

## THE SA-2239/WLQ-4(V) CUTTY SARK DISTRIBUTION SYSTEM

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### ABSTRACT

This paper describes a redundant frequency and time distribution system providing a multiplicity of isolated outputs, all of which are derived from three atomic frequency standards. The distribution system monitors input parameters of the signals coming from the Cesium Standards and selects one to be the primary standard, phase locks an internal oscillator which has excellent aging characteristics in the open loop mode and acts as a filter to provide phase noise improvement, and generates 1 megahertz and 100 kHz by direct synthesis.

Additionally, the system distributes RF and timing signals consisting of 5 MHz, 1 MHz, 100 kHz, BCD Time-of-Day, 1 pps and 1 ppm.

### INTRODUCTION

Modern submarines use a multitude of frequency standards for navigation, missile guidance, communications and time-keeping purposes. It has become necessary to develop a signal processing and distribution unit which accepts the input signals from the primary standards, provides readouts of signal integrity, improves signal characteristics, and distributes the signals to various users on the boat. The SA-2239/WLQ-4(V) Time Standard Selector Unit performs these functions utilizing redundant hardware with automatic switchover to maximize reliability and eliminate single point failures. The system is qualified to operate in a submarine environment and has battery backup providing thirty minutes of operation during ac mains failure.

### SYSTEM DESCRIPTION

The Cutty Sark system can be split into three major subsystems. The first is the RF processing and distribution system, the second is the timekeeping, test and distribution system, and the third is power generation and distribution. Table 1 itemizes the various interface signals of the SA-2239/WLQ-4(V). The three Cesium Standards supply 5 MHz, 1 PPS, 1 PPM, BCD Time-Of-Day (TOD), and a Standard fault signal.

Additional 1 PPS and TOD inputs are fed from the Navigation Center and Time Code Generator (TCG). Twenty-four sinewave signals, twelve timing pulses, and six TOD outputs are generated.

#### RF Distribution

Figure 1 is a block diagram of the RF distribution system. Three 5 MHz signals are accepted from the Cesium Standards and feed fast fault-detector circuits which detect a dropout of a signal and switch over to a standby input without introducing a phase shift in the system output signal exceeding  $90^\circ$ . The phase perturbation is relatively slow so as not to upset user equipment. The 5 MHz input is multiplied to 30 MHz and fault detected. The detection circuitry senses a failure within one cycle at 30 MHz. The 30 MHz signal then passes through a high speed, high isolation diode switch. The outputs from the three Input Modules are combined at the input to the two phase locked oscillators. A 30 MHz narrow band filter provides a flywheel effect eliminating signal dropout and a high speed comparator converts the sinewave to a TTL level. A divide-by-six circuit provides 5 MHz which phase locks a low noise VCXO. The oscillator provides rejection to spurious signals, improves the phase noise floor and acts as a redundant signal source in the event of failure or removal of the primary inputs. The oscillator output feeds a frequency divider subassembly generating 1 MHz and 100 kHz. These signals are filtered to provide sinewaves and are fed to a three channel driver amplifier which boosts the signal level for driving the output amplifiers. Since there are twenty-four RF outputs each at a level of +27 dBm, it is necessary to design the output amplifiers with high efficiency to minimize power drain and permit cooler system operation. Thus a Class C configuration is chosen with hybrid coupled amplifiers used to provide improved operating parameters.

#### Time Distribution System

The Digital System, shown in Figure 2, accepts three 1 PPS and 1 PPM inputs from the Cesium Standards. These signals are fault detected, selected, and amplified. Redundant output amplifiers are selected automatically or manually. An additional function of the SA-2239/WLQ-4(V) is to check and compare 1 PPS and TOD which is inputted from the Cesium Standards, Time Code Generator, and the Navigation Center. Once a particular source is selected as the primary source, all other inputs are compared to that signal and the information is presented on the front panel. Time coincidence errors in the leading edge of the 1 PPS or 1 PPM signals of greater than 200 microseconds trigger an alarm condition.

#### Power Management

The Cutty Sark requirements present a unique set of operating constraints regarding the generation and distribution of dc power internal to the chassis. Power source priorities are external ac;

external dc; and internal battery. When operating on battery, non-critical circuits are disabled but front panel displays can be manually enabled. Due to the tight packaging density and internal power dissipation of 120 watts, a low-noise (RF and acoustical) fan circulates air throughout the chassis. The system is designed to operate without external cooling although rack cooling is normally provided in the submarine environment. To minimize power dissipation, redundant dc to dc switching regulators and power supplies are utilized. On board linear regulation is provided for those circuits which cannot tolerate 25 kHz switching transients. Each module is RFI filtered with low pass filters having a 5 kHz bandwidth. Coaxial line filters are used at the ac and dc input interface. The entire package is RFI shielded to meet the requirements of MIL-STD-461A. Internal temperature is monitored for presentation on the front panel test meter.

#### CIRCUIT DESCRIPTION

The Cutty Sark mission requirements of non-dropout input switchover, multiple +27 dBm RF outputs with low source VSWR, and continuous comparison of multiple timing inputs required the development of several unique circuits. The following paragraphs discuss specific circuits developed to meet these goals.

##### Input Processing

The input module senses the integrity of the Cesium Standard output signals and switches over to standby inputs in the event of failure. Three input modules are utilized, one for each atomic standard. As shown schematically in Figure 3 the 5 MHz input is amplified by Q1 and then multiplied by six with Q2. The 30 megacycle signal passes through a high isolation switch which has an on to off ratio of 120 dB and a switching speed of 30 nanoseconds. Faults are detected both at 5 MHz and 30 MHz. These detectors provide a switchover command in less than 20 nanoseconds if the input signal amplitude falls below +10 dBm. The three module outputs are combined after selection by the high isolation switch. Only one of the three inputs is selected at a given time. Failure is detected and switchover occurs in less than one cycle at 30 megahertz which corresponds to 60° at 5 MHz. The selected 30 MHz signal passes through a narrow band LC filter and is divided by six in the phase locked oscillator to restore 5 MHz. The purpose of the multiplier, filter, high speed sensing circuit, and high isolation switch is to enable selection of the standby pass without interruption of the output signal and with a phase perturbation of less than 90 degrees.

