21	2.0	2.0	+15	23	125	TO-8U
UTO-1045Δ[4]	10-1000	9	8.5	6.5	7.5	+17	+17	1.0	1.0	+30	2.0	2.0	+15	60	100	TO-8T
UTO-1003	5-1000	9	8.5	8.0	8.5	+13	+13	1.0	1.0	+27	2.0	2.0	+24	50	100	TO-8U
UTO-1033	5-1000	10	9	8.0	8.5	+14	+13	1.0	1.0	+28	2.0	2.0	+15	48	100	TO-8T
UTO-1004	10-1000	6.0	5.5	12.0	12.5	+20	+19	0.7	1.0	+33	2.0	2.0	+15	110	71	TO-8T

For units with 71°C burn-in temperature, B column is −54 to +71°C
Δ Preliminary, contact factory.
Note 1: Third order intercept point.
Note 2: Second order intercept point.
Note 3: RF input pin is at DC ground.
Note 4: Both RF input and RF output pins are at DC ground.
Note 5: A portion of any DC voltage applied at the RF input pin will appear on the RF output pin (i.e., a resistive DC path exists between pins).
The factory can also provide information on operating specific MICamp modules at temperatures above +85°C or below −54°C. It is recommended that precautions be taken to assure that the CW power applied to the input of any UTO MICamp module never exceed +13 dBm or possible permanent noise figure degradation may result. Under certain conditions, higher CW or pulse power levels may be applied to specific modules without difficulty — contact the factory for recommendations.
Most UTO Series MICamp thin-film modules are available with high reliability screening under the Avantek "R" Series program. The "R" Series devices are conditioned with a full complement of Method 5004.2 screening procedures which provide Class B level reliability assurance. These test procedures, selected from MIL-STD-883, are sufficient to provide this assurance.

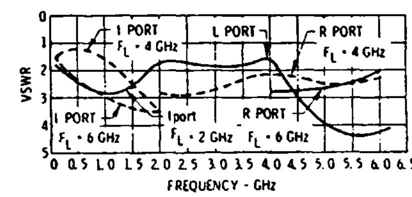
Typical Performance at 25°C



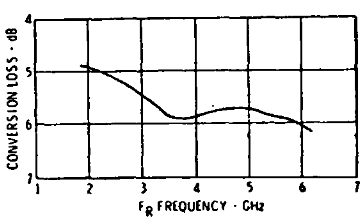
Conversion Loss vs. Drive Level: Conversion loss in a SSB system is a function of drive level (f_L) with f_L and f_R at approximately 3 GHz and f_R level at −6 dBm.



Isolation vs. Frequency: Level of the f_L signal fed through to the R- and I-ports with respect to the level of the f_L signal at the L-port.



VSWR vs. Frequency: VSWR of the L-, I- and R-ports in a 50 ohm system. Some variation in the R-port VSWR will occur as a function of the L-port frequency as shown above. Curves for R-port VSWR are plotted for L-port frequencies of 4 GHz and 6 GHz. A plot of I-port VSWR is also shown with f_L at 2 GHz, 4 GHz and 5 GHz.



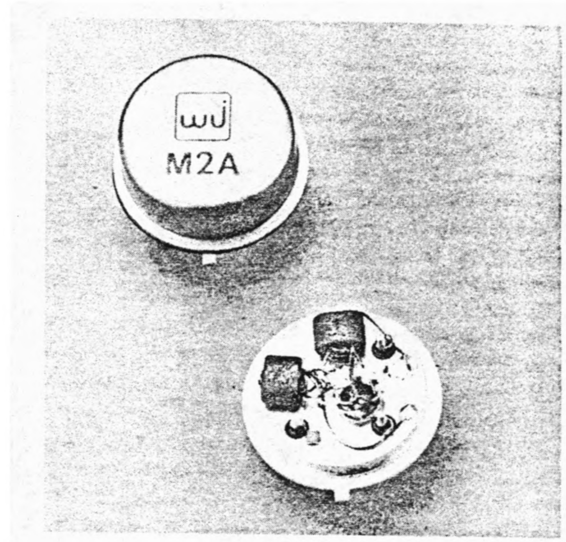
Conversion Loss and Noise Figure vs. Input Frequency: The frequency ordinate refers to the f_L and f_R inputs with a f_I frequency of 500 MHz for conversion loss and a f_I frequency of 30 MHz for noise figure.

WJ-M2A/M2AC

DOUBLE-BALANCED MIXER

LO } RF }	10 TO 1500 MHz
IF	DC TO 800 MHz

- MINIATURE PACKAGE: TO-8 (M2A)
- SMA CONNECTOR PACKAGE: (M2AC)
- LOW NOISE FIGURE: 6.5 dB (TYP.)
- HIGH ISOLATION: 35 dB (TYP.)
- HERMETICALLY SEALED



Guaranteed Specifications*

Characteristics	Min.	Max.	Test Conditions
SSB Conversion Loss			f_R 20 to 600 MHz f_L 10 to 800 MHz
		7.2 dB	f_I DC to 200 MHz
			f_R 10 to 1500 MHz f_L 10 to 1500 MHz
		8.2 dB	f_I DC to 200 MHz
		9.0 dB	f_I DC to 800 MHz
SSB Noise Figure			f_R 20 to 600 MHz f_L 10 to 800 MHz
		7.2 dB	f_I .4 to 200 MHz
			f_R 10 to 1500 MHz f_L 10 to 1500 MHz
		8.2 dB	f_I .4 to 200 MHz
		9.0 dB	f_I .4 to 800 MHz
Isolation			
f_L at R	35 dB		f_L 10 to 500 MHz
f_L at I	30 dB		
f_L at R	28 dB		f_L 500 to 1200 MHz
f_L at I	20 dB		
f_L at R	25 dB		f_L 1200 to 1500 MHz
f_L at I	18 dB		
Conversion Compression		1.0 dB	f_R Level = 0 dBm
Desensitization Level		1.0 dB	f_{R2} Level = −2 dBm
Third Order Intercept Point		+12 dBm (Typ)	f_L = +7 dBm

*Measured in a 50-ohm system with f_L at +7 dBm. Downconverter application only unless otherwise specified

Absolute Maximum Ratings

Operating Temperature*
- 10 to 20 MHz ....−20°C to +100°C
- 20 to 1500 MHz ....−54°C to +100°C

Storage
- Temperature ....−65°C to +100°C

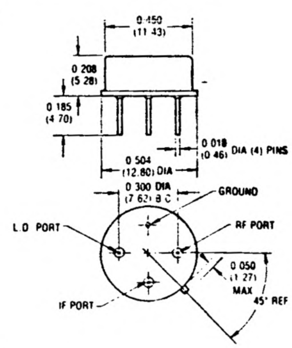
Maximum Peak RF Input
- Power ....200 mW@ 25°C, derate to 50 mW at 100°C (2 mW/°C)

Maximum Peak Input Current
- at 25°C .... 50 mADC

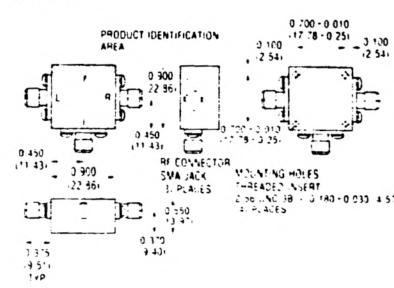
*For the SMA connector package operation within 0° to 50°C temperature range is recommended.

Outline Drawings

M2A

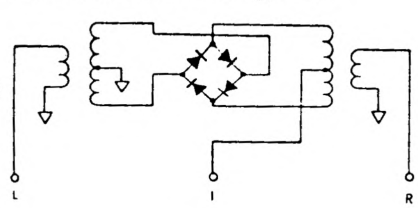


M2AC



DIMENSIONS ARE IN INCHES (MILLIMETERS)

Schematic Diagram



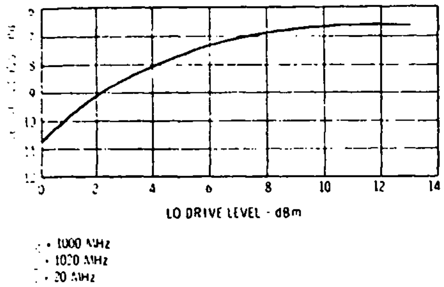
Weight

M2A 2 grams (.07 oz.) maximum
M2AC 20.14 grams (0.71 oz.) maximum

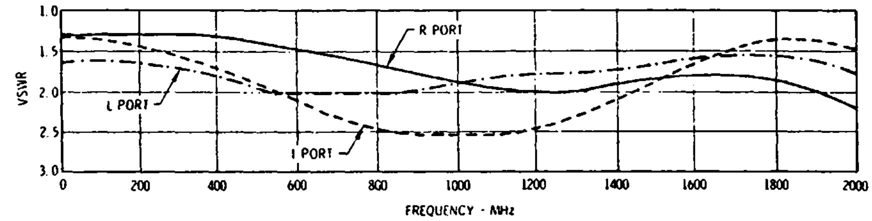
Price Each

1-9 M2A $50
M2AC $150

Typical Performance at 25°C

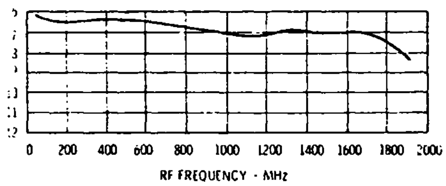


ive Level: The minimum recom-
nded drive level is +7 dBm.
The maximum recommended drive
el is +13 dBm.



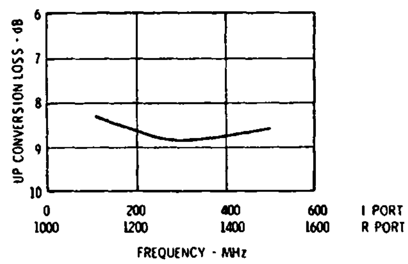
$P_{RF} = P_{IF} = -10$ dBm
$P_{LO} = +7$ dBm
$f_{LO} = 1000$ MHz

VSWR vs. Frequency: VSWR of the L-, I- and R-ports in a 50-ohm system with f_L at +7 dBm. Some variation in the R-port VSWR will occur as a function of the L-port frequency. R-port VSWR is plotted for f_L at 1.0 GHz. Also shown are the L-port VSWR and the I-port VSWR with f_L at 1.0 GHz.



