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AUTOCORRELATION RECEIVER, MODEL II: IF FILTER SYSTEM

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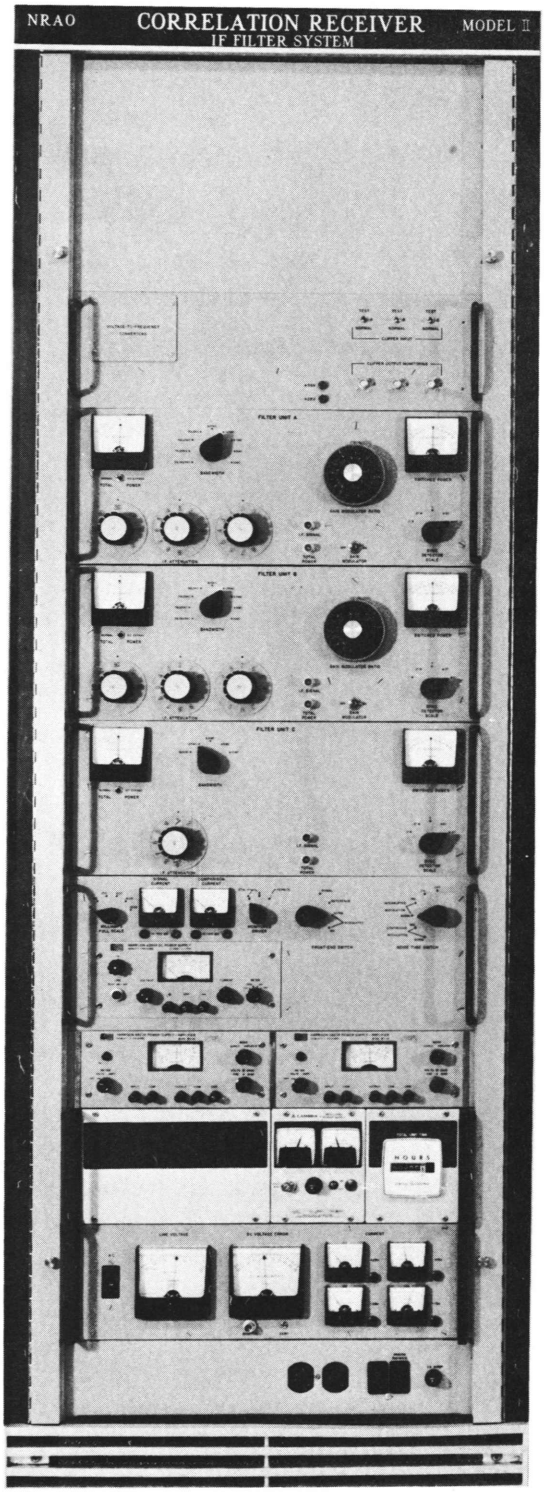
The IF Filter System described herein is a part of the Autocorrelation Receiver, Model II. Refer to Internal Report No. 75 for an overall description of the receiver. The IF system is contained in one rack shown in Figure 1. The rack contains, from top to bottom, a voltage-to-frequency converter/clipper drawer. IF Filter Units A, B, and C, the switch driver drawer, switch driver power amplifiers, and system power supplies. Connections to the Digital System, input signals, recorders, switches and AC power are made at the top of the rack.

IF Filter Unit

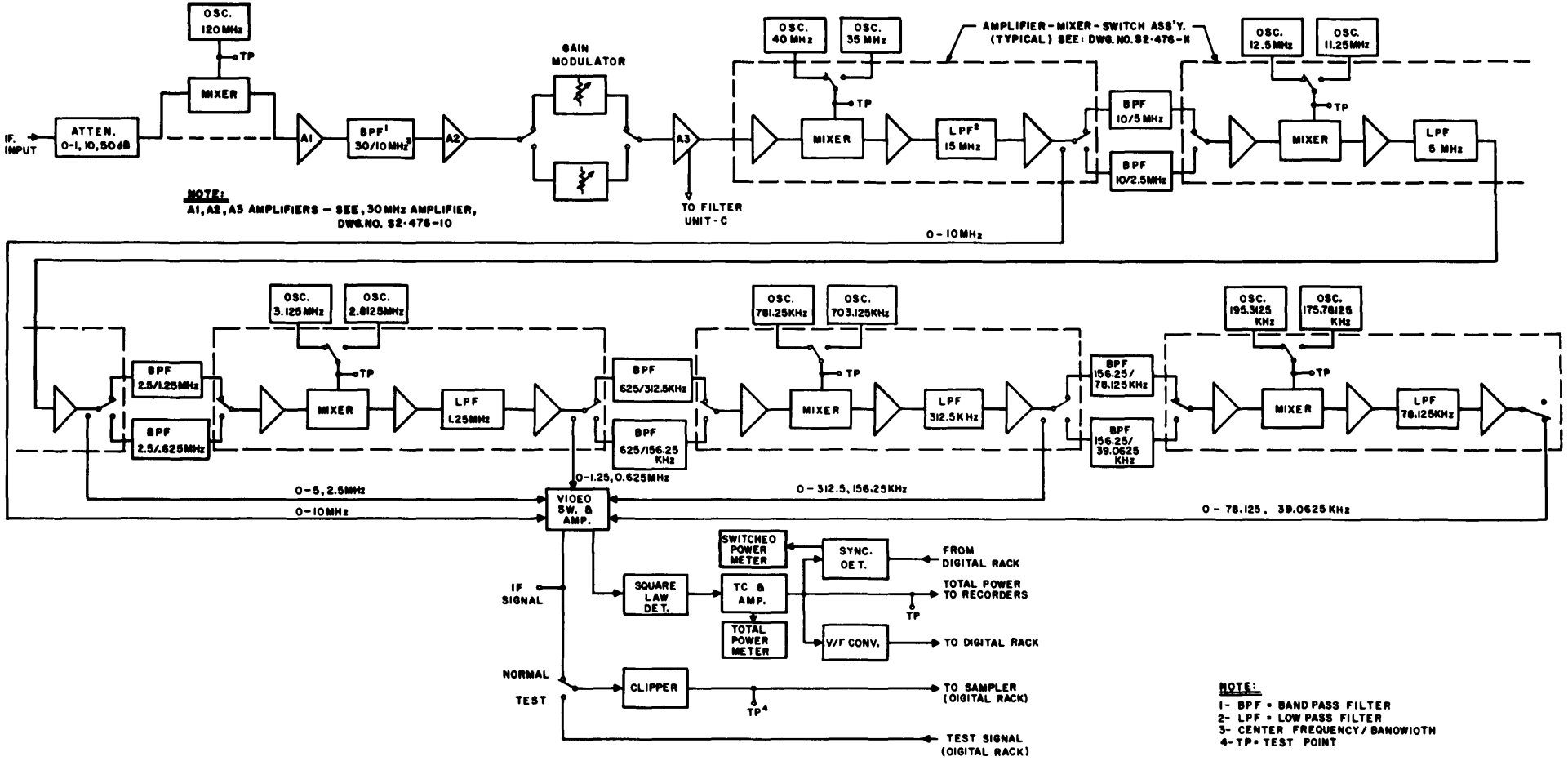
IF Filter Units A, B, and C are located in the center portion of the rack and contain most of the equipment. Units A and B are identical. Unit C has a narrower range of bandwidths and fewer controls. There are two IF inputs to the rack, A and B. These go to the corresponding filter units. Figure 2 shows the signal flow for one input. All components of this diagram, except the V/F converter and clipper, are contained in one filter drawer. The signal for Filter Unit C is derived from Unit A or B following the gain modulator as shown so that this function and those preceding it are common to both drawers. Units A and B provide bandwidths from 10 MHz to 39 kHz. Front panel controls are shown in Figure 3. Unit C has a bandwidth range of 10 MHz to 625 kHz.

The system will accept IF input signals at either 30 or 150 MHz center frequency having a level greater than -50 dBm per 10 MHz. To change frequency it is necessary to add or remove the first mixer shown in Figure 2 by a cabling change on the underneath side of the drawers. The first buffer amplifier contains a 60 MHz low pass filter at its input to provide additional suppression of oscillator leakage. The amplifier provides gain at 30 MHz and an improved impedance for the filter that follows. The gain modulator consists of two variable attenuators, one mounted on the front panel and the other inside the drawer. Coax relays, driven by the digital system, switch between them. The attenuator accessible on the front panel is in the circuit when the