Figure 4 is the schematic diagram of the 1 PPM timing fault detection circuit in the input module. The +10V input pulse is attenuated by a factor of two and feeds one-shot multivibrator U1 whose output is a 3 millisecond wide pulse at a rate of 1 PPM. This signal feeds timer U2

which is configured as a retriggerable one-shot with a time constant of sixty-five seconds. A pulse dropout causes an alarm signal which is summed with the other module alarms. A composite alarm signal is thus generated which selects the appropriate cesium standard input. Fault detection of the 1 PPS and BCD inputs is accomplished in a similar manner with the retriggerable one-shot time constant set to be 10% greater than the input signal period in each case. This system is relatively straightforward but a failure occurrence may not be detected for approximately one pulse repetition period if the failure occurs immediately after a triggering pulse sets the one shot. This, however, is sufficient since other alarm signals will generally flag a particular failure condition before the digital detectors. Each module has an independent LED indicator showing module status. These indicators are illuminated when a module failure occurs. Additionally, a front panel summary fault indicator alerts the operator to a particular alarm condition.

Figure 5 shows the mechanical construction of the input module. Independently shielded compartments are used for the different functions and dc power is RFI filtered at section interfaces to maintain a high degree of isolation between RF sections and RF to power carrying lines.

#### RF Amplification

The four channel, 5 MHz amplifier shown in Figure 6 was developed specifically for the Cutty Sark distribution system. The two major design characteristics are a collector efficiency of 72%, and a constant low output VSWR over a broad range of frequencies. The first goal is accomplished through Class C operation. The resultant high level of harmonics are reduced to 40 dB to below the carrier with LC output filtering. Each amplifier uses two quadrature hybrid coupled transistors to minimize transistor power dissipation and provide a constant input and output VSWR. Since the transistors are essentially operating in a switching mode during Class C operation, they present identical impedances to the isolated ports of the hybrids and any reflected power is absorbed in the hybrid 50 ohm terminating loads. Hence the overall amplifier input and output impedances is 50 ohms  $\pm$  10% over a 10% bandwidth. The hybrid is implemented as two 90 degree phase shift low pass sections which are capacitively coupled. The basic design of the 1 MHz and 100 kHz amplifiers is identical to the 5 MHz unit. A sample of each RF output is fed to a diode detector and low level sensing comparator circuit. The comparator outputs are wire-or'd to present a single logical zero in the event of failure of any amplifier. High current PIN diodes at each amplifier output enable the appropriate amplifier outputs upon command from the fault logic priority circuit. Figure 7 shows the 5 MHz amplifier package. Since a high degree of isolation is not required between the active stages a single non-enclosed double-sided PC board with a continuous ground plane is utilized for the structure.

## Time-of-Day and 1 PPS Comparison

The system accepts five independent time-of-day (TOD) inputs. Four are 24 bit BCD codes from the three Cesium Standards and the Navigation Center and the fifth is a 2137 code from a time code generator. The 2137 code is an amplitude modulated 1 kHz sinewave consisting of 20 bits of TOD at a 25 PPS pulse rate. Four of the TOD inputs are compared to the fifth which is manually or automatically selected as the primary TOD input. The 2137 input is normalized to 24 bits by a pulse injection technique and the amplitude is shifted for compatibility with the BCD signals. The four TOD pulse trains are then compared on a bit by bit basis with the primary. Any deviation of more than 2 milliseconds generates a front panel alarm and remote alarm output. The operator can then sequentially display the five TOD's to determine the error location and magnitude.

The 1 PPS inputs from the five sources are similarly compared to determine leading edge coincidence. An offset of more than 200 microseconds triggers an alarm. Time coincidence is measured by counting pulses generated from a 1 MHz signal derived from the selected primary input.

The display section uses a six digit numeric LED indicator which indicates TOD or 1 PPS coincidence with a resolution of 50 nanoseconds. A serial to parallel converter and storage register drives the display. Information is updated every second.

## Power Splitters

The 5 MHz, 1 MHz and 100 kHz outputs from the SA-2239/WLQ-4(V) feed power splitters which provide ten isolated outputs from one output. The splitters have 12 dB of insertion loss, isolation in excess of 40 dB from dc to 500 megahertz, and a VSWR of 1.3 to 1 maximum. As was discussed in the section RF Amplification, the output VSWR of the system is held to 1.10:1 over a ten percent bandwidth in order to provide a proper source impedance for the power splitters. This is necessary to insure that the isolation requirement is met. Outside of 10% band extremes, the isolation between outputs is maintained by two-pole LC filters on each output port. These filters have 60 dB of attenuation at the frequencies where the inherent power splitter isolation properties are no longer effective. Figure 8 is a view of the power splitter showing the filtering components and Figure 9 shows the overall power splitter enclosure. In conjunction with the power splitters, a single Cutty Sark switch is capable of supplying 150 5 MHz outputs, 30 1 MHz outputs, and 30 100 kHz outputs at a level of +13 dBm. Physically identical power splitters are used for distribution of 1 MHz and 100 kHz. As shown in the figures the modules are potted to reduce vibration induced noise and sidebands.

## MECHANICAL PACKAGING

Figures 10, 11 and 12 show various external views of the Cutty Sark Distribution System. As seen in Figure 12, the top view, high density packaging is necessary to provide the required functions in a single rack panel assembly. Since the unit dissipates 120 watts in the AC mode of operation, the subassemblies are heatsunk to the main chassis and air flow is provided by a high volume fan. Each module and subassembly is directly removable from the top without disturbing others. The modules have alarm override switches which enable the module to be turned off to conserve power when certain outputs are not needed and yet not create an alarm condition. A visual LED indicator on the top of each module indicates module failure. The three redundant input modules are seen in this Figure as are the two VCXO's and various amplifier boards. With the exception of the battery and time display circuitry, every module is redundant and switchover to a standby module is accomplished automatically. The entire chassis is of milled construction to meet the stringent naval shock and vibration requirements. The entire assembly weight 68 pounds.