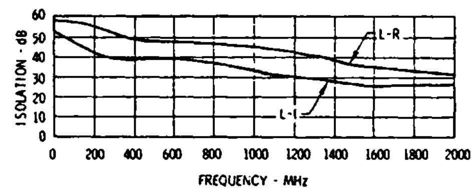
$f_{IF} = f_{LO} - f_{RF} = 20$ MHz
$P_{LO} = +7$ dBm
$P_{RF} = -10$ dBm

Conversion Loss vs. Input Frequency: Conversion loss of the mixer when used in an SSB system. The frequency ordinate refers to the R-port (f_R) with f_I of 20 MHz. Data plotted with an f_L level of +7 dBm.



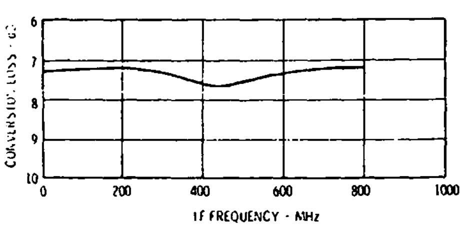
$f_{LO} = 1000$ MHz AT +7 dBm
$P_{IF} = -10$ dBm

Conversion Loss in Up Conversion Mode: The frequency coordinate refers to the frequencies fed into the I-port at −10 dBm. The LO frequency is 1000 MHz at +7 dBm input level. The output signal is at R-port.



$P_{LO} = +7$ dBm

Isolation vs. Frequency: Level of the f_L signal fed through to the R- and I-ports with respect to the level of the f_L signal at the L-port.



Conversion Loss vs. f_I Frequency: Conversion loss of the mixer when used in a SSB system. The frequency ordinate refers to the I-port (f_I) with f_R at 1000 MHz and f_L swept from 1000 to 1800 MHz.

M2A HARMONICS OF F_R

	F_R	dB SUPPRESSION
5	1500	49
4	1200	36
3	900	24
2	600	21
1	300	0

TEST CONDITIONS
LO SIGNAL IS 1000 MHz AT +7 dBm
IF SIGNAL IS 300 MHz AT −10 dBm
300 MHz SIGNAL FROM R PORT IS SET AS REFERENCE AND ITS HARMONICS DATA TAKEN

M2A MIXER HARMONIC INTERMODULATION

Harmonics of f_{RF} \ Harmonics of f_{LO}	0	1	2	3	4	5
5			>64	>64	>64	>64
4		>64	>64	>64	>64	>64
3	55	56	54	60	60	54
2	61	47	64	48	>64	
1	18	0	30	17	43	
0		16	33	18		

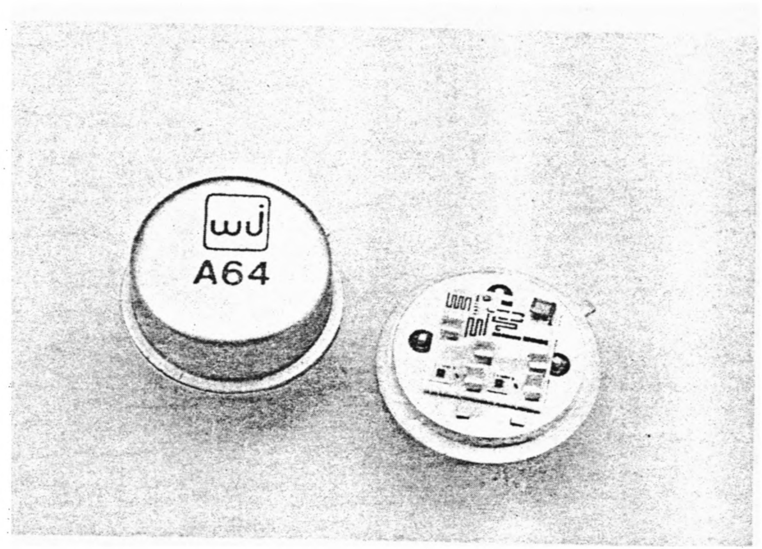
F_R, AND F_{LO} AT 500 AND 520 MHz, RESPECTIVELY.

WJ-A64

CASCADABLE AMPLIFIER

10 TO 1200 MHz

- LOW NOISE: 3.2 dB (TYP)
- HIGH GAIN-TWO STAGES
- ULTRA LOW PHASE DEVIATION FROM LINEARITY: <±2°, 100-1000 MHz
- LOW VSWR: 1.2:1 (TYP), 10-1000 MHz
- MEDIUM LEVEL OUTPUT: +8 dBm (TYP)
- SMALL SIZE: TO-8



Guaranteed Specifications*

Characteristic	Typical	0°-50°C	−54°C-+85°C
Frequency (Min.)	2-1250 MHz	10-1200 MHz	10-1200 MHz
Small Signal Gain (Min.)	26.0 dB	24.0 dB	23.0 dB
Gain Flatness (Max.)	<±0.5 dB	±0.8 dB	±1.0 dB
Noise Figure (Max.)	10-1000 MHz 3.0 dB	3.8 dB	4.3 dB
	10-1200 MHz 3.4 dB	4.3 dB	4.8 dB
Power Output at 1 dB Compression (Min.)	+8.0 dBm	+7.0 dBm	+6.5 dBm
VSWR (Max.) Input/Output	10-1000 1.2:1	1.7:1	1.8:1
	10-1200 1.5:1	1.9:1	2.0:1

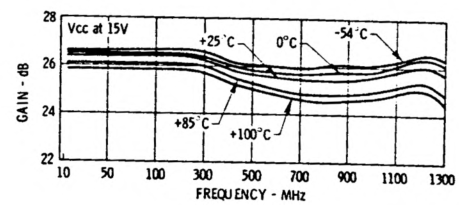
Second Order Harmonic Intercept Point: +47 dBm (Typ.)
Second Order Two Tone Intercept Point: +41 dBm (Typ.)
Third Order Two Tone Intercept Point: +20 dBm (Typ.)

DC Volts (Nominal) 15; **DC Current at 15 Volts** 35 mA

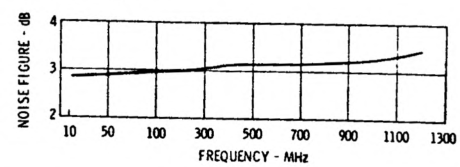
*Measured in a 50-ohm system

Typical Performance at 25°C

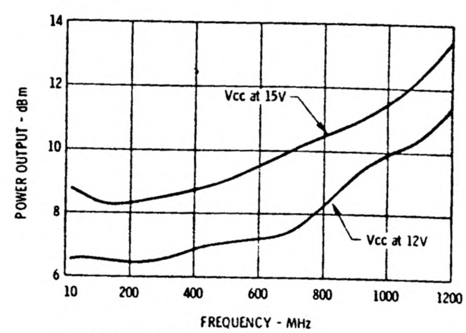
Gain



Noise Figure

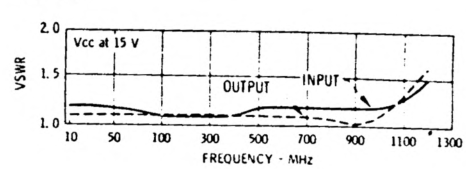


Power Output*



*at 1 dB Gain Compression

VSWR

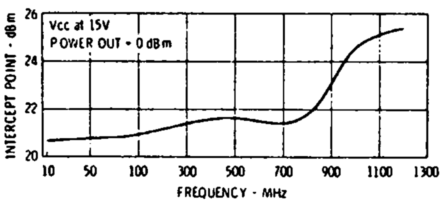


Absolute Maximum Ratings

Ambient Operating Temperature ......−54°C to +100°C
Storage Temperature ......−62°C to +125°C
Maximum Case Temperature .....125°C
Maximum DC Voltage ....+20 Volts
Maximum CW Input Power ....+100 Milliwatts
Maximum Peak Power 0.5 Watt (3 μsec maximum)
"S" Series Burn-In Temperature ..125°C

Price Each 1-9: $160

Two-Tone Intermodulation



Typical Automatic Test Data

V_{CC} = 12V

FREQ MHZ	VSWR IN	VSWR OUT	GAIN DB
100.	1.1	1.2	25.4
200.	1.1	1.1	25.3
300.	1.1	1.2	25.3
400.	1.1	1.2	25.3
500.	1.2	1.2	25.4
600.	1.2	1.1	25.2
700.	1.2	1.1	24.9
800.	1.2	1.1	24.6
900.	1.2	1.1	24.5
1000.	1.3	1.2	24.4
1100.	1.3	1.4	24.6
1200.	1.6	1.7	24.9

V_{CC} = 15V

FREQ MHZ	VSWR IN	VSWR OUT	GAIN DB
100.	1.0	1.1	26.0
200.	1.1	1.1	25.9
300.	1.1	1.2	25.9
400.	1.1	1.2	25.9
500.	1.1	1.2	25.9
600.	1.2	1.2	25.8
700.	1.2	1.1	25.4
800.	1.2.	1.1	25.1
900.	1.2	1.0	24.9
1000.	1.2	1.1	24.8

Linear S-Parameters

V_{CC} = 12V

FREQ	S11		S21		S12		S22	
MHZ	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG
100.	.04	2.2	18.70	-31.3	.01	-6.9	.07	168.5
200.	.05	-17.9	18.41	-57.8	.01	-11.2	.07	156.9
300.	.05	-34.1	18.46	-84.9	.01	-14.4	.07	142.5
400.	.06	-41.3	18.47	-112.0	.01	-19.1	.07	124.0
500.	.07	-51.8	18.54	-140.4	.01	-23.9	.07	102.3
600.	.08	-62.7	18.22	-167.6	.01	-29.0	.07	82.6
700.	.09	-75.9	17.61	165.0	.01	-32.6	.05	57.8
800.	.10	-89.9	16.99	135.7	.01	-38.7	.03	19.2
900.	.10	-112.5	16.70	106.3	.01	-43.5	.03	-104.2
1000.	.11	-141.1	16.53	77.3	.01	-47.7	.08	-153.5
1100.	.15	-169.9	17.06	47.1	.02	-52.0	.16	-175.0
1200.	.23	134.8	17.49	11.0	.02	-68.7	.26	146.1