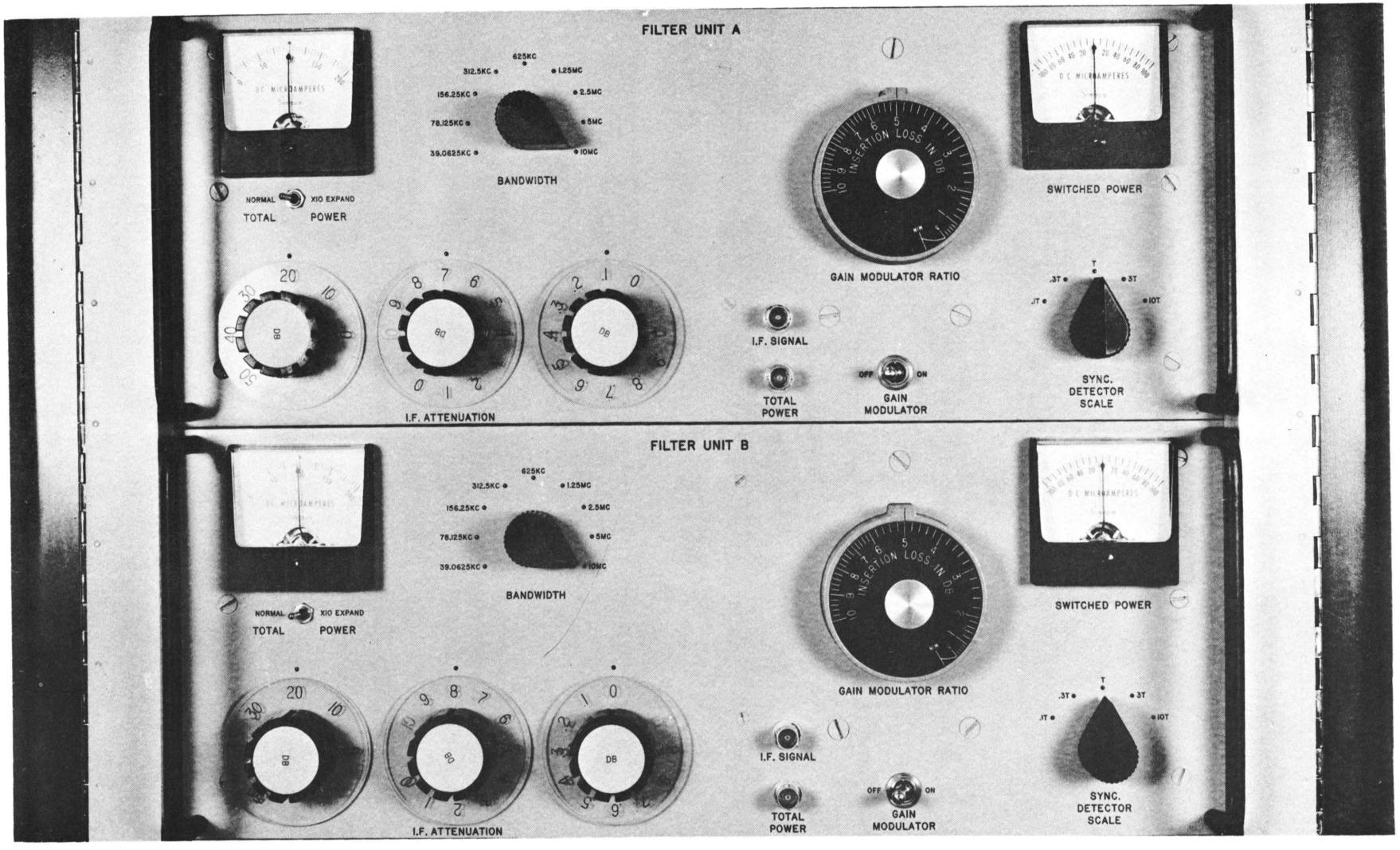
IF Filter System

Figure 1



Block Diagram of IF Filter System

Figure 2



Filter Units

Figure 3

system is switched to reference. All power, switching signals and switch monitoring lines entering the filter units are filtered by an LC network adjacent to the input connectors. These consist of lossy RF chokes followed by 0.1 μF feed-through capacitors. Bandwidth switching is performed by applying +15 V to the proper oscillators and to diode switches that select the filters and oscillators. The oscillator frequencies may be monitored at the rear of each filter drawer.

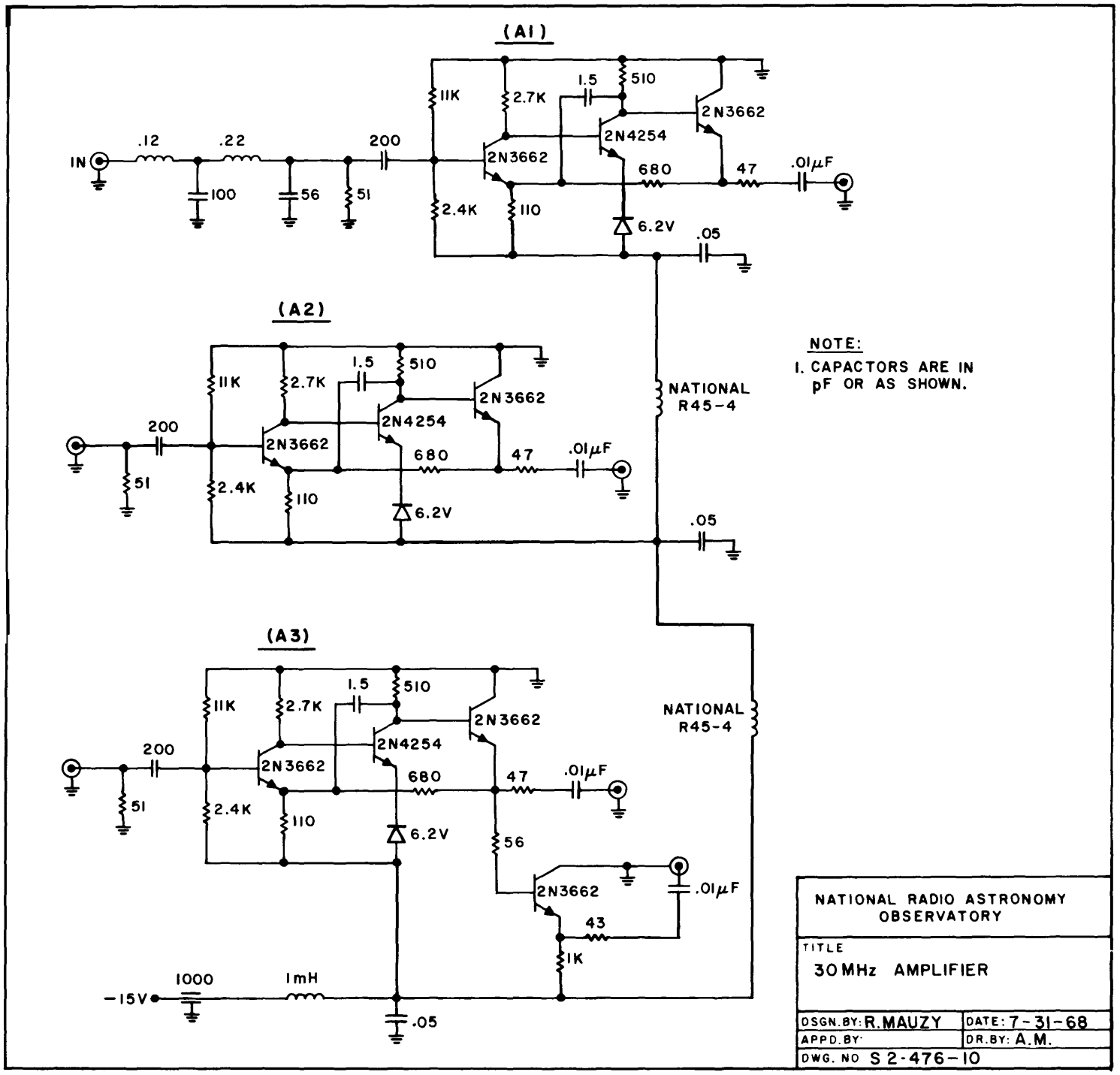
30 MHz Amplifier

The first three buffer amplifiers shown in Figure 2 are contained in a single unit and operate over a broad band around 30 MHz. They have a gain of about 11 dB and a very flat response within the 10 MHz band. Each section is a three-stage feedback amplifier as shown in Figures 4 and 5. The first section includes a low pass filter mentioned previously and the third section has a second output to feed the signal to Filter Unit C.

Amplifier-Mixer-Switch Assembly

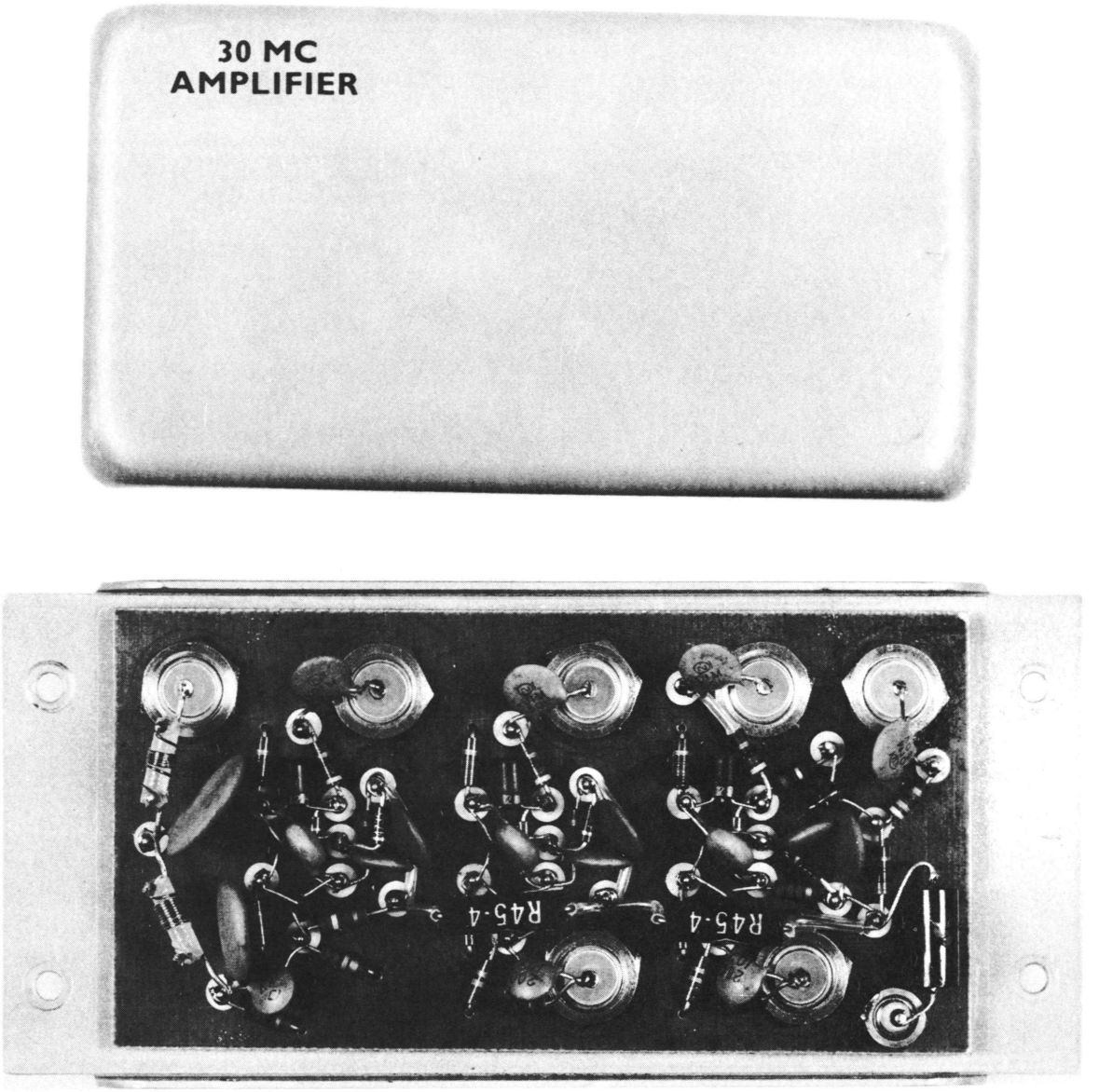
The amplifier-mixer-switch units contain one mixer, three amplifiers and three switches, that is, all the electronics located between the bandpass filters of different center frequency and the oscillators. The low pass filters are located on the cover of the unit. This arrangement provides the most compact and mechanically convenient construction. The amplifiers are three-stage feedback units having a matched gain of 11 dB. They have been used generously to provide a good source and load impedance for all filters. For this reason, a simple, stable, wide band, low gain amplifier was designed. See Figures 6, 7 and 8. Initially, a single design was intended to be used at all frequencies from 30 MHz down. During gain stability checks it was found that some improvement could be obtained by changing Q_2 in the lower frequency units from a 2N3662 to a 2N4124. Gain stability with temperature for these amplifiers is in the order of .0025 dB/°F.