## CONCLUSION

This paper describes the main features of the Cutty Sark Distributions System. The RF and timing distribution system are discussed and a detailed description of three unique functional blocks is presented. The mechanical package is photographically shown and the design of the auxiliary CU-2253/U 1 x 10 power splitter is described.

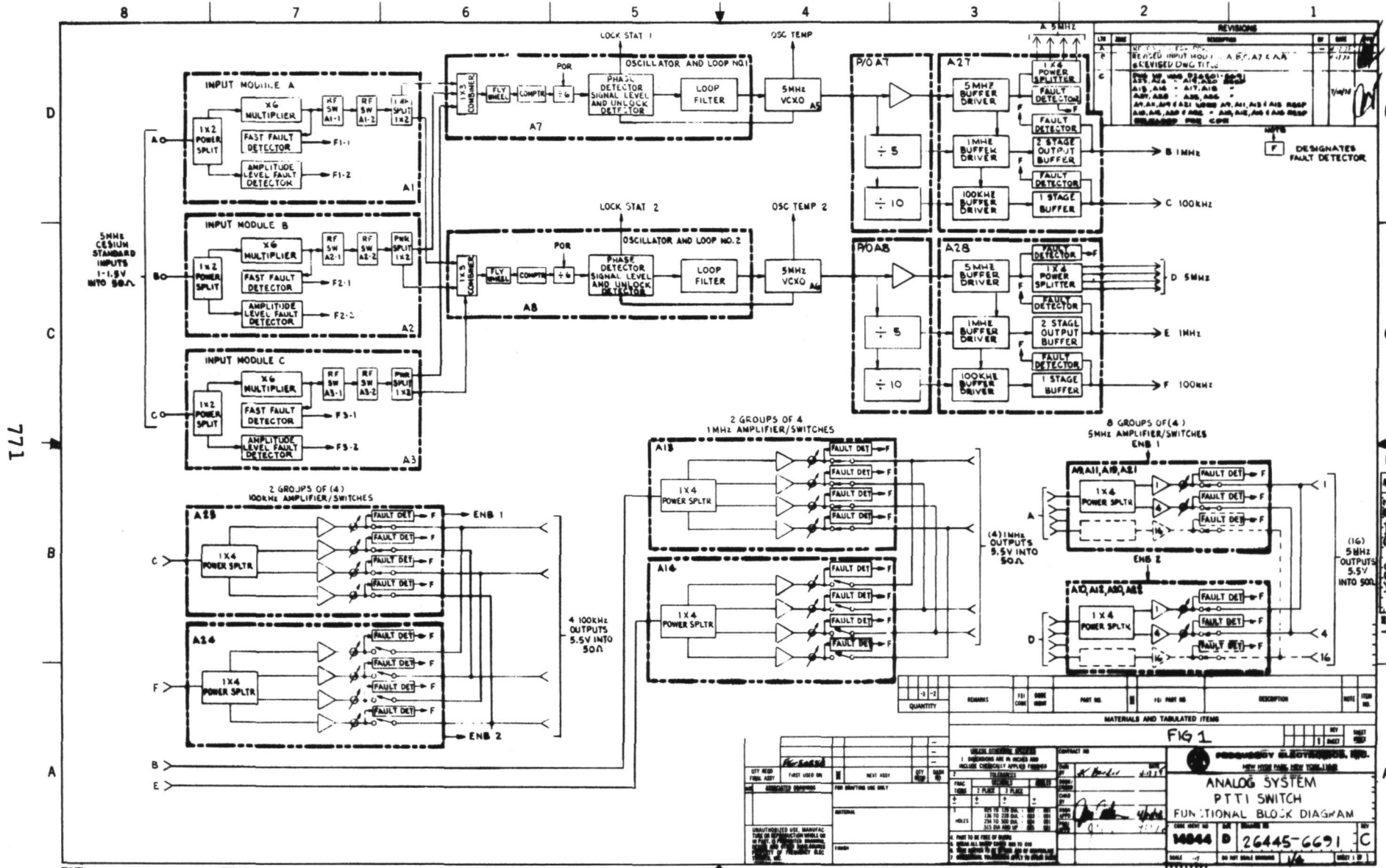


Figure 1. Analog System, Block Diagram

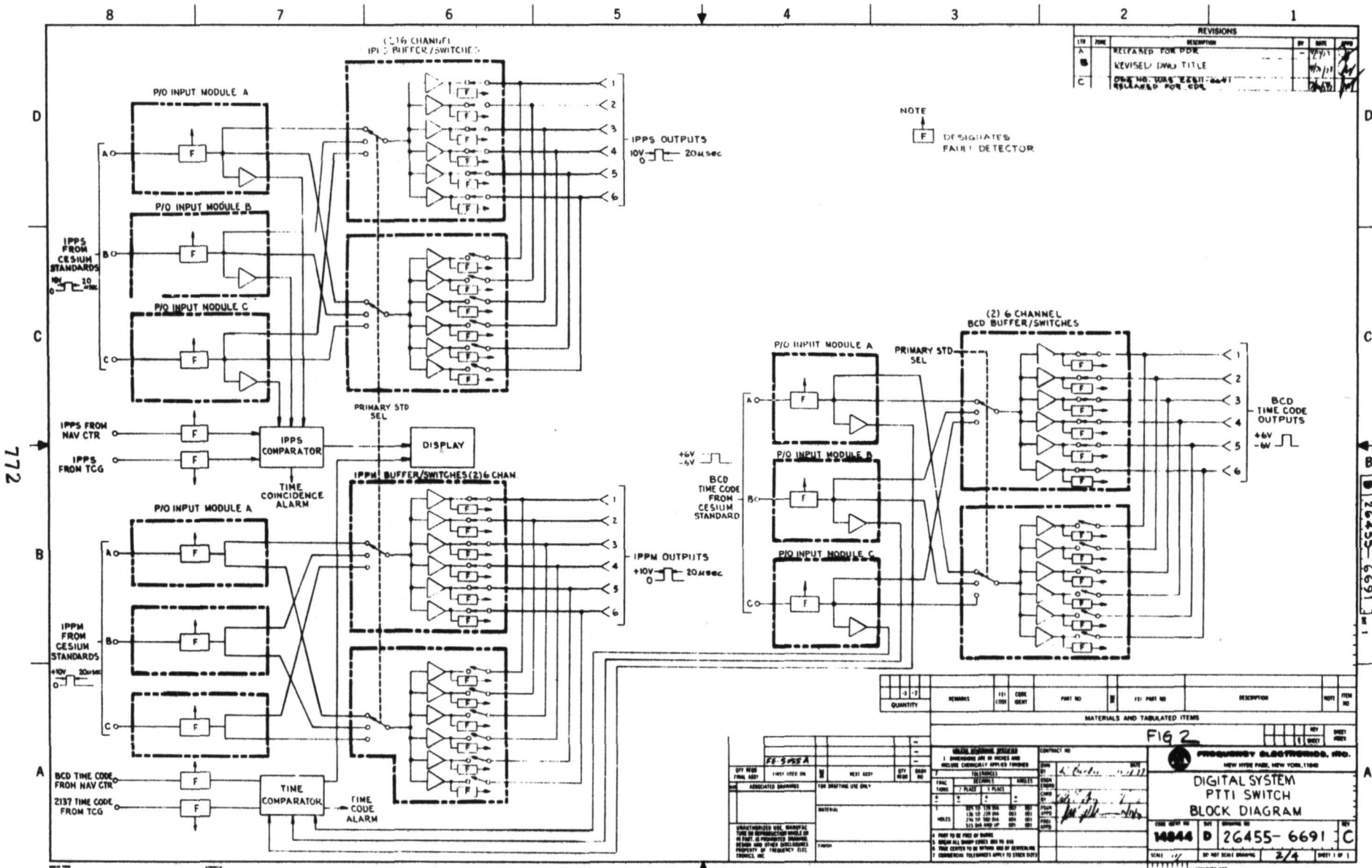


Figure 2. Digital System, Block Diagram (Sheet 1 of 3)



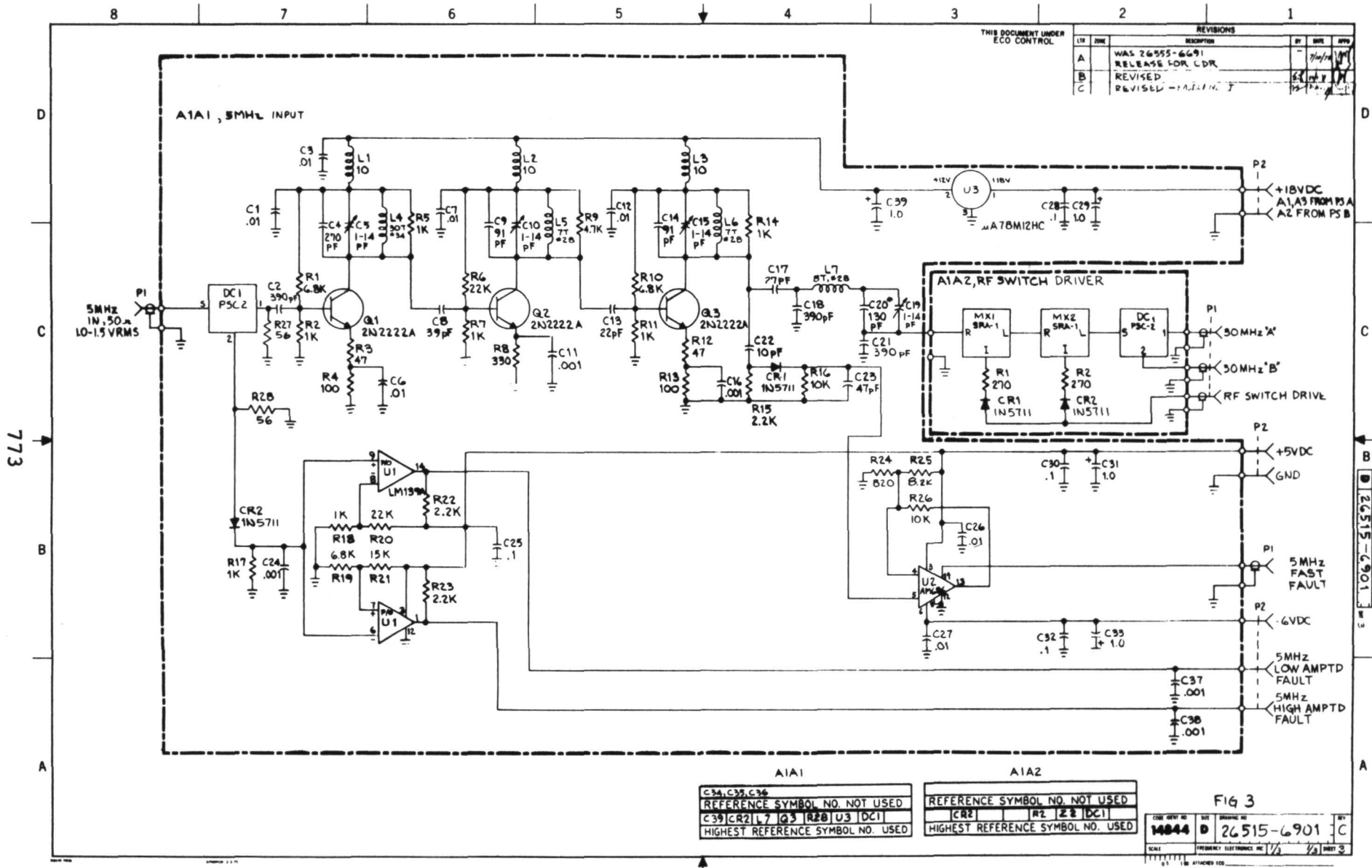


Figure 3. Digital System, Block Diagram (Sheet 2 of 3)