V_{CC} = 15V

FREQ	S11		S21		S12		S22	
MHZ	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG
100.	.02	39.5	20.06	-31.2	.01	-4.7	.07	170.8
200.	.03	6.5	19.75	-57.8	.01	-10.1	.07	162.7
300.	.03	-4.8	19.77	-84.9	.01	-14.0	.07	147.0
400.	.04	-9.5	19.74	-111.7	.01	-18.0	.08	129.0
500.	.06	-23.2	19.78	-140.3	.01	-22.5	.08	106.6
600.	.07	-36.5	19.41	-167.4	.01	-27.5	.08	87.3
700.	.08	-50.8	18.72	165.4	.01	-32.2	.06	63.5
800.	.10	-70.4	17.96	136.3	.01	-37.9	.04	31.3
900.	.10	-93.6	17.60	107.1	.01	-42.3	.02	-65.3
1000.	.10	-124.8	17.36	78.5	.01	-47.4	.06	-146.4

Deviation From Linear Phase, Gain and Group Delay

V_{CC} = 12V

FREQ MHZ	DEV LIN 0 DEG	REL 0 DEG	GAIN DEV DB	ABS GAIN DB	GROUP DELAY N-SEC
100.	-3.98	.00	.54	25.44	.74
200.	-1.92	-26.47	.40	25.30	.74
300.	-.48	-53.58	.43	25.33	.75
400.	.95	-80.69	.43	25.33	.77
500.	1.13	-109.05	.46	25.36	.77
600.	2.38	-136.35	.31	25.21	.76
700.	3.55	-163.72	.01	24.91	.79
800.	2.80	-193.00	-.30	24.60	.82
900.	1.94	-222.40	-.45	24.46	.81
1000.	1.49	-251.40	-.54	24.37	.82
1100.	-.17	-281.61	-.26	24.64	.92
1200.	-7.68	-317.65	-.05	24.85	1.00

FREQ MHZ	DEV LIN 0 DEG	REL 0 DEG	GAIN DEV DB	ABS GAIN DB	GROUP DELAY N-SEC
100.	-1.70	.00	.63	26.04	.74
200.	-.52	-26.63	.50	25.91	.75
300.	.13	-53.79	.50	25.92	.75
400.	1.21	-80.52	.49	25.91	.77
500.	.35	-109.19	.51	25.92	.77
600.	1.12	-136.23	.35	25.76	.75
700.	1.71	-163.45	.03	25.45	.78
800.	.37	-192.60	-.33	25.09	.81
900.	-.93	-221.71	-.51	24.91	.80
1000.	-1.76	-250.35	-.63	24.79	.80

ANALOG DEVICES

Lowest Cost High Accuracy IC Op Amps

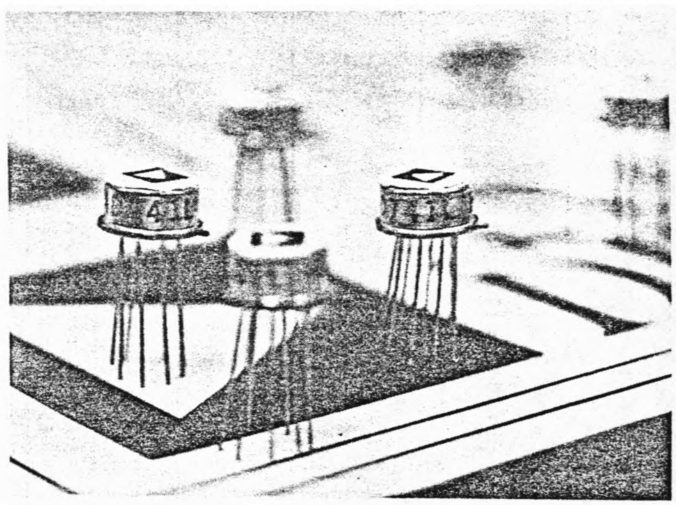
AD741J,K,L,S

FEATURES

Precision Input Characteristics
- Low V_{OS}: 0.5mV max (L)
- Low V_{OS} Drift: 5μV/°C max (L)
- Low I_b: 50nA max (L)
- Low I_{OS}: 5nA max (L)
- High CMRR: 90dB min (K, L)

High Output Capability
- A_{ol} = 25,000 min, 1kΩ load (J, S) T_{min} to T_{max}
- V_O = ±10V min, 1kΩ load (J, S)

Low Cost



GENERAL DESCRIPTION

The Analog Devices AD741J, AD741K, AD741L and AD741S are specially tested and selected versions of the popular AD741 operational amplifier. Improved processing and additional electrical testing guarantee the user precision performance at a very low cost. The AD741J, K and L substantially increase overall accuracy over the standard AD741C by providing maximum limits on offset voltage drift, and significantly reducing the errors due to offset voltage, bias current, offset current, voltage gain, power supply rejection, and common mode rejection (see Error Analysis). For example, the AD741L features maximum offset voltage drift of 5μV/°C, offset voltage of 0.5mV max, offset current of 5nA max, bias current of 50nA max, and a CMRR of 90dB min. The AD741S offers guaranteed performance over the extended temperature range of −55°C to +125°C, with max offset voltage drift of 15μV/°C, max offset voltage of 4mV, max offset current of 25nA, and a minimum CMRR of 80dB.

HIGH OUTPUT CAPABILITY

Both the AD741J and AD741S offer the user the additional advantages of high guaranteed output current and gain at low values of load impedance. The AD741J guarantees a minimum gain of 25,000, swinging ±10V into a 1kΩ load from 0 to +70°C. The AD741S guarantees a minimum gain of 25,000, swinging ±10V into a 1kΩ load from -55°C to +125°C.

All devices feature full short circuit protection, high gain, high common mode range, and internal compensation. The AD741J, K and L are specified for operation from 0 to +70°C, and are available in both the TO-99 and mini-DIP packages. The AD741S is specified for operation from −55°C to +125°C, and is available in the TO-99 package.

GUARANTEED ACCURACY

The vastly improved performance of the AD741J, AD741K, AD741L and AD741S provides the user with an ideal choice when precision is needed and economy is a necessity. An error budget is calculated for all versions of the AD741 (see further); it is obvious that these selected versions offer substantial improvements over the industry-standard AD741C and AD741. A typical circuit configuration (see Figure 1) is assumed, and the various errors are computed using maximum values over the full operating temperature range of the devices. *The results indicate a factor of 8 improvement in accuracy of the AD741L over the AD741C, a factor of 5 improvement using the AD741K, and a factor of 2.5 improvement using the AD741J. The AD741S, similarly, achieves a factor of 3.5 improvement over the standard AD741.* Note that the total error has been determined as a sum of component errors, while in actuality, the total error will be much less. Also, while the circuit used for the error analysis is only one of a multitude of possible applications, it effectively demonstrates the great improvement in overall 741 accuracy achievable at relatively low cost with the AD741J, K, L or S.

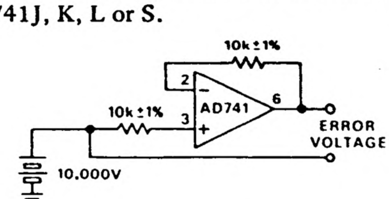


Figure 1. Error Budget Analysis Circuit

SPECIFICATIONS (typical @ +25°C and ±15V dc, unless otherwise specified)

MODEL	AD741J	AD741K	AD741L	AD741S
OPEN LOOP GAIN				
$R_L = 1k\Omega$, $V_O = \pm10V$	50,000 min (200,000 typ)			•
$R_L = 2k\Omega$, $V_O = \pm10V$		50,000 min (200,000 typ)	50,000 min (200,000 typ)	
Over Temp Range, T_{min} to T_{max}, same loads as above	25,000 min	•	•	•
OUTPUT CHARACTERISTICS				
Voltage @ $R_L = 1k\Omega$, T_{min} to T_{max}	±10V min (±13V typ)			•
Voltage @ $R_L = 2k\Omega$, T_{min} to T_{max}		±10V min (±13V typ)	±10V min (±13V typ)	
Short Circuit Current	25mA	•	•	•
FREQUENCY RESPONSE				
Unity Gain, Small Signal	1MHz	•	•	•
Full Power Response	10kHz	•	•	•
Slew Rate, Unity Gain	0.5V/μs	•	•	•
INPUT OFFSET VOLTAGE				
Initial, $R_S \leq 10k\Omega$ (adjustable to zero)	3mV max (1mV typ)	2mV max (0.5mV typ)	0.5mV max (0.2mV typ)	2mV max (1mV typ)
T_{min} to T_{max}	4mV max	3mV max	1mV max	•
Avg vs Temperature (untrimmed)	20μV/°C max	15μV/°C max (6μV/°C typ)	5μV/°C max (2μV/°C typ)	15μV/°C max (6μV/°C typ)
vs Supply, T_{min} to T_{max}	100μV/V max (30μV/V typ)	15μV/V max (5μV/V typ)	15μV/V max (5μV/V typ)	•
INPUT OFFSET CURRENT				
Initial	50nA max (5nA typ)	10nA max (2nA typ)	5nA max (2nA typ)	10nA max (2nA typ)
T_{min} to T_{max}	100nA max	15nA max	10nA max	25nA max
Avg vs Temperature	0.1nA/°C	0.2nA/°C max (0.02nA/°C typ)	0.1nA/°C max (0.02nA/°C typ)	0.25nA/°C max (0.1nA/°C typ)
INPUT BIAS CURRENT				
Initial	200nA max (40nA typ)	75nA max (30nA typ)	50nA max (30nA typ)	75nA max (30nA typ)
T_{min} to T_{max}	400nA max	120nA max	100nA max	250nA max
Avg vs Temperature	0.6nA/°C	1.5nA/°C max (0.6nA/°C typ)	1nA/°C max (0.6nA/°C typ)	2nA/°C max (0.6nA/°C typ)
INPUT IMPEDANCE				
Differential	1MΩ	2MΩ	2MΩ	2MΩ
INPUT VOLTAGE RANGE (Note 1)				
Differential, max safe	±30V	•	•	•
Common Mode, max safe	±15V	•	•	•
Common Mode Rejection, $R_S \leq 10k\Omega$, T_{min} to T_{max}, $V_{in} = \pm12V$	80dB min (90dB typ)	90dB min (100dB typ)	90dB min (100dB typ)	•
POWER SUPPLY				
Rated Performance	±15V	•	•	•
Operating	±(5 to 18)V	±(5 to 22)V	±(5 to 22)V	±(5 to 22)V
Current, Quiescent	3.3mA max (2.0mA typ)	2.8mA max (1.7mA typ)	2.8mA max (1.7mA typ)	2.8mA max (2.0mA typ)
TEMPERATURE RANGE				
Operating, Rated Performance	0 to +70°C	•	•	−55°C to +125°C
Storage	−65°C to +150°C	•	•	•

Note 1: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
*Specifications same as AD741J.
Specifications subject to change without notice.