The mixers are of the double balanced type made from commercial transformers and matched hot carrier diodes. At the time of this design the now common double balanced mixers were not available with solder pin connectors or with a sufficiently low frequency response. At one and five MHz the total spurious output due to the oscillator drive is less than -45 dBm. At 30 MHz the output is about -30 dBm.



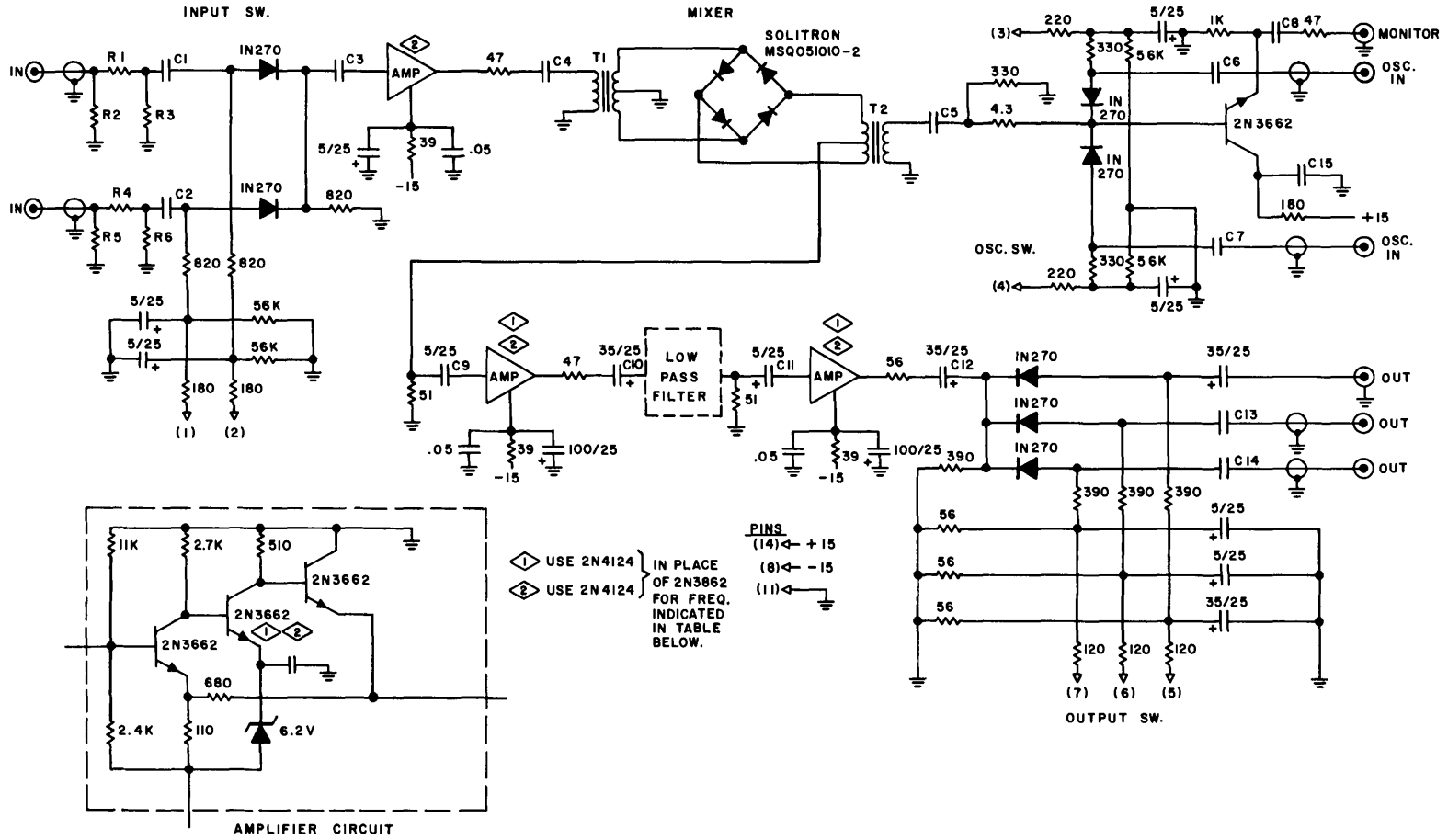
30 MHz Amplifier

Figure 4



30 MHz Amplifier

Figure 5



FREQ. INPUT	AMP. #	Q'T'Y.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	T1&T2
30 MHz	1	3	no input Sw.		.01	.01	.01	.01	.01	.01	SEE SCHEMATIC				.01	.01	.05	0500
① 10 MHz	2	3	.01	.01	.01	.01	.01	.01	.01	.01					.05	.05	.05	0500
② 2.5MHz	3	2	.01	.01	.01	.05	.01	.01	.01	.01					.05	.05	.05	0500
② 2.5MHz	3'	1	.01	.01	.01	.05	.01	.01	.01	.01					one output only		.05	0500
② 625KHz	4	2	.05	.05	.01	.2	.05	.05	.05	.05					.01	.01	.01	10595
② 156KHz	5	2	.05	.05	.01	.47	.01	.01	.01	.01					one output only		.01	10595

TABLE OF COMPONENT VALUES FOR AMPLIFIER FUNCTION

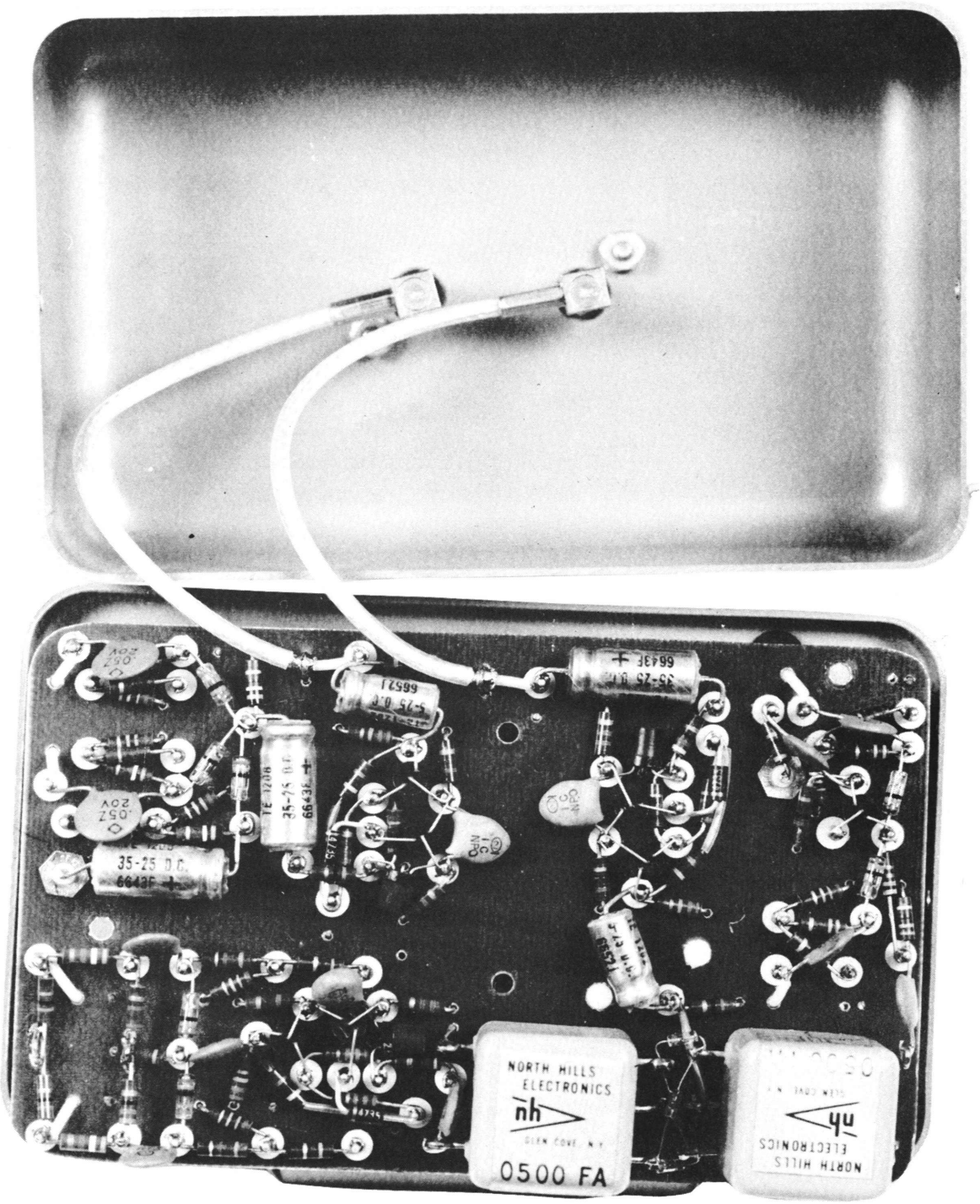
NOTE:

1. R1, THRU R6 VALUES ARE TO BE ADJUSTED TO COMPENSATE FOR EACH FILTER ATTENUATION.
2. CAP. VALUES SHOWN AS- 5/25 -, READS: μF/V.
3. T1&T2 ARE: NORTH HILLS ELECTRONICS.

NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE CORRELATION RECEIVER AMPLIFIER-MIXER-SWITCH ASSEMBLY	
DESIGN BY R. MAUZY	DATE 8-1-68
APPROVED BY	DRAWN BY A.M.
DWG No S 2-476-11	

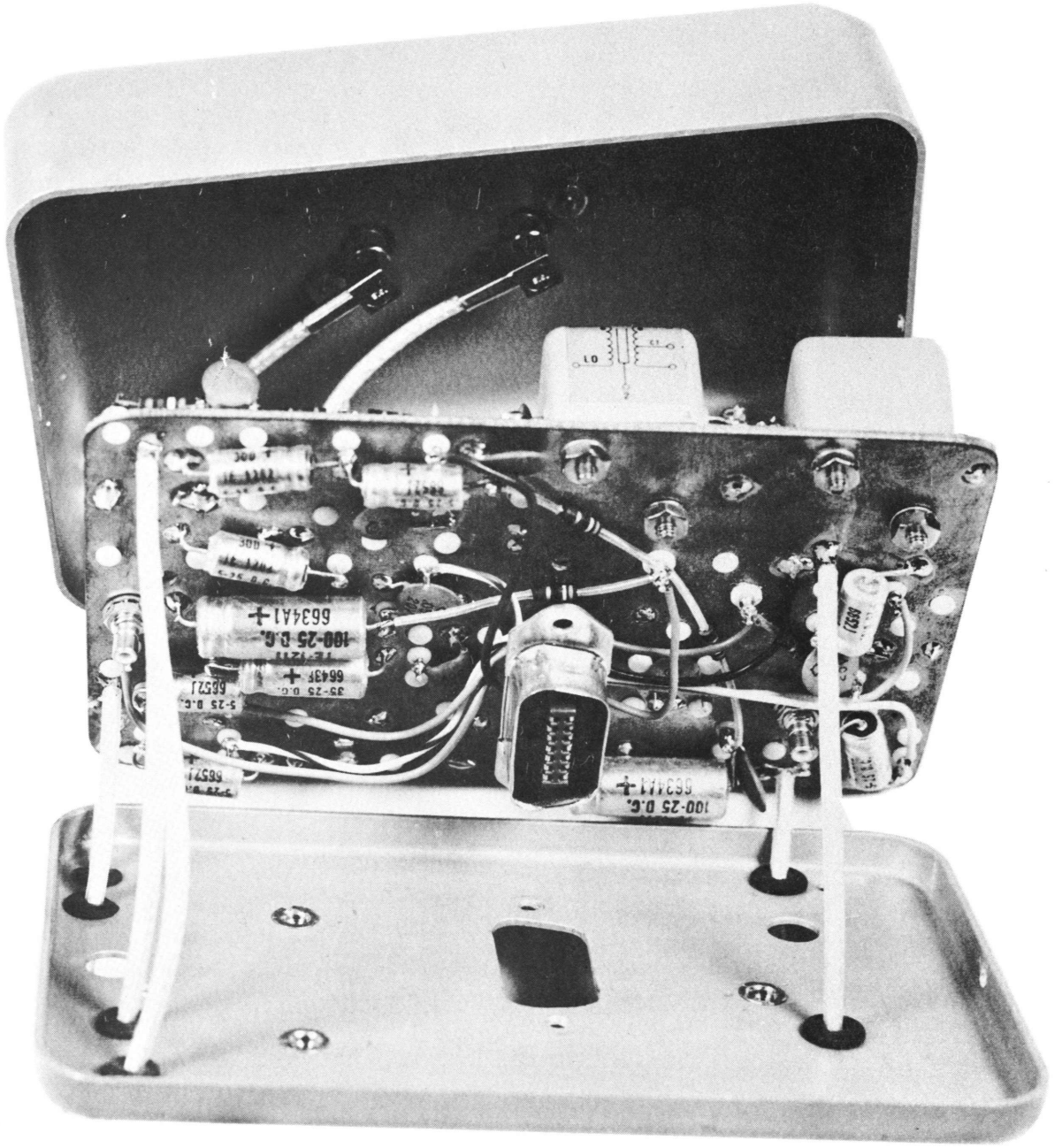
Amplifier-Mixer-Switch Assembly

Figure 6



Amplifier-Mixer-Switch Assembly

Figure 7



Amplifier-Mixer-Switch Assembly

Figure 8

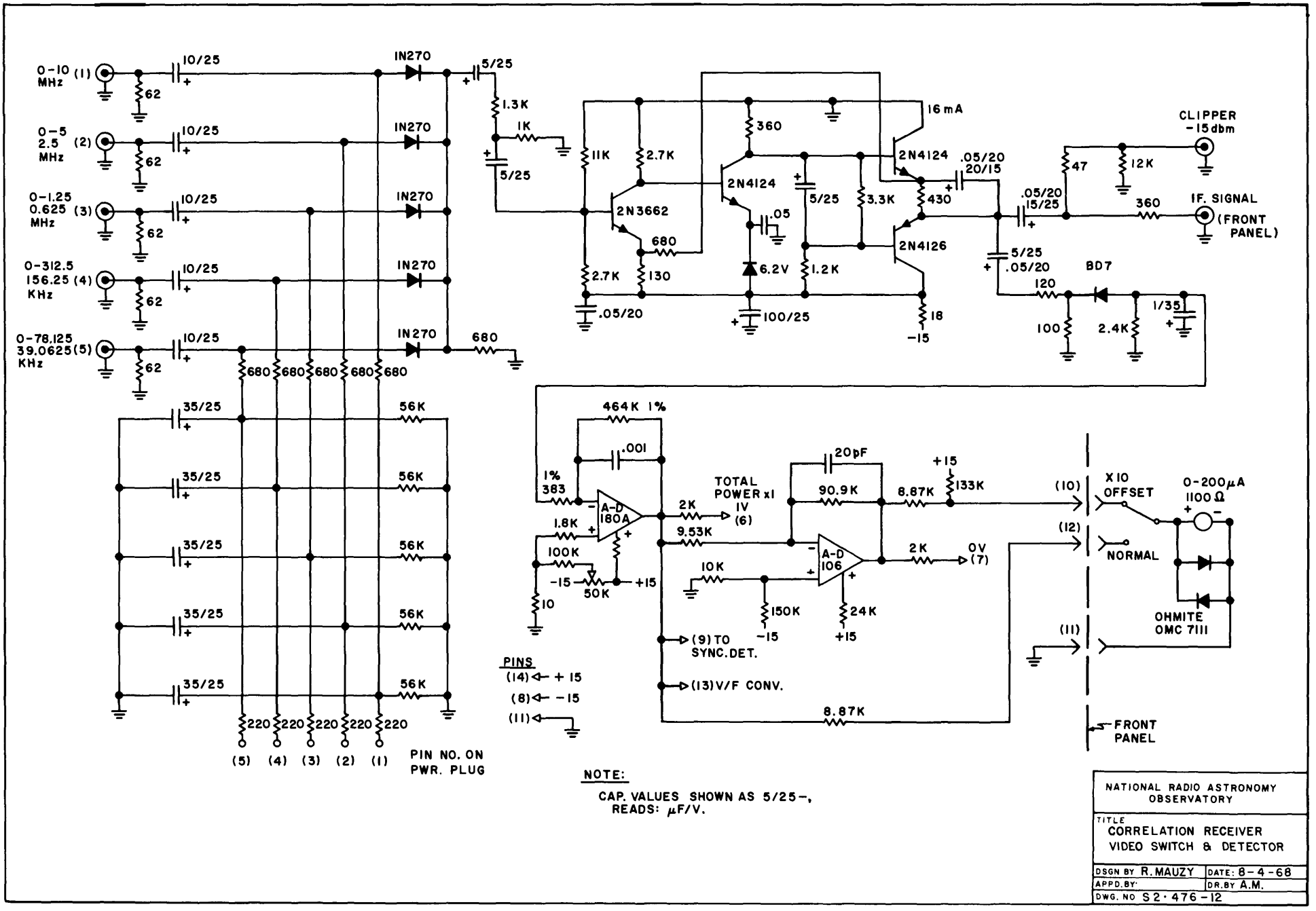
Diode switches provide compact, economical switching of signal and LO lines. They are operated by applying +15 V to the proper control lead, forward biasing the desired diode and back biasing the others. The control voltage was made the same as the oscillator supply voltage to simplify switching circuitry. An emitter-follower in the LO line feeds the frequency being used to the back of the drawer for monitoring.

Specifications for the bandpass filters permitted insertion losses up to 15 dB. Attenuation to compensate for smaller losses and for the power change due to a change in bandwidth are located at the input to each Amp. -Mix. -Sw. Unit. The design operating levels for these units are: -39 dBm input beyond the attenuators, -15 dBm output and +7 dBm LO input. A test adapter is available for convenient troubleshooting of units removed from the drawer.

Video Switch and Detector

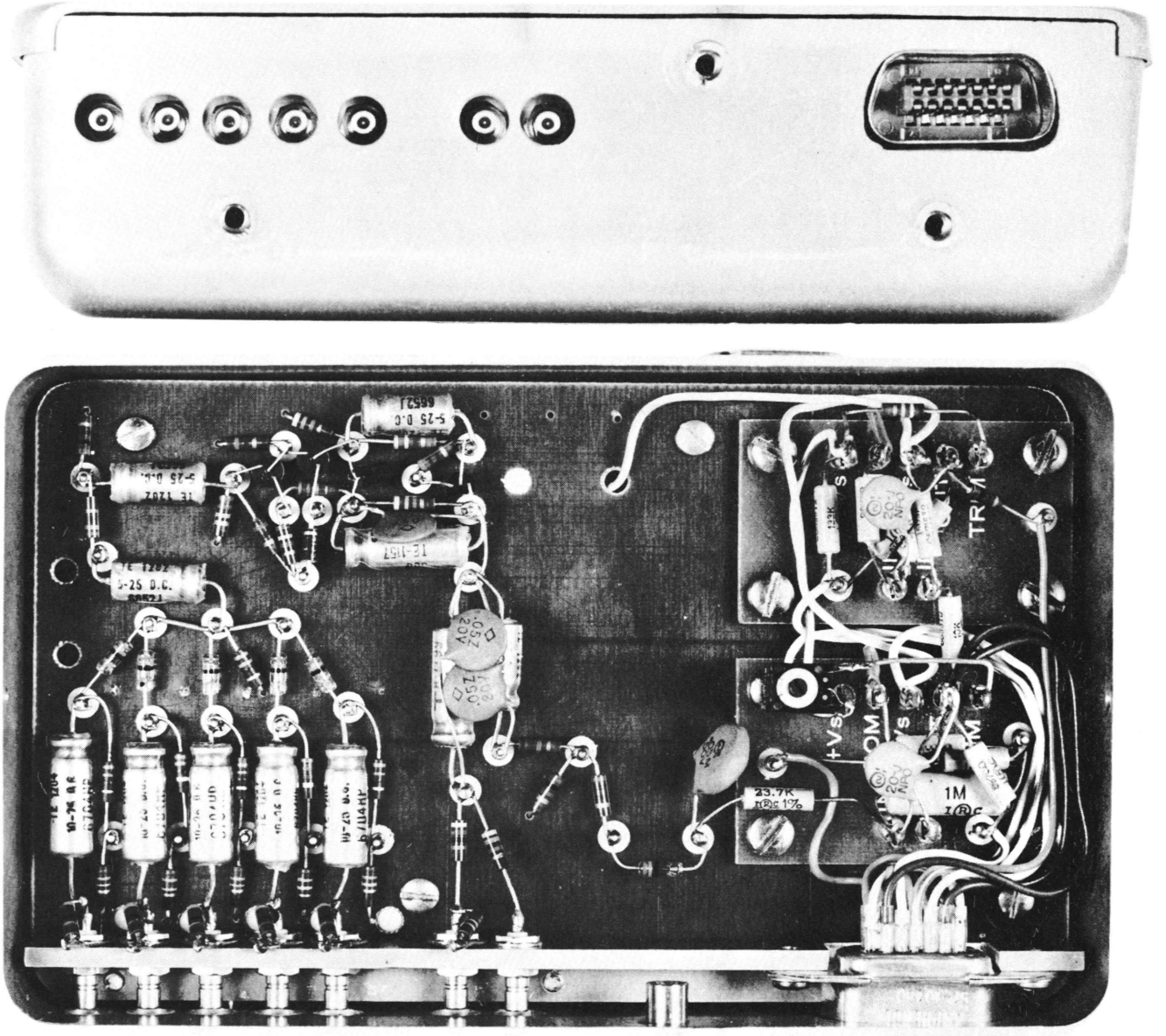
The Video Sw. and Det. Unit selects the desired video line, amplifies and detects the signal, and provides detected signal amplification for driving meters and recorders. See Figures 9 and 10. The diode switch is similar to those discussed previously. The amplifier is a modified version of the basic circuit used elsewhere. In this circuit the output stage has been changed to a complementary pair to permit a higher output level without limiting.