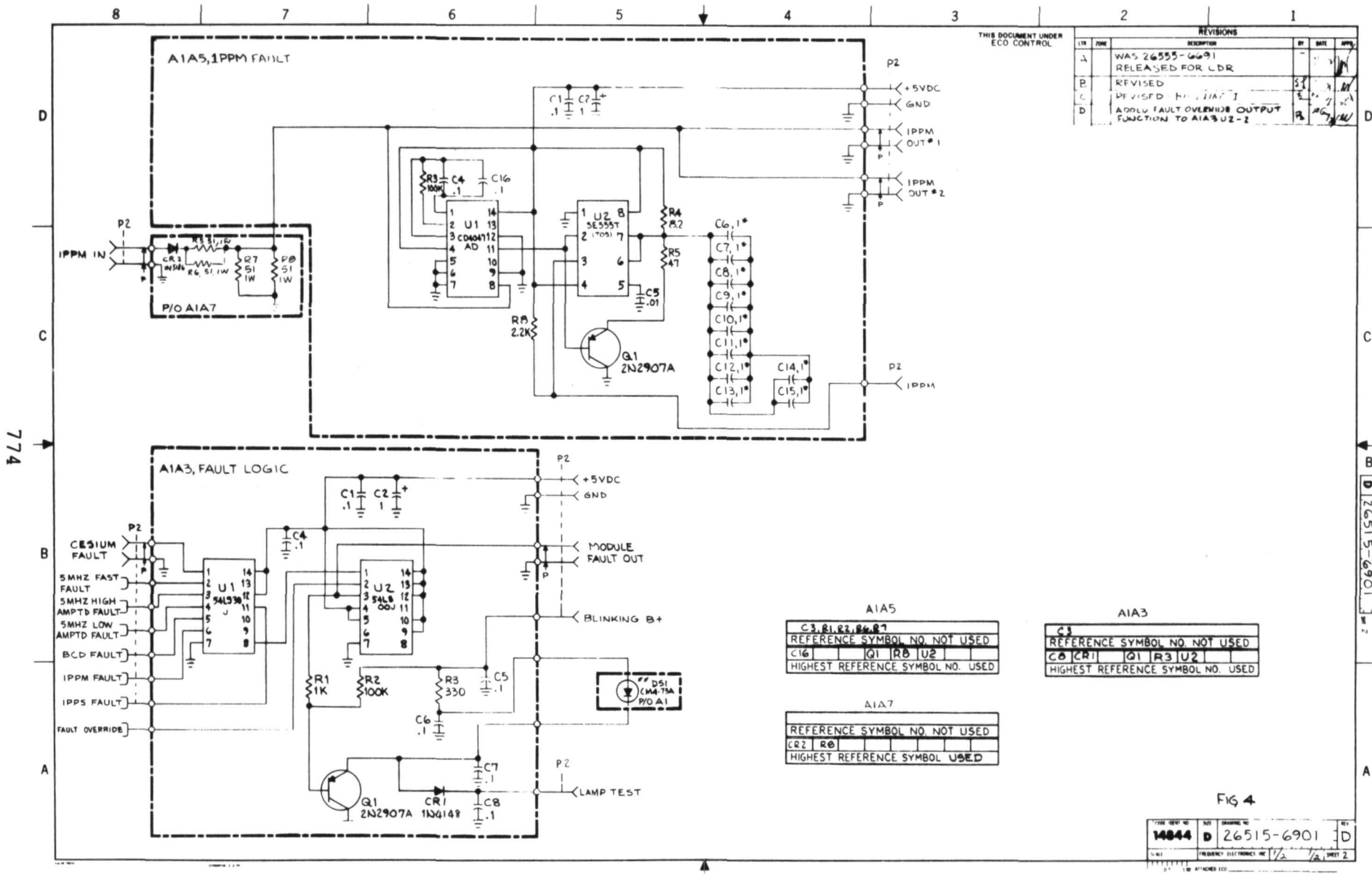


Figure 4. Digital System, Block Diagram (Sheet 3 of 3)