ERROR BUDGET ANALYSIS

PARAMETER	AD741C SPEC (0 to +70°C)	AD741C ERROR	AD741J SPEC (0 to +70°C)	AD741J ERROR	AD741K SPEC (0 to +70°C)	AD741K ERROR	AD741L SPEC (0 to +70°C)	AD741L ERROR	AD741 SPEC (−55°C to +125°C)	AD741 ERROR	AD741S SPEC (−55°C to +125°C)	AD741S ERROR
Gain *(Error = $10V_{in}/G$)*	15,000	660µV	25,000[1]	400µV	25,000	400µV	25,000	400µV	25,000	400µV	25,000[1]	400µV
I_b *(Error = I_b x resistor mismatch)*	800nA	160µV	400nA	80µV	120nA	24µV	100nA	20µV	1500nA	300µV	250nA	50µV
I_{os} *(Error = I_{os} x 10kΩ)*	300nA	3000µV	100nA	1000µV	15nA	150µV	10nA	100µV	500nA	5000µV	25nA	250µV
$\Delta V_{os}/\Delta T$ *(Error = $\Delta V_{os}/\Delta T$ x ΔT)*	25µV/°C[2]	1125µV	20µV/°C	900µV	15µV/°C	675µV	5µV/°C	225µV	25µV/°C[2]	2500µV	15µV/°C	1500µV
CMRR *(Error = 10V/CMRR)*	70dB	3300µV	80dB	1000µV	90dB	330µV	90dB	330µV	70dB	3300µV	80dB	1000µV
PSRR *(assume a ±5% power supply variation)*	150µV/V	450µV	100µV/V	300µV	15µV/V	45µV	15µV/V	45µV	150µV/V	450µV	100µV/V	300µV
TOTAL		8.7mV		3.7mV		1.6mV		1.1mV		12.0mV		3.5mV

[1] AD741J and AD741S...Open Loop Gain is guaranteed with a 1kΩ load.
[2] AD741C and AD741..$\Delta V_{os}/\Delta T$ is not guaranteed (for complete specifications, contact the factory for data sheet).

INPUT CHARACTERISTICS

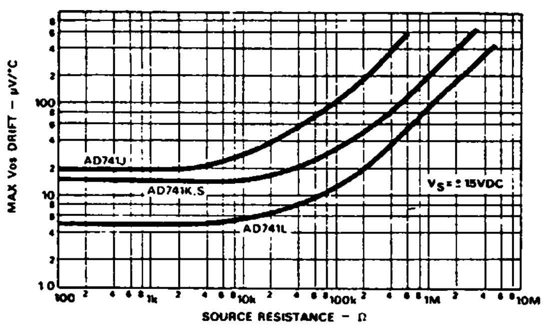


Figure 2. Max Equivalent Input Offset Drift vs. Source Resistance

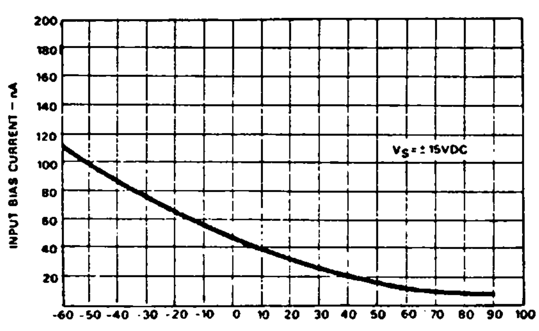


Figure 3. Input Bias Current vs. Temperature

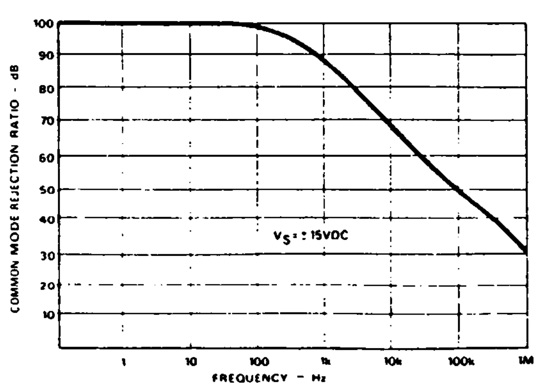


Figure 4. Common Mode Rejection vs. Frequency

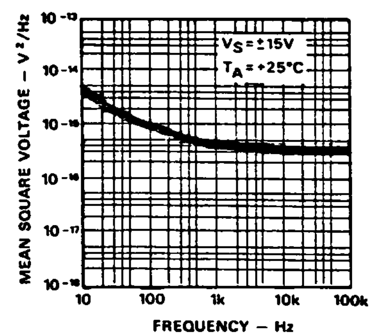


Figure 5. Input Noise Voltage vs. Frequency

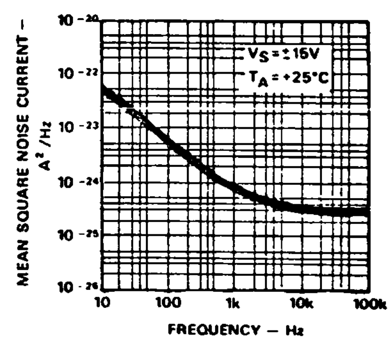


Figure 6. Input Noise Current vs. Frequency

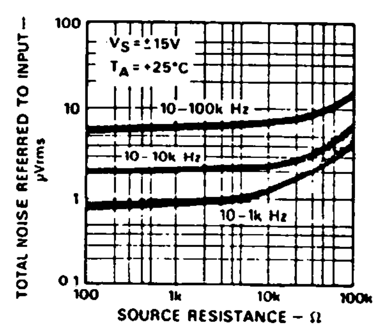


Figure 7. Broadband Noise vs. Source Resistance

OUTPUT CHARACTERISTICS

The AD741J and AD741S are specially selected for high output current capability. High efficiency output transistors, thermally balanced chip design and precise short circuit current control insure against gain degradation at high current levels and temperature extremes. The AD741J guarantees a minimum gain of 25,000, swinging ±10V into a 1kΩ load from 0 to +70°C. The AD741S guarantees minimum gain of 25,000, swinging ±10V into a 1kΩ load from -55°C to +125°C. The AD741K and AD741L are guaranteed with the standard 2kΩ load.

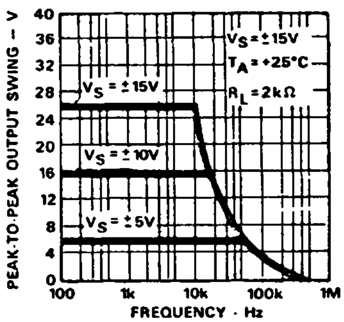


Figure 8. Output Voltage Swing vs. Frequency

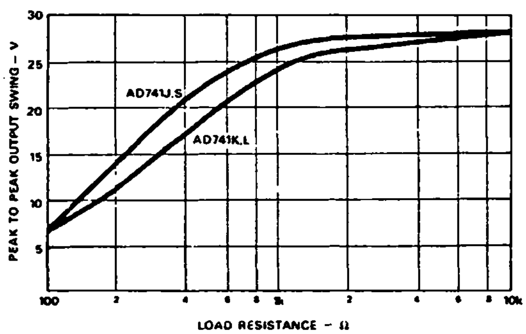


Figure 9. Output Voltage Swing vs. Load Resistance

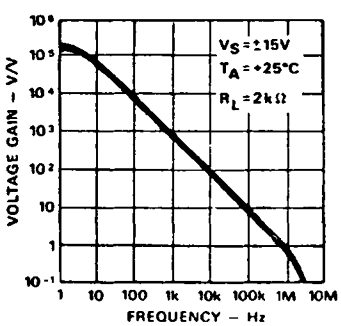
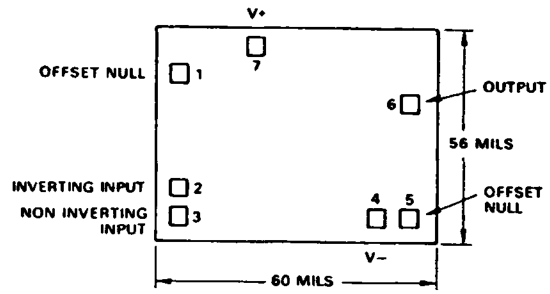


Figure 10. Open Loop Gain vs. Frequency

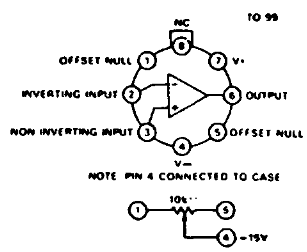
BONDING DIAGRAM

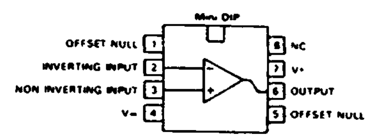
All versions of the AD741 are available in chip or wafer form, fully tested at +25°C. Because of the critical nature of using unpackaged devices, it is suggested that the factory be contacted for specific information regarding price, delivery and testing.



CONNECTION DIAGRAMS

(Top View)

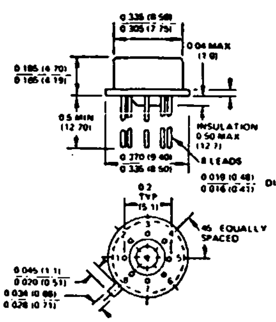




(H package) (N package)

PHYSICAL DIMENSIONS

Dimensions shown in inches and (mm).



MIL-STANDARD-883

The AD741S is available with 100% screening to MIL-STD-883, Method 5004, Class A, B, or C. Consult the factory for pricing and delivery.

ORDERING GUIDE

MODEL	TEMP. RANGE	ORDER NUMBER
AD741J	0°C to +70°C	AD741J*
AD741K	0°C to +70°C	AD741K*
AD741L	0°C to +70°C	AD741L*
AD741S	−55°C to +125°C	AD741SH

*Add Package Type Letter; H = TO-99, N = Mini-DIP.