A back diode is used as the square law detector because of its better temperature characteristic. Other diodes or multiple diode circuits may be made more accurate at a given temperature but the accuracy is lost without temperature control. This detector circuit has a temperature coefficient of about -.008 dB/°F. The coefficient is fairly constant over the operating range so that little degradation in the square law characteristic occurs. The back diode detector is operated at a nominal DC output level of about 1 mV into 330 ohms. An operational amplifier boosts the level to 1 V, drives the V/F converter, synchronous detector, recorder output, and another operational amplifier. The second op amp provides a gain of 10 and an offset voltage to produce 0 V output with +1 V input. Deviations from 1 V are thereby amplified, displayed on the total power meter and provided for recording. The first op amp is zeroed by a control accessible through the top of the drawer. To zero the amplifier place the bandwidth switches in the undesignated position beyond the



Video Switch and Detector

Figure 9



Video Switch and Detector

Figure 10

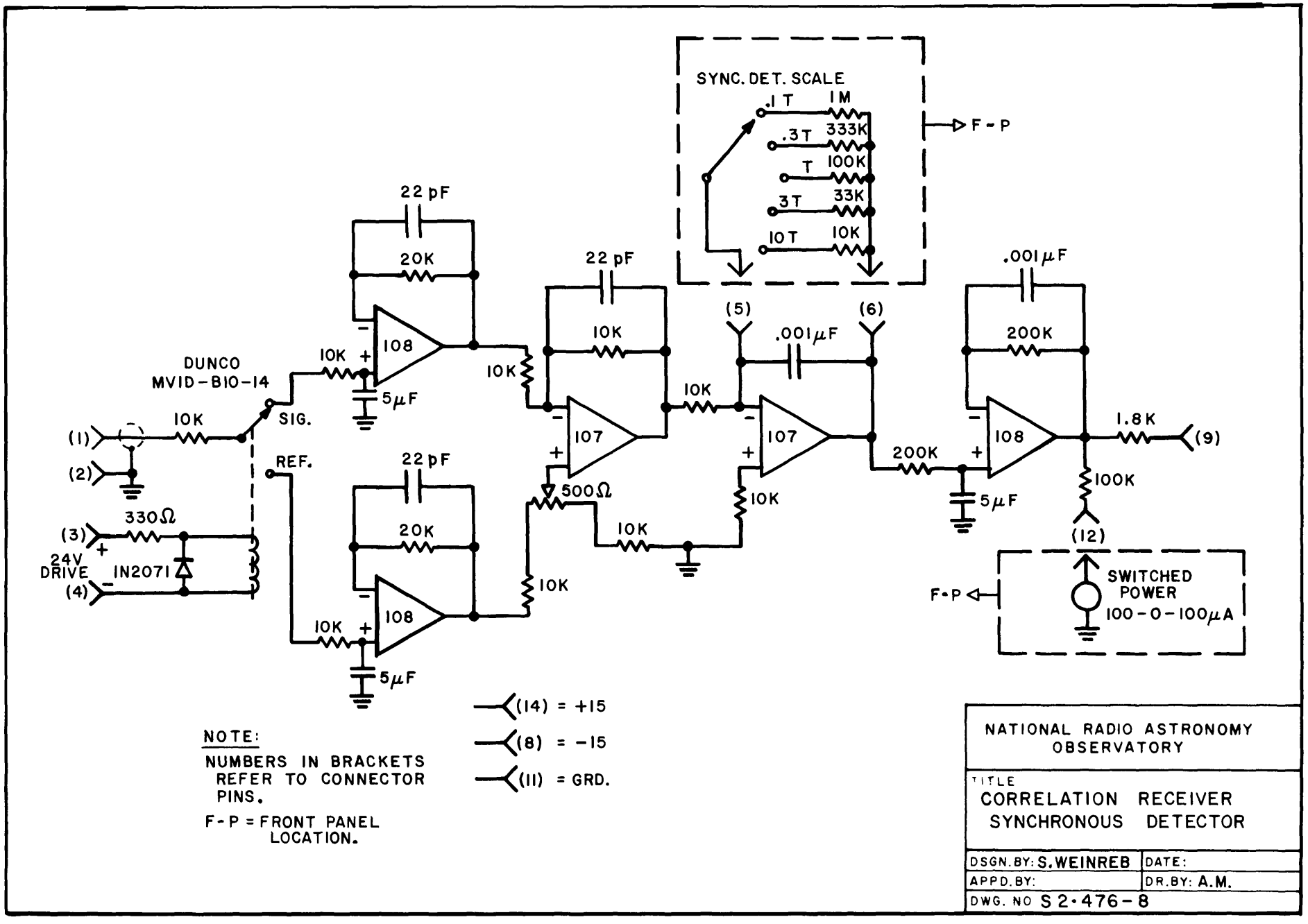
narrowest setting and adjust for less than 0.5 mV at the front panel total power jack. The bandwidth switch setting turns off all oscillators except the 120 MHz unit and opens all diode switches to provide a minimum noise level into the detector. The amplifier noise internal to the drawer is about 26 dB below the input signal and should be removed for accurate zeroing.

Synchronous Detector

The Synchronous Detector provides switched power output for meter display and recording. It is used during receiver adjustment to obtain an accurate gain modulator setting. The unit subtracts the reference total power level from the signal total power and amplifies the difference for meter display and recording. See Figures 11 and 12. The DC input is switched from signal to reference in sync with the front-end switch. A voltage is thereby stored on the two input capacitors corresponding to the total power levels in each of the two conditions. These voltages are fed to a difference op amp via voltage follower amps. After subtraction the signal is amplified by a fourth op amp and smoothed by a one second time constant. An output amplifier provides drive for the switched power meter on the front panel and for recorders. The gain of the fourth op amp can be varied by a front panel switch calibrated in system noise temperature and referring to full scale meter deflection. The entire unit is zeroed by a pot at the input to op amp three. To zero the unit, turn the gain modulator off, obtain a constant noise signal (no front-end, noise tube or LO switching) and adjust for a minimum reading on the 0.1 T scale. This unit was designed by S. Weinreb.

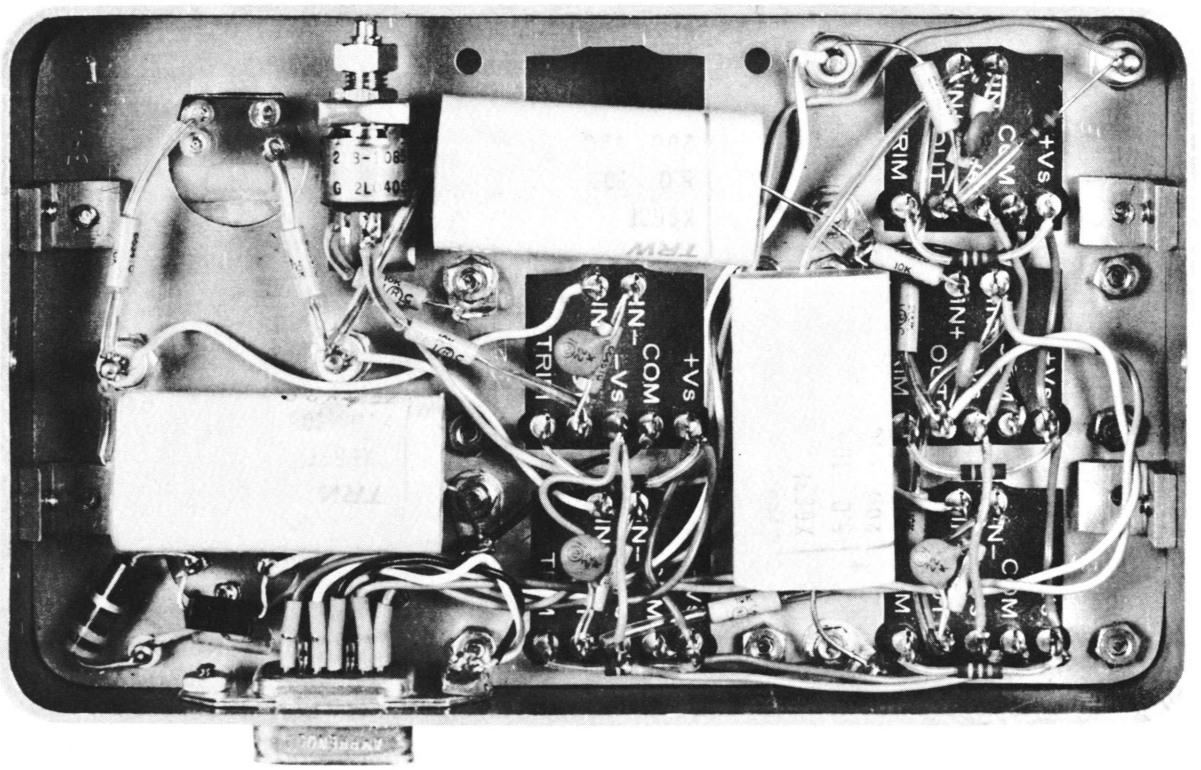
Clipper

The clipper is one of the more unusual units in the system. It is the second clipper developed by the writer for correlation use and is much superior to the first. The requirements on the unit were that it should provide 60 dB of limiting on input signals from 1 kHz to 10 MHz, should have a bandwidth of at least 100 MHz, an output rise and fall time of less than 5 ns and a clipping level asymmetry at least 30 dB down.