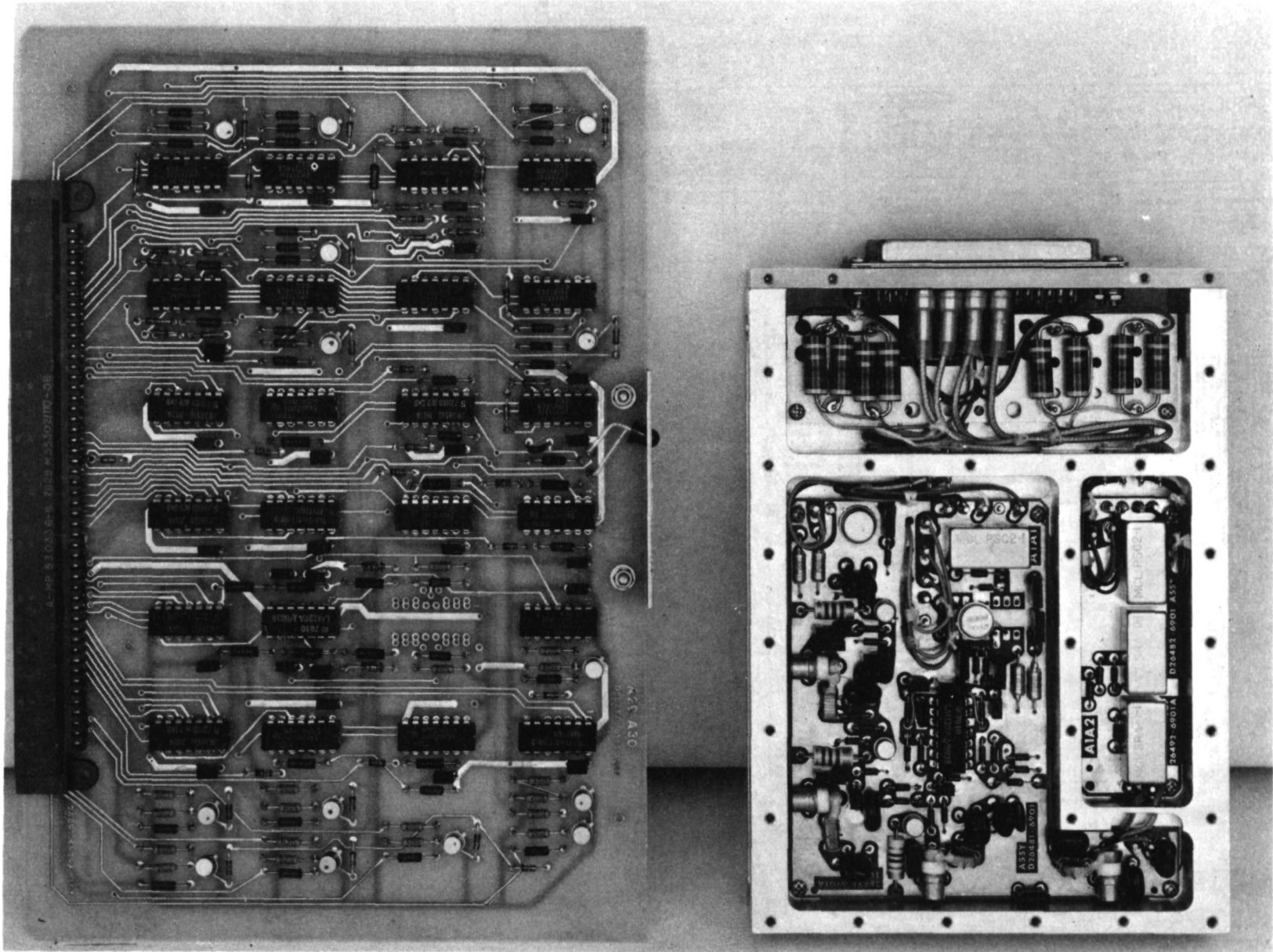
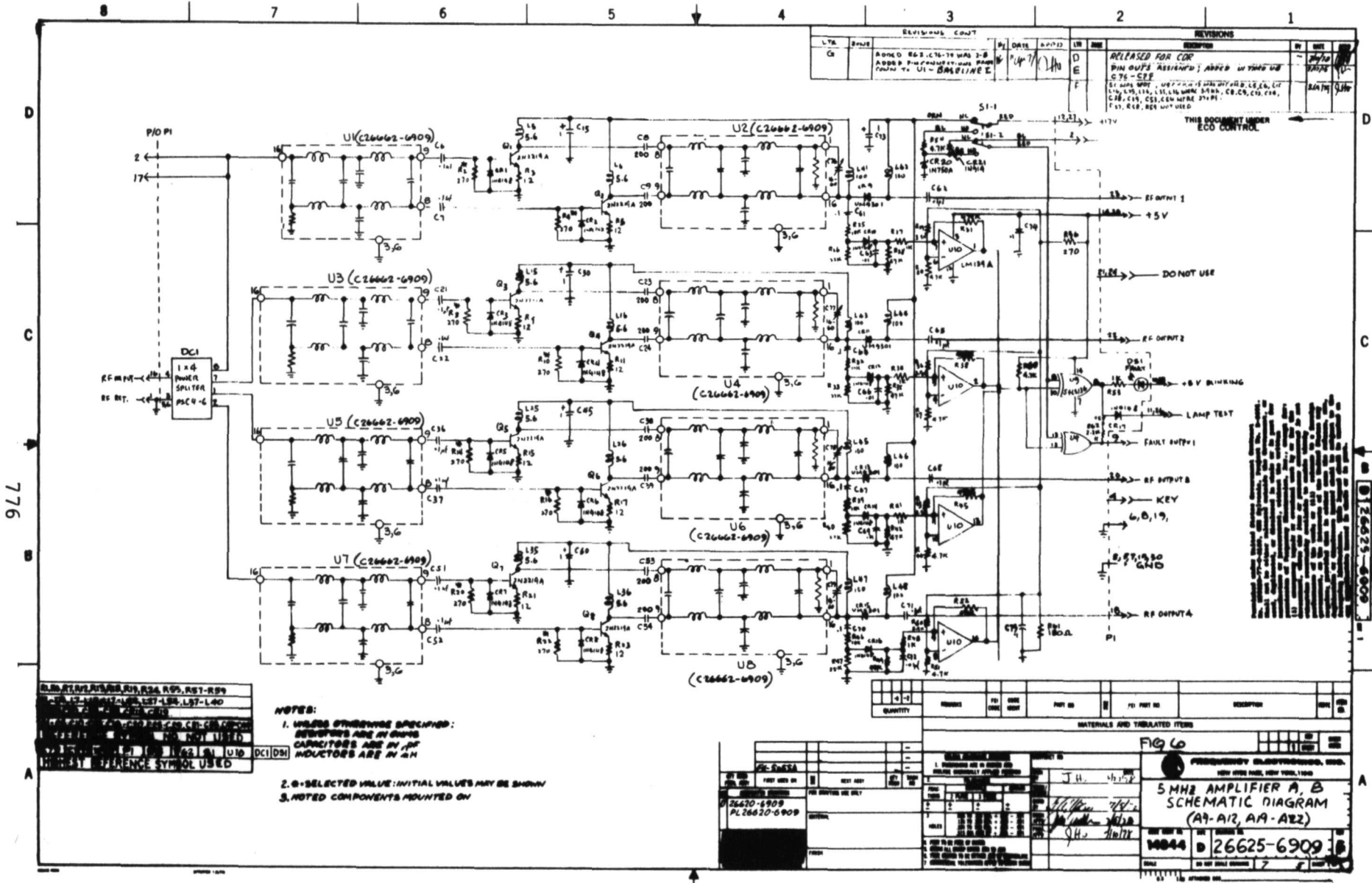