TABLE B
ELECTRICAL SPECIFICATIONS

	Frequency (GHz)	Type	Cap. (Max.)[8] pF (Cv)	K (Min.) mV/mW	M (Min.)	Flatness Typical (dB)	TSS[7] Typ. (dBm)	VSWR (Max.)	VSWR Typ.
Standard Octaves	0.1-0.5	105D	500	1000	100	±0.2	−51	2.0	1.5
	0.5-1.0	510D	100	1000	100	±0.2	−51	2.0	1.5
	1.0-2.0	102B	50	1000	100	±0.2	−51	2.0	1.5
	2.0-4.0	204B	25	1000	100	±0.2	−51	2.0	1.5
	4.0-8.0	408B	15	700	70	±0.4	−50	2.5	1.7
	8.0-12.0	812B	15	700	70	±0.4	−50	2.5	1.7
	8.0-16.0	816B	15	450	45	±0.6	−48	3.0	2.2
	12.0-18.0	208F*	7	400	40	±0.5	−48	2.5	2.0
	18.0-26.0	806F**†	5	250	25	± 1.0	−46	4.0	2.5
Broad Bands	0.1-1.0	110D	500	700	70	±0.5	−50	3.0	1,8
	0.5-2.0	520D	100	800	80	±0.5	−50	3.0	1,8
	0.7-1.4	714D	50	1000	100	±0.3	−51	2.0	1.5
	1.0-4.0	104B	50	800	80	±0.5	−50	3.0	2.0
	1.0-12.0	112B	25	500	50	±1.5	−50	4.0	2.5
	2.0-8.0	208B	25	600	60	±0.7	−50	3.5	2.0
	2.0-12.0	212B	15	500	50	±1.0	−50	4.0	3.0
	2.0-18.0	218B*	15	400	40	±1.0	−48	4.0	3.0
	4.0-12.0	412B	15	600	60	±0.7	−48	3.5	2.0
	7.0-11.0	711B	15	700	70	±0.4	−50	2.5	1.8
	7.0-12.0	712B	15	600	60	±0.5	−50	3.0	2.0
Waveguide Mounted	8.2-12.4	W812B	15	700	70	±0.4	−50	2.0	1.7
	8.5-9.6	W8596B	15	1000	100	±0.2	−51	1.7	1.4
	12.0-18.0	W208F	7	500	50	±0.5	−48	2.5	2.0
	18.0-26.5	W806F†	5	250	25	± 1.0	−46	4.0	2.5
	26.5-40.0	W264F†	2	250	25	±1.0	−45	4.0	3.0

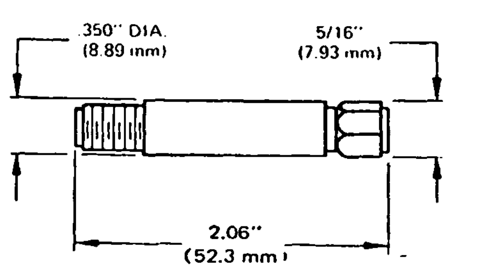
15

TECHNICAL NOTES ON SPECIFICATIONS:

1. Detectors can be matched within ±0.25 dB over octave band widths and ±0.4 dB over wider band widths. Add 10% to price per unit for matching in pairs, and add suffix letter "P" to the model number.
2. The 1 dB non-square-law point varies with the value of the video load. Typical values are −17 dBm for open circuit and −12 dBm for a 100-ohm video load.
3. No bias is required to obtain the performance specified. All standard models have a built-in DC return. Detectors can be supplied without DC returns on special request.
4. RF Power Input must be limited to 50 mW, CW or 3 ergs spike. On models specified above 12 GHz, power ratings are 10 mW, CW or 1 erg spike. The video input must be limited to 0.5 volt forward voltage and 10 mA reverse current. Forward voltage is defined as a negative voltage at the video connector for a forward (−) output detector. Voltage and power levels higher than those specified may result in permanent damage to the detector.
5. VSWR, K and flatness ratings are given for input powers from tangential sensitivity to −23 dBm.
6. Flatness is defined as the RF power variation required to maintain a constant voltage output across the frequency range.
7. BW = 2 MHz, NF = 3 dB @ ambient temperature.

* Available only in DM, DO, DMM, and DOM Series.
** Available only in DMM, and DOM Series.
† Not available in field replaceable mount.

8. Capacity, C_V, can be supplied in other values. Add the letter "Z" to the model number to reduce C_V by 50%. Example: D204BZ would have 12 pF. Add 5% to the price for "Z" models.



DM, DO SERIES

TANGENTIAL SIGNAL SENSITIVITY

The figure of merit, M, defines the detector parameters and is given by

$$M = \frac{K}{\sqrt{R_v}}$$

where, K = open circuit voltage sensitivity in mV/mW
R_v = video resistance of detector in ohms

However, tangential signal sensitivity (TSS) is a measure of the combined detector-amplifier performance as a video receiver and is a function of temperature, bandwidth, and amplifier noise figure as well as the figure of merit of the detector. TSS has become accepted as being that signal power which produces 8 dB signal-to-noise voltage ratio: and at 300°K

$$P_{TSS} = \frac{3.22\sqrt{BF}}{M} \times 10^{-7}$$

with P in milliwatts, B in Hz, and F expressed as a power ratio.

An important consideration in achieving detector-amplifier sensitivity is optimizing video amplifier noise figure as a function of detector video resistance. Transistor video amplifiers are quite suitable for such application, and noise figures <3.0 dB are easily attainable for the source resistance (75 to 200 ohms) of the tunnel diode detector.

DYNAMIC RANGE

Tunnel detector square-law performance is essentially unaffected by changes in microwave power level at small signal levels ($P_{IN} \leq -23$ dBm). At higher power levels there are necessarily deviations, since a strict adherence to square-law performance would require a conversion gain.
16 Proper loading of the tunnel device can, however, extend square-law performance to beyond −15 dBm, and dynamic ranges greater than 40 dB are typically achievable in systems with bandwidths of several MHz.

A particularly convenient application of the tunnel detector is its use in conjunction with narrow band 1 kHz amplifiers such as the HP415E SWR meter. On "low" input, excellent square-law performance is realized, and typical sensitivities are below −65 dBm.

1/f NOISE CHARACTERISTICS

The tunnel diode detector offers significant improvement for low-frequency narrow-band video applications where 1/f noise predominates. Tunnel detectors differ from crystal detectors in that the 1/f noise corner is as much as three decades in frequency below that of the crystal detector. This is due in part to the high doping levels and low resistivity of the back diode semiconductor wafer, and to the fact that no bias is required for normal operation. This physical characteristic of the tunnel detector can improve the sensitivity of video receivers below 100 kHz; e.g., in Doppler radar systems, by 15 to 30 dB, when the detector is properly integrated with a transistor video amplifier.

TEMPERATURE STABILITY

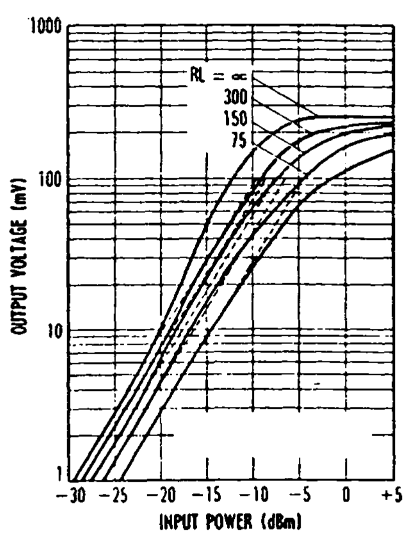
In addition to performing well in systems requiring large dynamic ranges, the tunnel detector displays excellent temperature stability characteristics. Although the I-V characteristic of the tunnel diode is affected by temperature variations, the greatest change occurs in the p-n junction current region beyond the valley voltages; by comparison, the tunneling region (where the detector operates under small signal conditions) is relatively independent of temperature. Typical variation in sensitivity for the tunnel detector is ±0.5 dB over the temperature range from −65° to +85°C. This represents a considerable improvement over competitive crystal devices.

APPLICATION OF BIAS

A further microwave receiver consideration is that the tangential sensitivities mentioned herein are for unbiased tunnel detectors. This operational mode is generally optimal when sensitivity, VSWR, dynamic range, and system simplicity are all considered. When tangential sensitivity is of primary concern, improvements can be obtained by biasing the tunnel device to operate near the peak current. Increasing sensitivities, on the order of 2 to 5 dB, can be realized in this manner, at the expense, however, of reduced dynamic range and increased RF mismatch.

POWER HANDLING CAPABILITIES

The tunnel diode's power handling capabilities are higher than the point-contact crystals; however, because of the low resistance (100 ohms compared to 5,000 ohms) it is much easier to exceed the power ratings through transient voltages. For example, a capacitor charged to 10 volts will generate a peak power of approximately 1 watt when discharged through the tunnel detector and only about 20 milliwatts when discharged through the crystal detector. For high reliability application CW input powers should be kept below 50 mW.



TYPICAL TUNNEL DETECTOR
TRANSFER CHARACTERISTICS

Aertech INDUSTRIES

SSEMBLY, TEST FINISH SPEC

MODEL NO. AMF 6035
JOB NO.
CUSTOMER
SERIAL NO.

DWN
CHK
APVD

Aertech AMF-6035

ELECTRICAL SPECIFICATIONS

FREQUENCY 1225 – 1425 MHz

TEMP	INS LOSS	ISOL	VSWR
-20°C	<0.4	>20	<1.25
AMB			
+65C			

STORAGE -30 °C TO +70 °C

SET GAUSS LEVEL TO FULL

NOTES:

1. TEMP CYCLE ✓ YES __ NO
   -55 °C TO +85 °C
2. GLUE
   __ PLIOBOND __ ECCOBOND 55
   __ SILICON ✓ OTHER 123

FINISHING

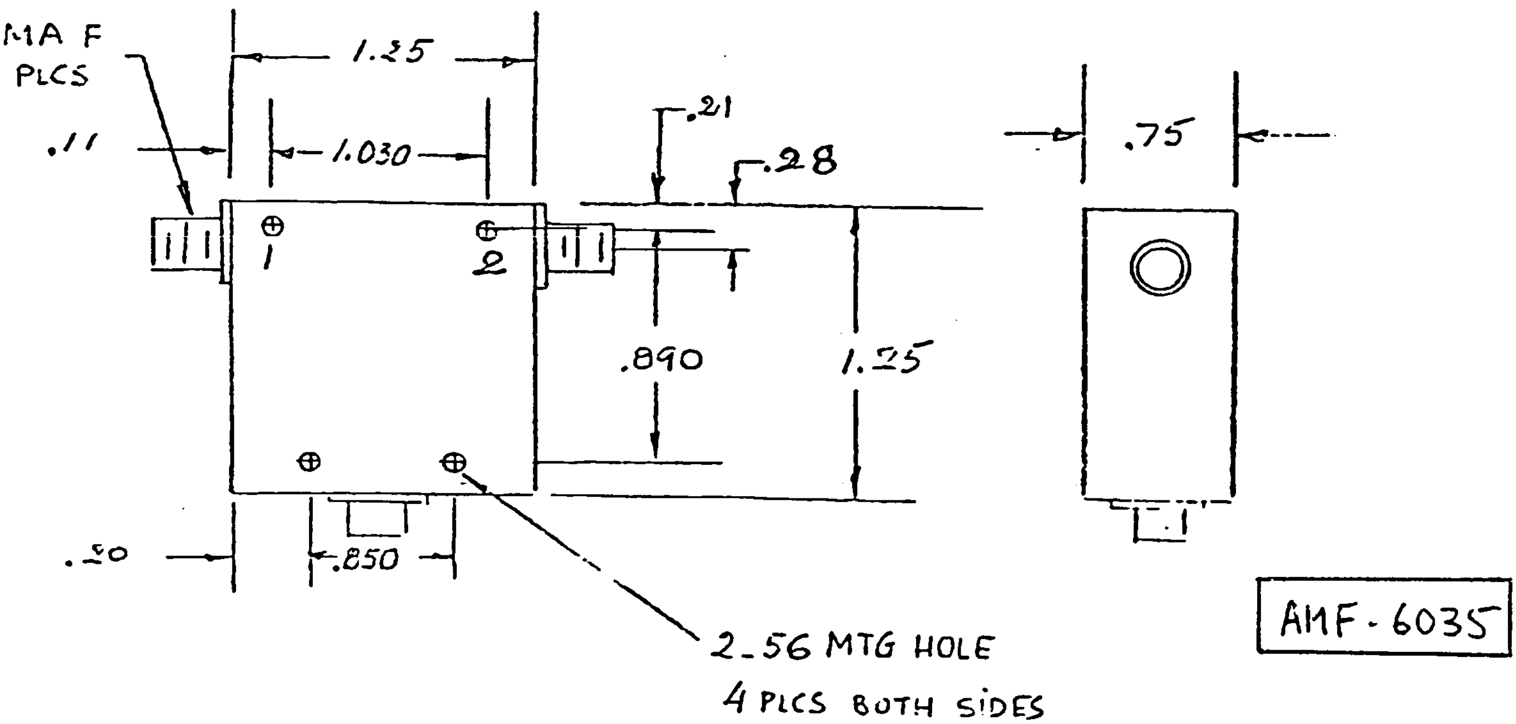
✓ POT MAGNET WELL & SHUNTS
__ POT SEAMS
__ SILVER PAINT SEAMS
__ POT FLAT HEAD SCREWS
__ PRIME & PAINT

NAMEPLATE __ LARGE ✓ SMALL
__ RUBBER STAMP __ SILKSCREEN
__ FREQ ____ ____ PORT MARKING
__ IN/OUT __ BIAS ✓1 ✓2 __3
__ OTHER

__ L-770 VINYL TEXTURED
__ GREY GREEN 24148
__ BROWN
__ BLACK

__ GREY
__ FED
__ MIL
✓ OTHER NICKEL PLATE

1. CYCLE MAGNETS IN THE UNITS WITH C.R.S COVER
2. FOIL FERRITE



TOL: xx ± .03
xxx ± .01

Ref: AMI 0114

Aertech Industries

ASSEMBLY, TEST & FINISH SPEC

MODEL NO. AMF 6036
JOB NO.
CUSTOMER
SERIAL NO.

DWN
CHK
APVD

LTR	ECO	APV

Aertech AMF-6036

ELECTRICAL SPECIFICATIONS

FREQUENCY 13.75 - 14.75 GHz

TEMP	INS LOSS	ISOL	VSWR
-20°C	<0.4	>20	<1.25
AMB			
65 C			

STORAGE -30 °C TO +70 °C

SET GAUSS LEVEL TO FULL

NOTES:

1. TEMP CYCLE ✓ YES __ NO
   -55 °C TO +85 °C
2. GLUE
   __ PLIOBOND __ ECCOBOND 55
   __ SILICON ✓ OTHER 123

FINISHING

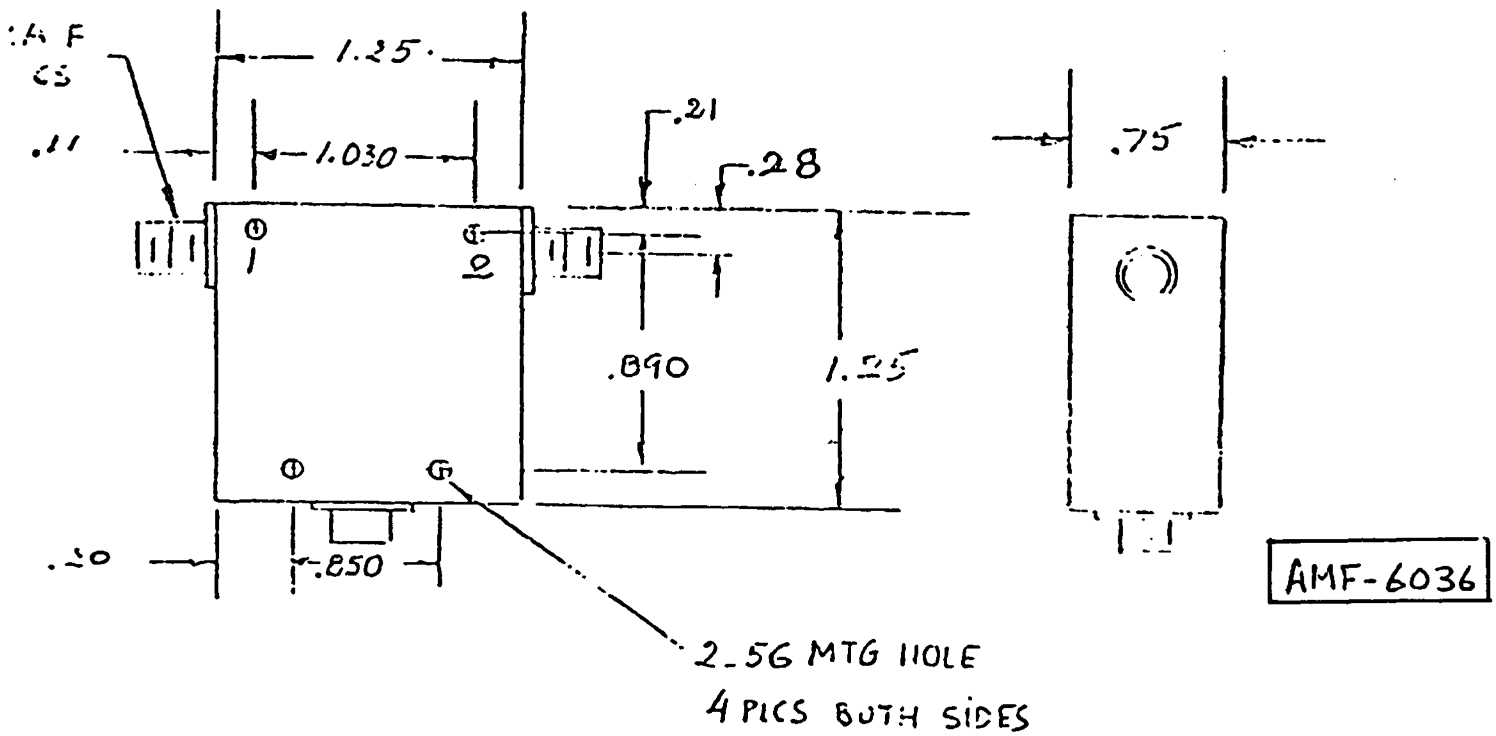
POT MAGNET WELL & SHUNTS
POT SEAMS
SILVER PAINT SEAMS
POT FLAT HEAD SCREWS
PRIME & PAINT

L-770 VINYL TEXTURED
GREY GREEN 24148
BROWN
BLACK

NAMEPLATE __ LARGE ✓ SMALL
__ RUBBER STAMP __ SILKSCREEN
__ FREQ ____ ____ PORT MARKING
__ IN/OUT __ BIAS ✓1 ✓2 __3
__ OTHER

__ GREY
__ FED
__ MIL
✓ OTHER NICKEL PLATE

1. CYCLE MAGNETS IN THE UNITS WITH C R S COVER
   FOIL FERRITE



TOL: xx ± .03
xxx ± .01

Aertech INDUSTRIES

ASSEMBLY, TEST FINISH SPEC

MODEL NO.
JOB NO.
CUSTOMER
SERIAL NO.

DR.
CHK
APVD

Aertech AMF-6037

ELECTRICAL SPECIFICATIONS

FREQUENCY 1.485 — 1.665 GHz

TEMP	INS LOSS	ISOL	VSWR
-20°C	< .4	>20	<1.25
AMB			
+65°C			

STORAGE - °C TO + °C

SET GAUSS LEVEL TO Full

NOTES:

1. TEMP CYCLE ✓ YES __ NO
   - 55 °C TO + 85 °C
2. GLUE
   __ PLIOBOND __ ECCOBOND 55
   __ SILICON ✓ OTHER 123

FINISHING

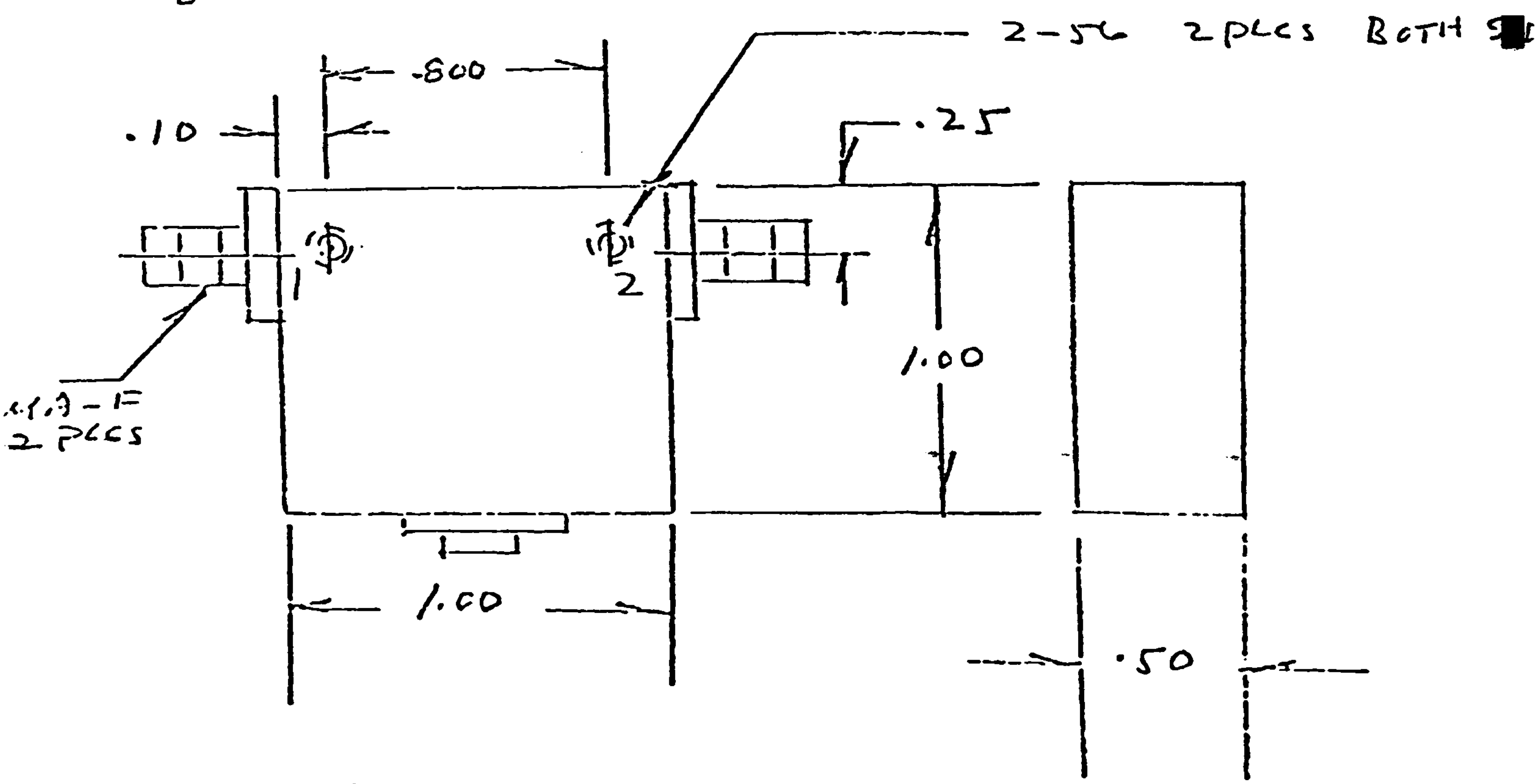
✓ POT MAGNET WELL & SHUNTS
__ POT SEAMS
__ SILVER PAINT SEAMS
__ POT FLAT HEAD SCREWS
__ PRIME & PAINT

__ L-770 VINYL TEXTURED
__ GREY GREEN 24148
__ BROWN
__ BLACK

NAMEPLATE __ LARGE ✓ SMALL
__ RUBBER STAMP __ SILKSCREEN
__ FREQ PORT MARKING
__ IN/OUT __ BIAS ✓1 ✓2 __3
__ OTHER

__ GREY
__ FED
__ MIL
✓ OTHER nickel PLATE

1. Foil Ferrites
2. Cycle magnets in unit with all C.R.S. on.



Tol xx ±.03
xxx ±.01

AMF-6037

Aertech Industries

ASSEMBLY, TEST FINISH SPEC

JOB NO. 6038
CUSTOMER
SERIAL NO.

CHK
APVD

Aertech AMF-6038

ELECTRICAL SPECIFICATIONS

FREQUENCY 1.58 — 1.77 GHz

TEMP	INS LOSS	ISOL	VSWR
+20°C	< .4	>20	<1.25
AMB			
+65°C			

STORAGE – 7 °C TO + °C

SET GAUSS LEVEL TO Full

NOTES:

1. TEMP CYCLE ✓ YES __ NO
   – 55 °C TO + 85 °C
2. GLUE
   __ PLIOBOND __ ECCOBOND 55
   __ SILICON ✓ OTHER 123

FINISHING

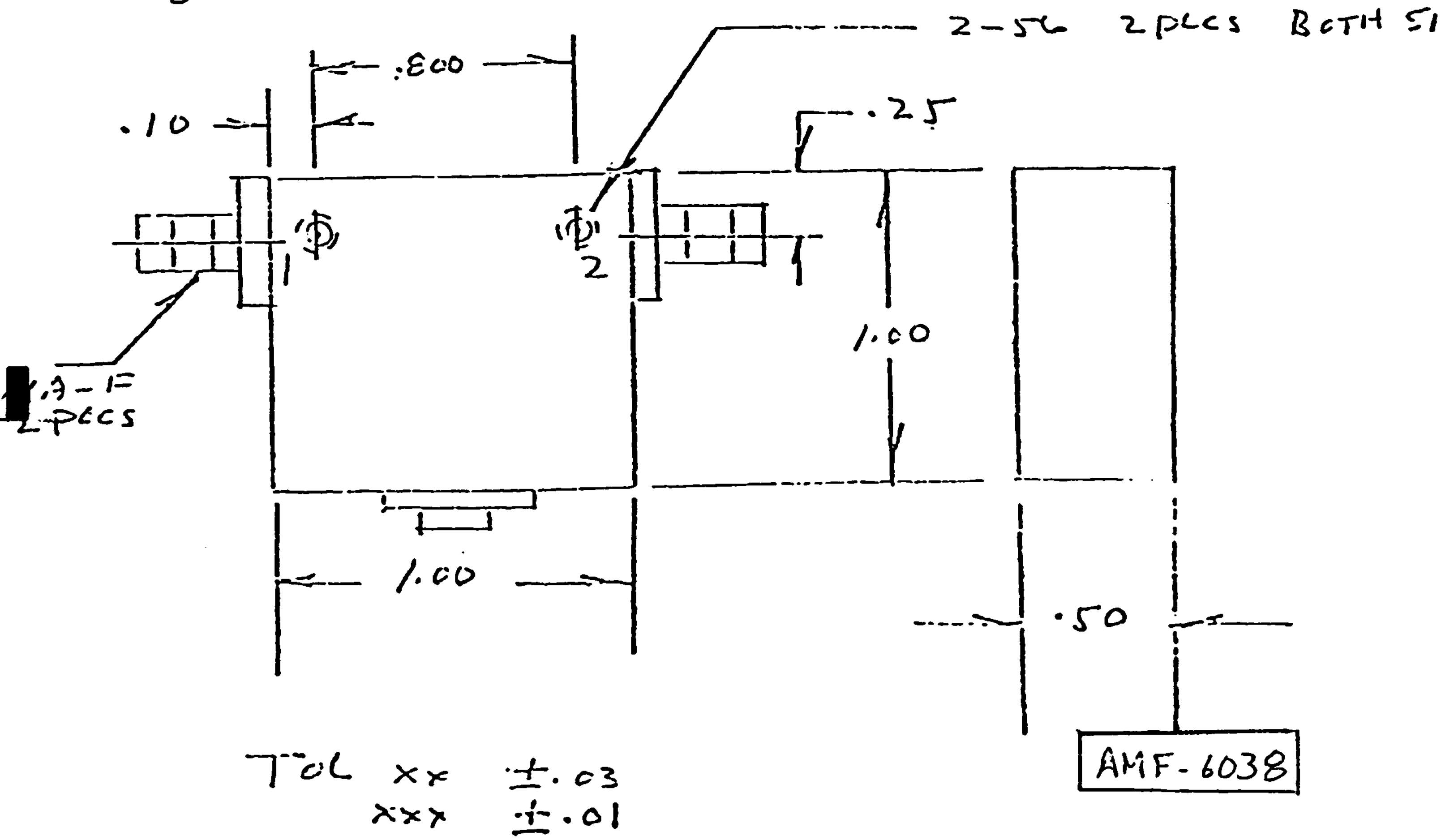
✓ POT MAGNET WELL & SHUNTS
__ POT SEAMS
__ SILVER PAINT SEAMS
__ POT FLAT HEAD SCREWS
__ PRIME & PAINT

__ L-770 VINYL TEXTURED
__ GREY GREEN 24148
__ BROWN
__ BLACK

NAMEPLATE __ LARGE ✓ SMALL
__ RUBBER STAMP __ SILKSCREEN
__ FREQ __ __ PORT MARKING
__ IN/OUT __ BIAS ✓ 1 ✓ 2 __ 3
__ OTHER

__ GREY
__ FED
__ MIL
✓ OTHER nickel PLATE

1. Foil Ferrites
2. Cycle Magnets in Unit with all C.P.S. cu.

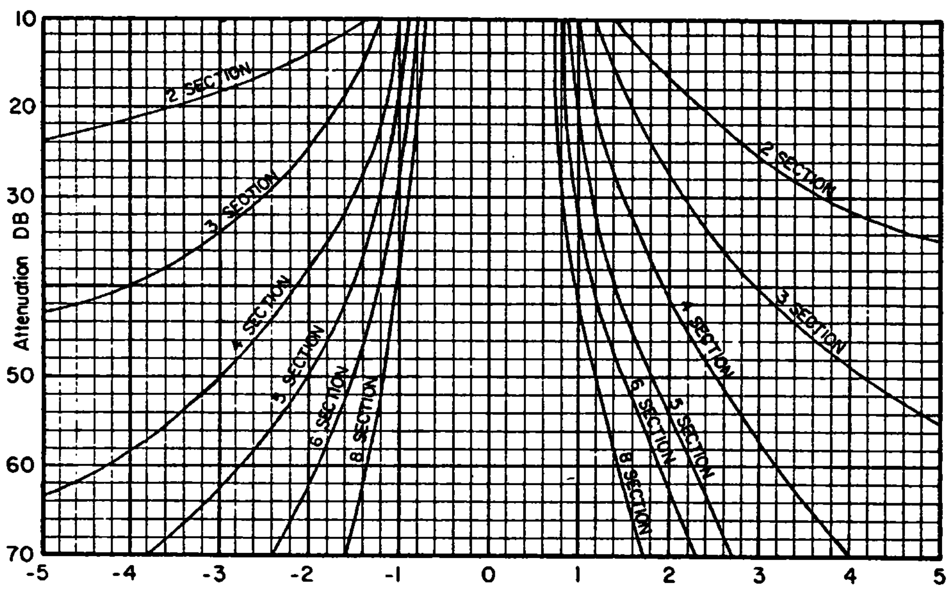


Miniature Cavity

Specifications

Frequency Range (MHz)	3dB BW %	VSWR	Average Power	Impedance	Number of Sections	Shock	Vibration	Temp.	Relative Humidity
200-1000	1-10	1.5:1	2 Watts	50 Ohms	2-8	30 G's 11 M's	10 G's 5-1000 Hz	-20°C +85°C	0-95%

Attenuation



To determine the out-of band or stopband attenuation for K&L miniature cavity filters this series of curves are used. These curves show the attenuation as multiples of the 3dB bandwidth for filters with 2 to 8 sections.