Synchronous Detector

Figure 11



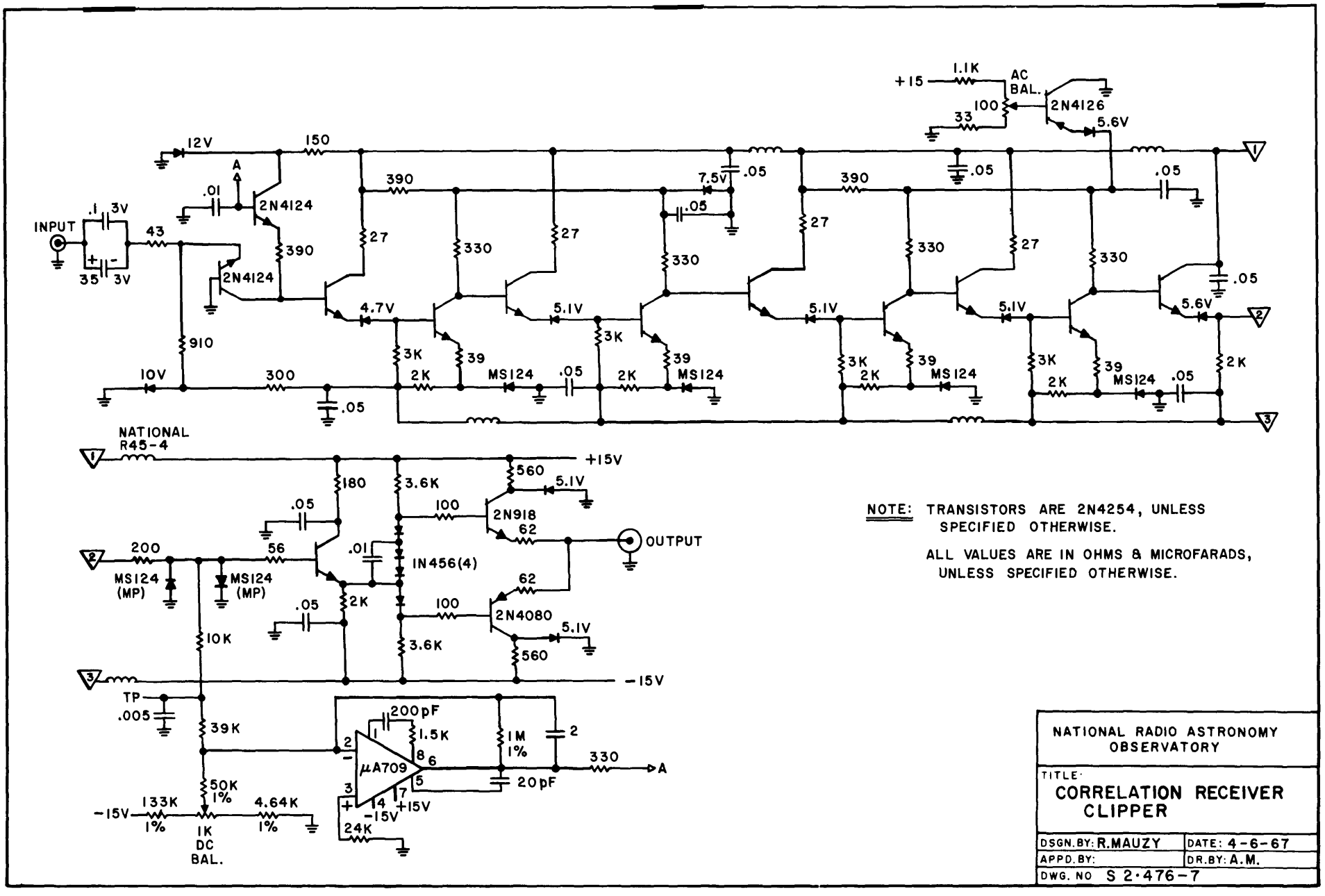
Synchronous Detector

Figure 12

The first experience with a limiter for this application was with an AC coupled amplifier-double diode limiter chain that required many electrolytic capacitors and had a disappointing bandwidth. It was decided to try a direct coupled circuit with overall feedback to stabilize the clipping point. With a 1 kHz lower limit on the signal there is little problem in keeping the feedback frequency range below the signal band. The next step was to determine the most desirable basic limiting amplifier configuration. A grounded emitter-emitter follower pair with emitter feedback in the amplifier stage gave a gain of 14 dB and a 1 dB bandwidth of 180 MHz. The amplifiers were made into limiters by adding fast switching diodes in the emitter feedback circuit. The final limiting amplifier has four cascaded pairs driving a matched pair of hot carrier diodes. See Figures 13 and 14. Limiting occurs due to cutoff of the transistor in one direction and cutoff of the diode in the other direction. Diode cutoff increases the emitter feedback by a factor of about 40 thereby preventing further amplification. Zeners are used between stages to shift the DC level. After final limiting the signal is fed through emitter followers with a complementary output stage to drive a 50 ohm line to the sampler. Zeners are used in place of capacitors for decoupling on the limiters to give better regulation and eliminate some likely problems with loop phase at low frequencies.

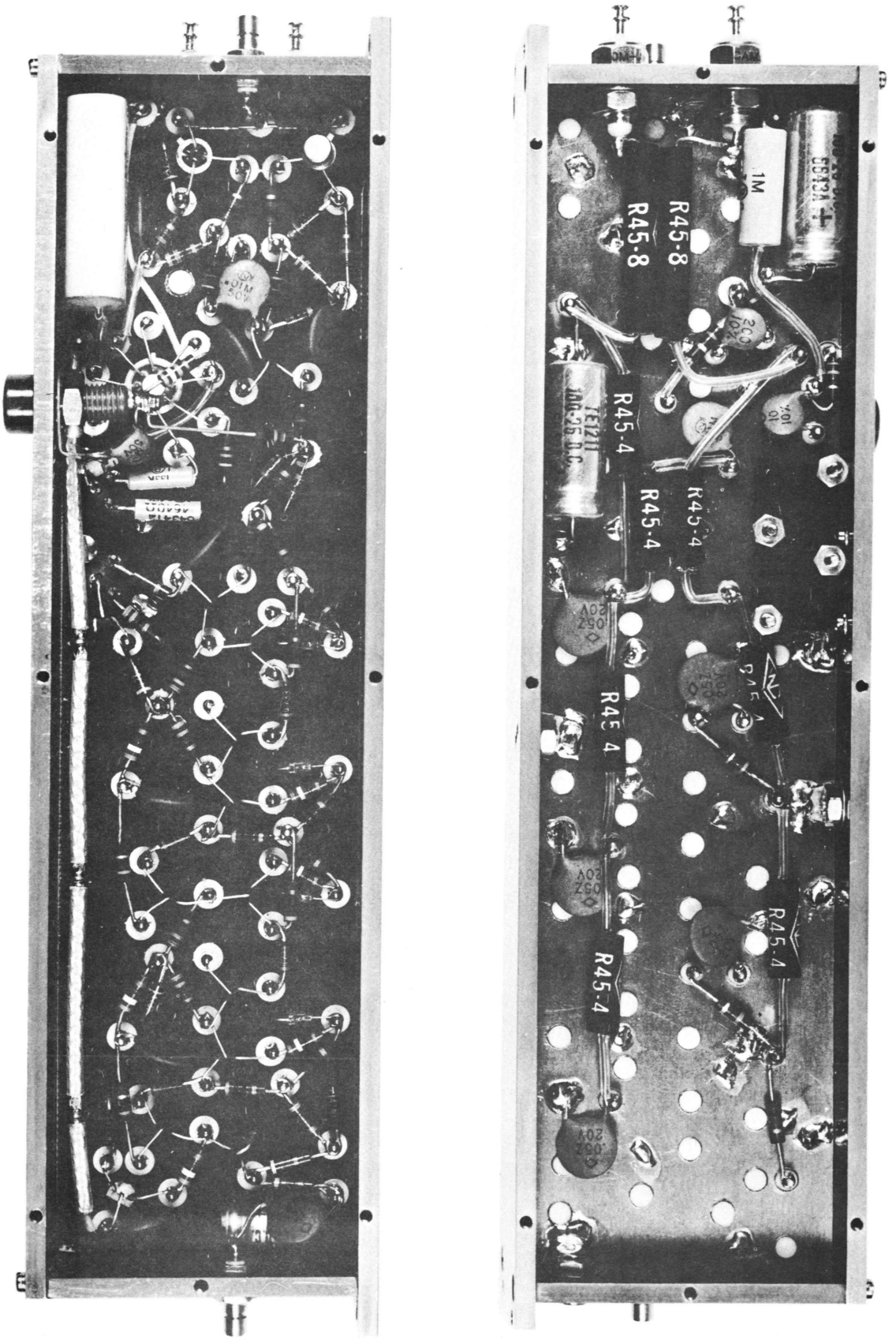
The DC feedback is taken from the last clipping point, fed through an op amp having a gain of 20 and into the collector of the first stage. The op amp circuit time constant starts the loop gain rolloff at .08 cycles. Loop gain is about 82 dB with no input but decreases as input signal increases. At the nominal input level of -15 dBm the DC gain through the limiters is near 0 dB. Therefore, it was necessary to add gain in the feedback circuit for stabilization.

There are two adjustments required to zero the unit. With the input disconnected the DC Balance control is set for zero volts (< 0.1 mV) at the test point. This sets the operating points with only partial limiting on internal noise. With the signal applied the AC Balance is adjusted for zero volts on the test point or for equal probability of the two output polarities. This can be observed on the digital rack channel display as a minimum number of correlations. The AC Balance circuit provides a means of shifting the drive levels into the dual diode limiting stage so that the voltages will be symmetrical about ground. The transistor and zener in the balancing



Clipper

Figure 13



Clipper

Figure 14

circuit provide regulation for two limiting amps and temperature compensation for similar components driving the diode pair. At the nominal input level of -15 dBm an unbalance in the clipping level that is 30 dB down will produce a 12 mV error signal at the test point.

Typical measurements are as follows:

1) Maximum input level -- 0 dBm.
2) Input level for threshold of limiting -- -74 dBm (10 MHz c.w.).
3) DC error vs. input level -- peak of 1.3 mV at TP for -4.5 dBm in.
4) Phase shift vs. input level -- less than 0.5 ns for a 30 dB change.
5) Output -- 0.6 V p-p into 50 ohms, symmetrical about ground.
6) Rise and fall times -- approximately 1.6 ns.