Figure 5. Input Module



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Figure 6. 5 MHz Amplifier, Schematic Diagram

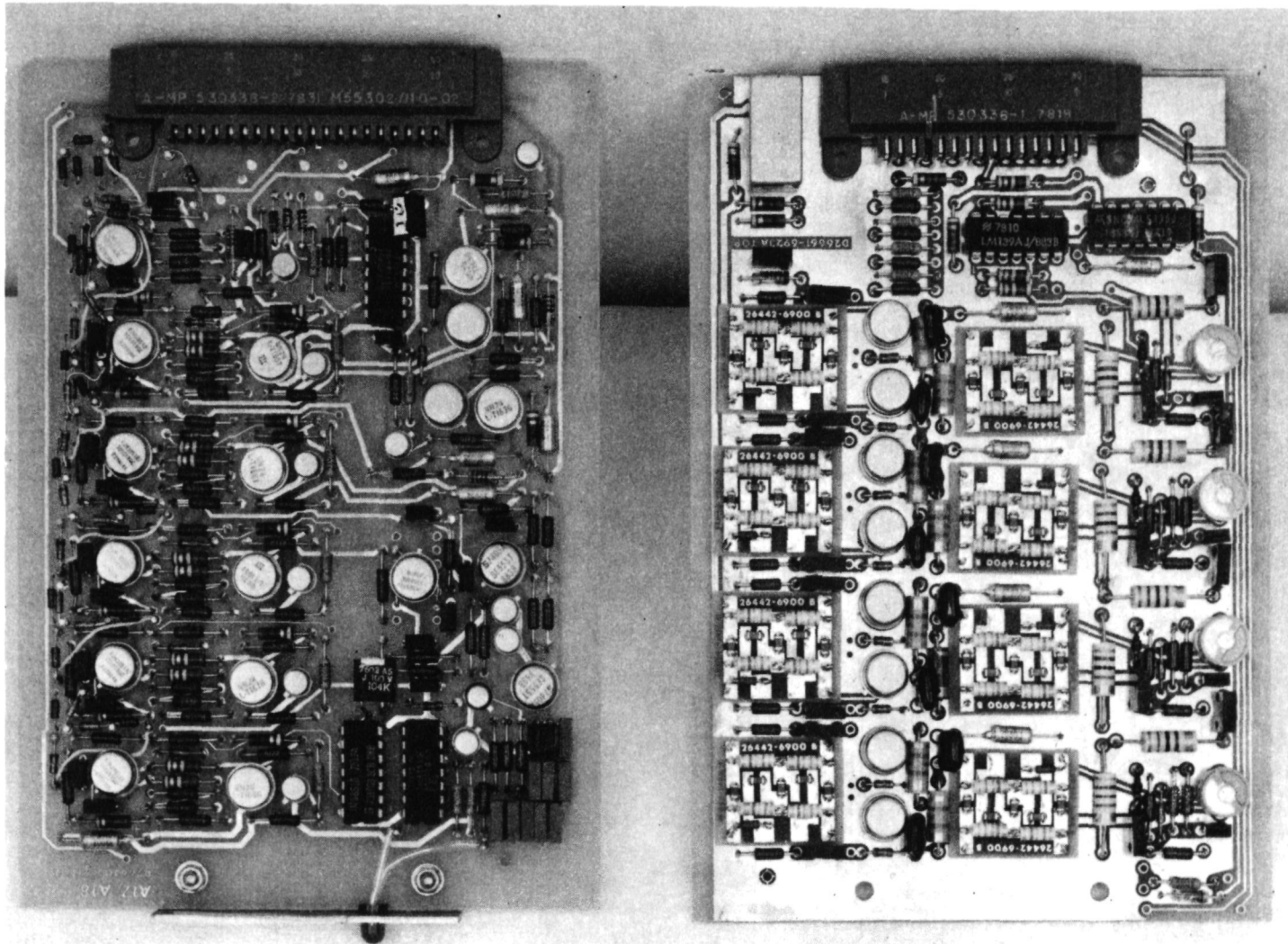


Figure 7. 5 MHz Amplifier