The following formula is used to determine the stopband attenuation:

$$\text{3dB BW's from FO} = \frac{\text{Reject Freq—Center Freq.}}{\text{3dB BW}}$$

Example:

Center Freq. = 500
3dB BW = 10 MHz
No. of Sections = 6
Find the attenuation at 80 MHz and 520 MHz.

By substituting in the formula, the 3 db BW's from FO = $\frac{520-500}{10} = +2$

3db BW's from FO—$\frac{430-500}{10}$ = —2

Referring to the attenuation curves we find the attenuation in dB's for a 6 section response +2BW's from FO to yield 62 dB and —2Bw's from FO to yield 62 dB.

Insertion Loss

Loss Constant vs. Frequency

FREQ.	LOSS CONSTANT
160-200	3.0
201-400	2.5
401-1000	2.0

To determine the approximate insertion loss at the center frequency the following formula is used:

$$\text{Insertion Loss} = \frac{\text{(Loss Const.)(No. of sect. } + \frac{1}{2})}{\text{Percent 3 dB BW}} + 0.5$$

Example:

CF = 500 MHz
3 dB BW = 10
No. of sections = 6
The % 3dB BW = $\frac{100 \times 10}{50} = 2\%$

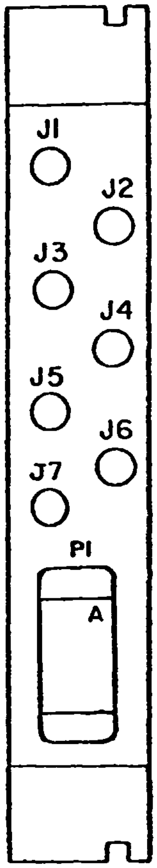
Loss constant from table = 2.0
Insertion Loss = $\frac{(2.0)(6.5)}{2} + 0.5 = 7.0\text{dB}$

K&L MICROWAVE INCORPORATED
Phone 301-749-2424 • TWX 710-864-9683

APPENDIX F: REAR-PANEL CONNECTORS

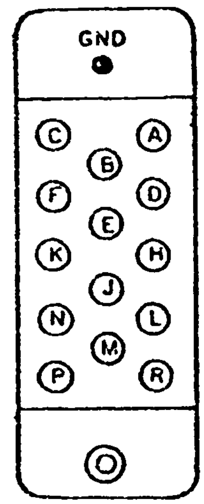
The rear-panel connector configurations of F4, F7 and F8 are illustrated on the following pages.

F4



SINGLE WIDE MODULE
(REAR VIEW)

CONN	FUNCTION
J1	IF Output
J2	RF Input
J3	LO Input
J4	Alternate Input
J5	From BPF
J6	To BPF
J7	Detector Input



P1 (REAR VIEW)

P1		
PIN	FUNCTION	WIRE COLOR
A*		*
B	+15 V Supply	Red
C*	+5 V Supply	* Orange
D	High Quality Ground	Black
E	-15 V Supply	Yellow
F	Alternate Input Control	Brown
H	Sync Detector Switching	Red/White
J	Input Level Monitor Out	White
K	Sync Detector Monitor Out	Green
L	ALC Out	Yellow/White
M	Total Power Monitor Out	Blue
N	Total Power	Blue/White
P	Peak Detector Monitor Out	Black/White
R	ALC On Control	Violet

* INDICATES A FUNCTION NOT FOUND IN THIS MODULE

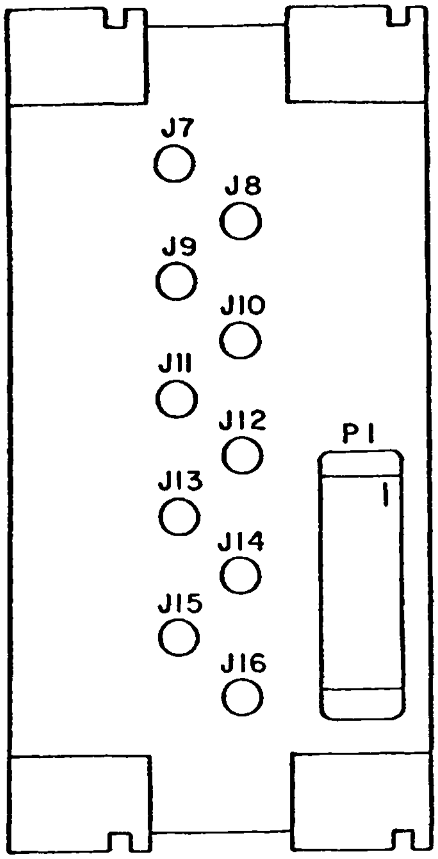
DRAWN BY: D. GILL DATE: 790130

APPROVED BY: DATE: 790131

F4: FREQUENCY CONVERTER
REAR PANEL CONNECTORS

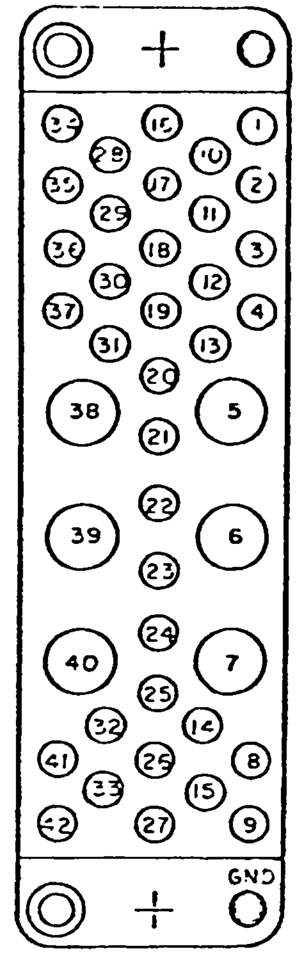
DWG NO. A13180W02 Rev:

F7



TRIPLE WIDE MODULE
(REAR VIEW)

CONN	FUNCTION
J7	INPUT
J8	OUTPUT
J9	
J10	
J11	
J12	
J13	
J14	
J15	
J16	



P1 (REAR VIEW)

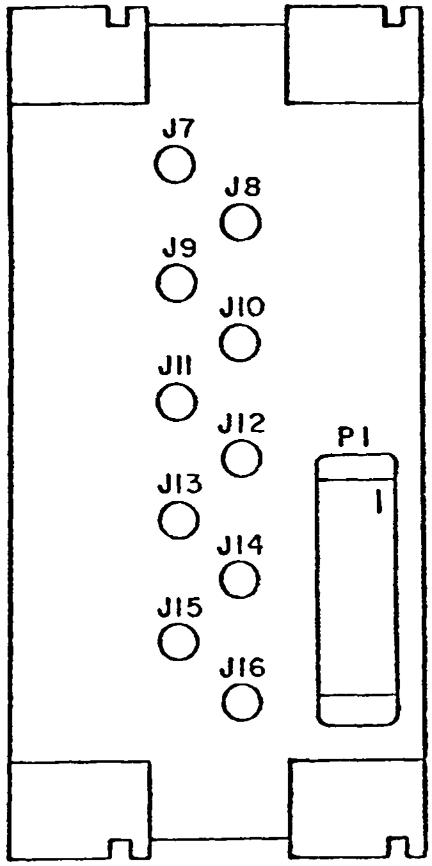
P1

PIN	FUNCTION	WIRE COLOR	PIN	FUNCTION	WIRE COLOR
1			22	MANUAL CONTROL	GRY
2			23		
3			24		
4			25		
5			26		
6			27		
7			28	-28V SUPPLY	*
8			29	+28V SUPPLY	*
9			30		
10	+5V SUPPLY	ORN	31		
11	-5V SUPPLY	*	32		
12			33		
13			34	PWR GROUND	BLK
14			35		
15			36		
16	+15V SUPPLY	*	37		
17	-15V SUPPLY	YEL	38		
18			39		
19	FILTER SELECT BIT 0	VIO	40		
20	FILTER SELECT BIT 1	BLU	41		
21	FILTER SELECT BIT 2	GRN	42		

* INDICATES A FUNCTION NOT FOUND IN THIS MODULE

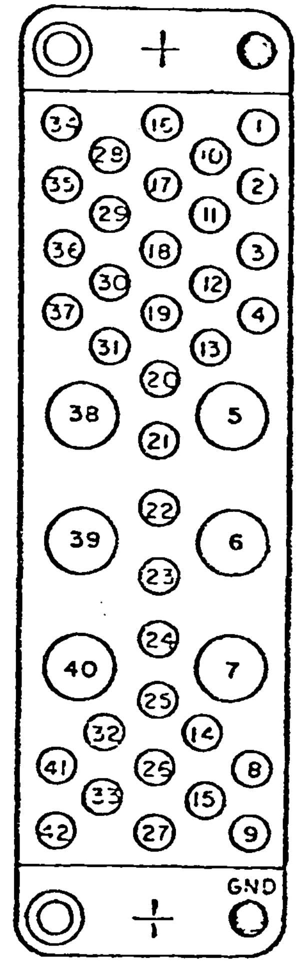
F7	
A13190W03	SH 1 of 1

F8



TRIPLE WIDE MODULE
(REAR VIEW)

CONN	FUNCTION
J7	50 Mhz comb input
J8	Composite IF out
J9	Chan A det. out
J10	Chan D det. out
J11	Chan B det. out
J12	Chan C det. out
J13	Chan C input
J14	Chan B input
J15	Chan D input
J16	Chan A input



P1 (REAR VIEW)

P1					
PIN	FUNCTION	WIRE COLOR	PIN	FUNCTION	WIRE COLOR
1			22		
2			23		
3			24		
4			25		
5			26		
6			27		
7			28	-28V supply	(not used)
8			29	+28V supply	(not used)
9			30		
10	+5 V supply	(not used)	31		
11	-5 V supply	(not used)	32		
12			33		
13			34	Power ground	Black
14			35		
15			36		
16	+15V supply	Red	37		
17	-15V supply	(not used)	38		
18			39		
19			40		
20			41		
21			42	High quality ground	(not used)

* INDICATES A FUNCTION NOT FOUND IN THIS MODULE

Dwn: LRD 790518
Approved: 790518

F8 REAR PANEL CONNECTIONS
Dwg No. A13190W02 Rev.