Sampler

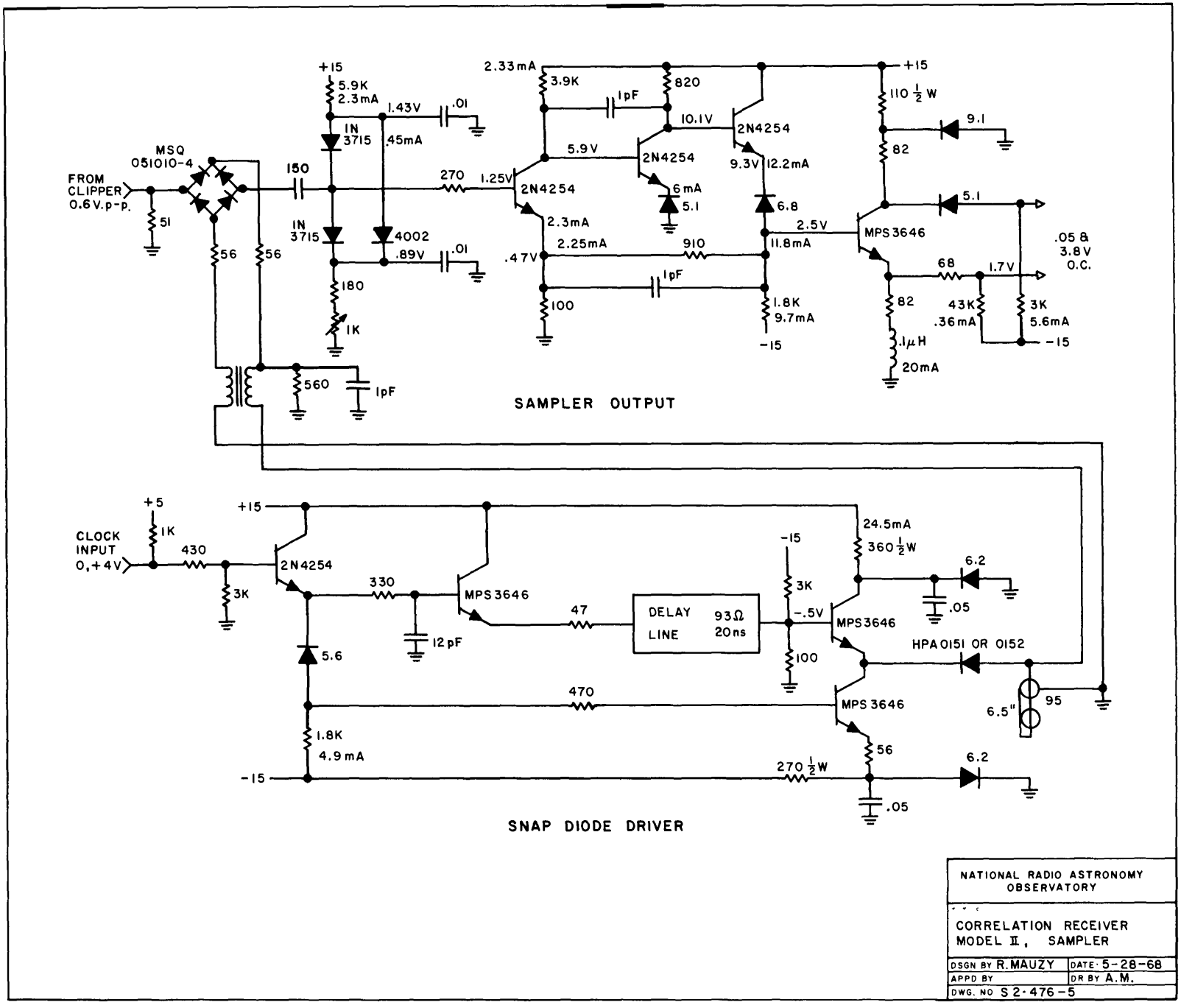
The sampler receives 0.6 V p-p rectangular waves of random frequency in the range of 1 kHz to 10 MHz. These signals are sampled at periodic intervals by a pulse generated from the clock in the digital system. The samples are held until the next sampling time by tunnel diodes and made compatible with the digital equipment by an amplifier and phase inverter. Because both clock input and logic output signals are normally at an impedance level higher than coax, the signal input is at low impedance, and because it was desirable to reduce the delay time between clock input and sampled output, the sampler was mounted in the digital rack on a printed circuit card.

The sampler is designed to operate with a clock input of +4 V having a width of 20 to 30 ns and switching times of about 7 ns. The optimum width is about 23 ns. The clock rate can be any frequency from 20 MHz down. Direct coupling is used in the sampling pulse generator to make circuit operation independent of rate. In this system the sampling rate is always twice the bandwidth setting.

The clock input signal is fed through an emitter follower and split for two functions. See Figures 15 and 16. One pulse goes through a second emitter follower to drive a delay line. The other pulse drives an amplifier. The amplifier operates as a current generator to produce conduction in a step recovery or snap diode. The snap diode (HPA 0151) is operated by having a forward current produce a stored charge and then reversing the current flow until there is an abrupt end to the charge and to conduction. The diode suddenly becomes an open circuit. Approximately 20 ns after forward current begins in the snap diode the clock pulse arrives through the delay line and emitter follower to reverse the diode current. Current through the diode flows to ground via the shorted coax line. When the diode suddenly opens the current in the line flows through the load. The current is sustained for a period equal to twice the line propagation time, in this case about 1.5 ns. A bifilar transformer is used to adapt the unbalanced line to a balanced load. The pulse produces conduction in the diode bridge thereby switching the signal input voltage to the tunnel diodes (1N 3715's). Reverse bias on the bridge diodes is not necessary since the signal input voltage is about one-fifth the amplitude required to drive the diodes into conduction and cause tunnel diode switching in the absence of a gate pulse.

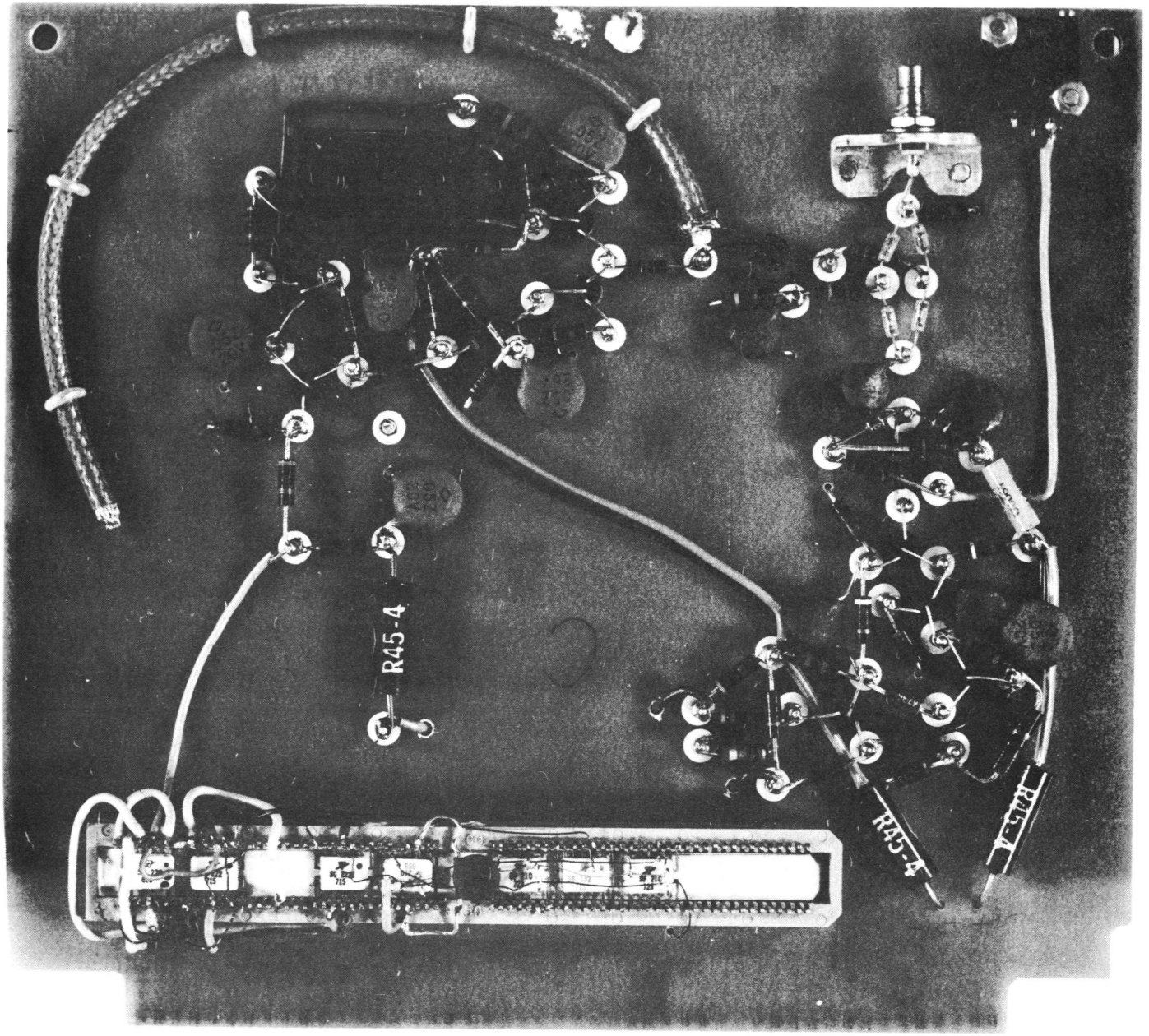
The tunnel diodes are forward biased with a current about 15 percent below their peak. If both diodes should be in their low state simultaneously, the current will exceed the rated peak value causing one of the diodes to switch to the high state. A third diode (1N 4002) prevents both diodes from being in their high state by limiting the total voltage across them. These limits assure that the two diodes are in opposite states so they can act as a flip-flop or holding circuit with very fast switching time.

The three stage feedback amplifier provides a gain of 10 and drives a phase inverter to furnish complementary outputs having levels of zero and +3.8 V. A DC level control in the tunnel diode circuit allows compensation for component tolerances. With the diodes switched to produce conduction in the output transistor (emitter output about +3.8 V) the pot is adjusted for a level of 0 to +0.2 V on the output from the collector when loaded by the digital circuits.



Sampler

Figure 15



Sampler

Figure 16

Voltage-to-Frequency Converters

Three voltage-to-frequency converter cards are mounted in the top drawer. These units are a commercial type, Vidar Model 211-02 modified. The input resistor R1 (20 K ohms) has been shunted by 20 K ohms to double the sensitivity. A one volt DC input signal will generate output pulses at a 2 kHz rate.

Noise Generator

The noise generator provides a flat noise spectrum at both IF frequencies for use in testing the system. It is located in the V/F converter/clipper drawer. The output covers a band from less than one MHz to about 200 MHz. Total output power is -15 dBm and 10 MHz bandwidth power is about -29 dBm. The noise is generated by amplification of first stage noise in conventional amplifiers. See Figures 17 and 18. Six amplifier-emitter follower pairs have a gain of 65 dB. As an amplifier the response is flat to 100 MHz, has a 0.8 dB peak at 140 MHz and is down 1 dB at 200 MHz. As a noise generator, the spectrum appears flat to 185 MHz.

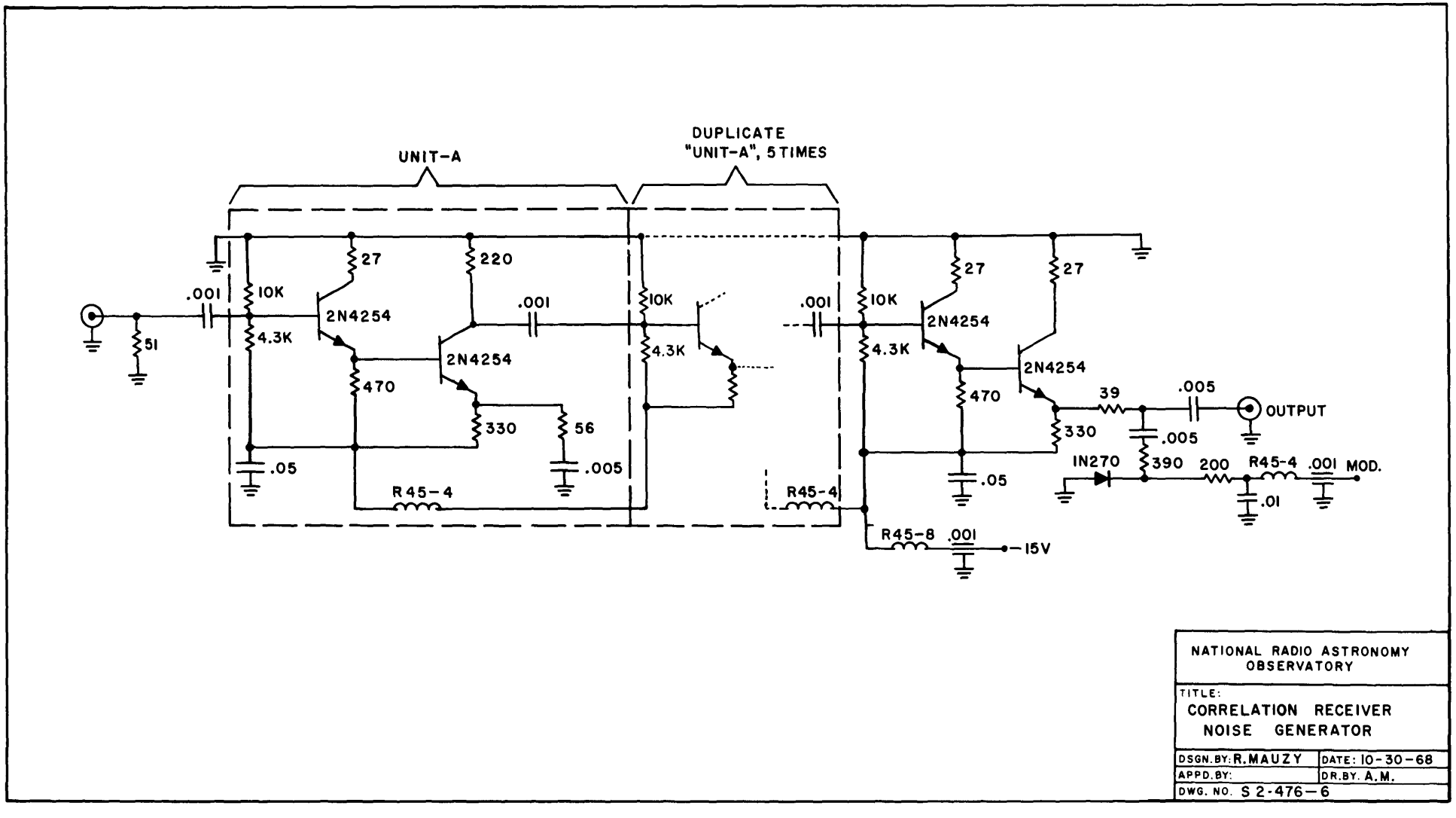
The output circuit contains a modulator to simulate noise tube calibration signals from the front-end. The modulation signal is obtained from a special driver in the switch driver drawer and is controlled by the noise tube switch. The level change is about 0.2 dB.

Switch Driver

The switch driver drawer receives front-end and noise tube switching signals from the digital rack, provides manual selection of these signals and generates the voltage and current levels required to drive the switches. See Figure 19. The drawer contains three drivers, one ferrite and one diode driver for front-end switching and one diode driver for noise tube switching. Most of the circuits are identical to those used on the Standard Receiver so no further discussion will be given.

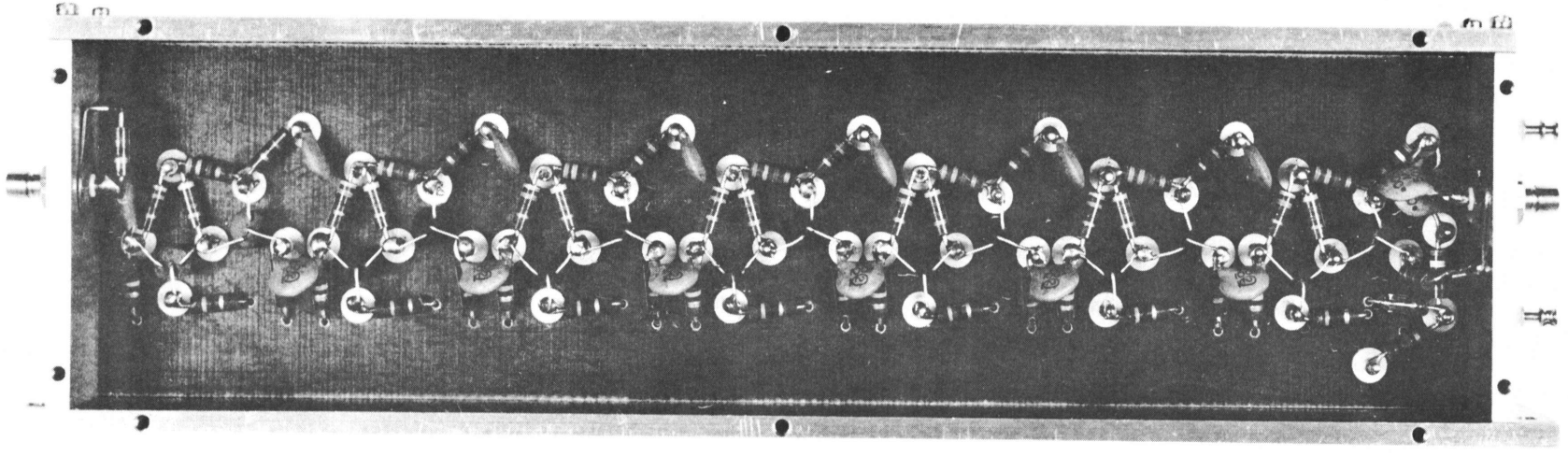
Acknowledgment

The writer wishes to acknowledge the contributions by A. M. Shalloway and S. Weinreb to the overall design requirements, specifying operating controls, and answering numerous questions on the project. S. A. Mayor was responsible for the construction and contributed to the design both mechanically and electrically.



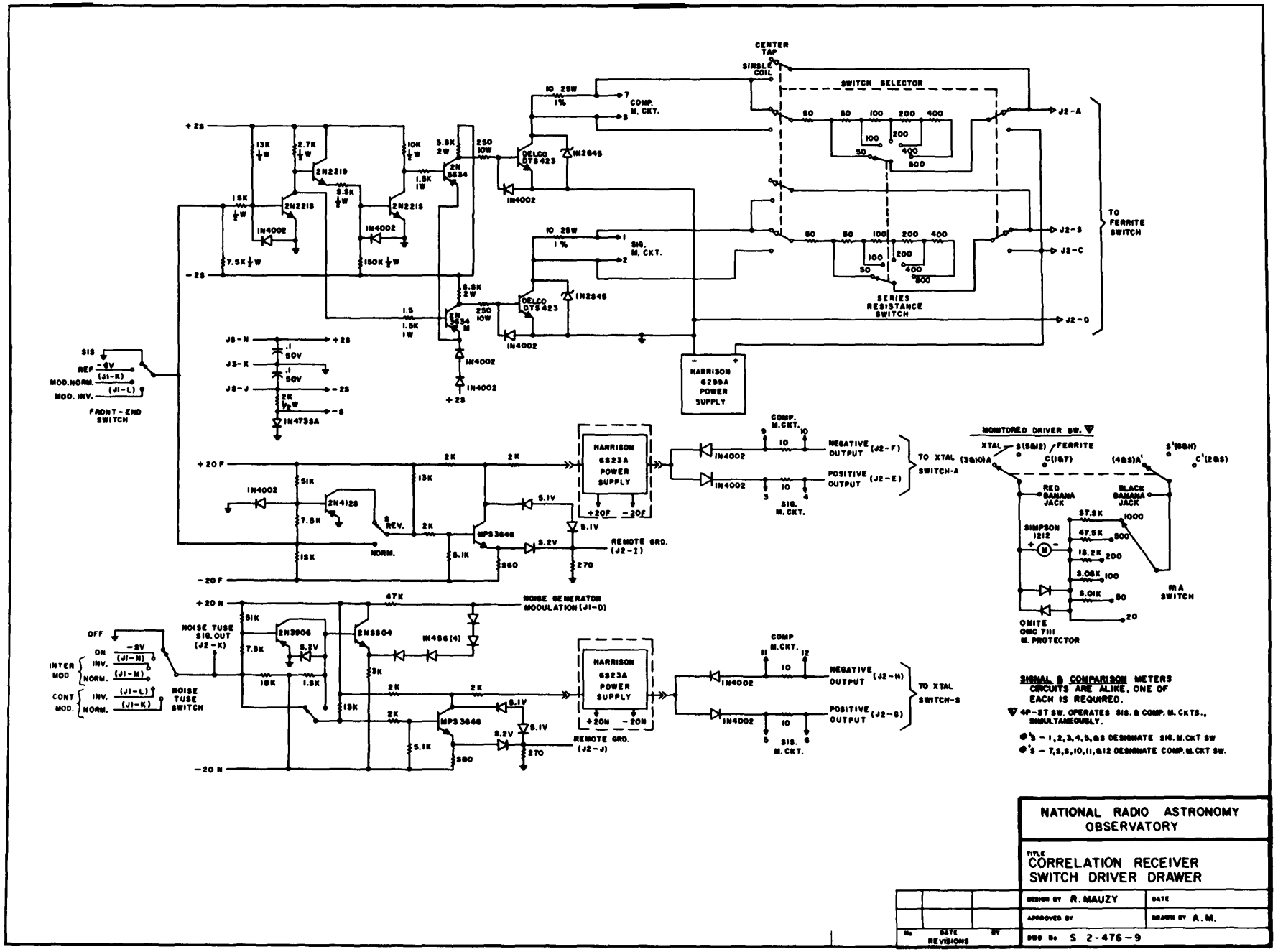
Noise Generator

Figure 17



Noise Generator

Figure 18



Switch Driver Drawer

Figure 19