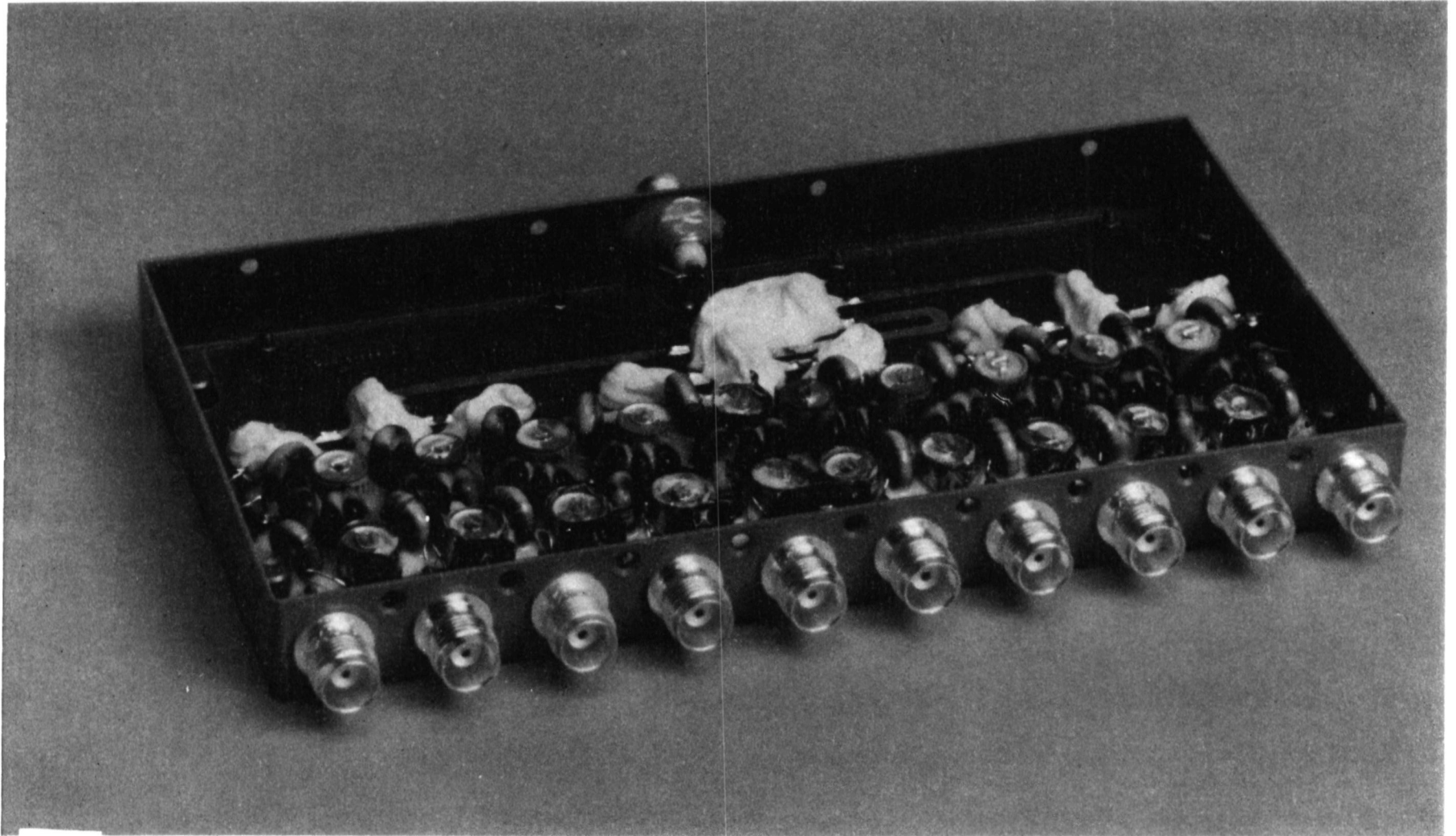


Figure 8. Power Splitter (1 X 10), Inside

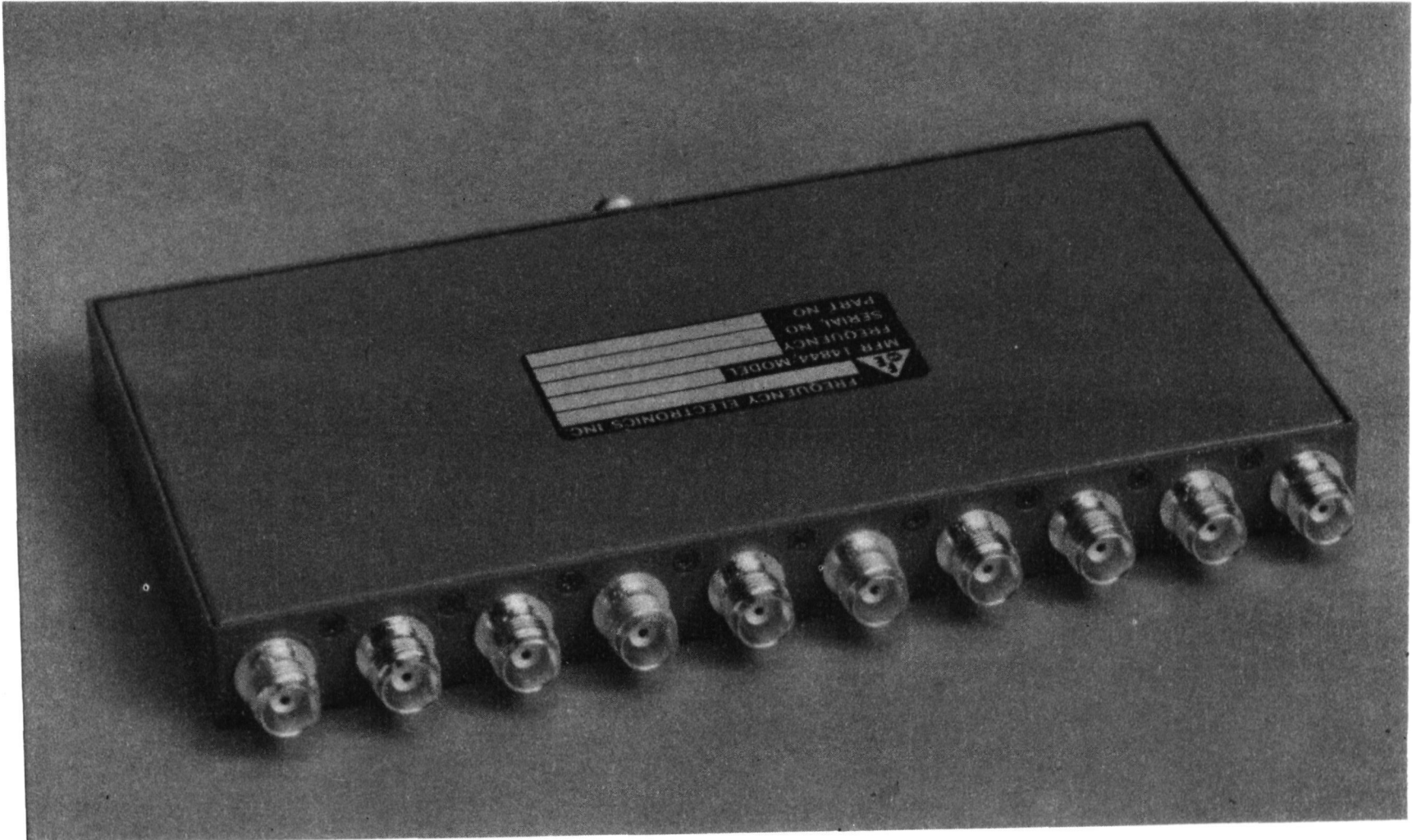


Figure 9. Power Splitter (1 X 10), Outside

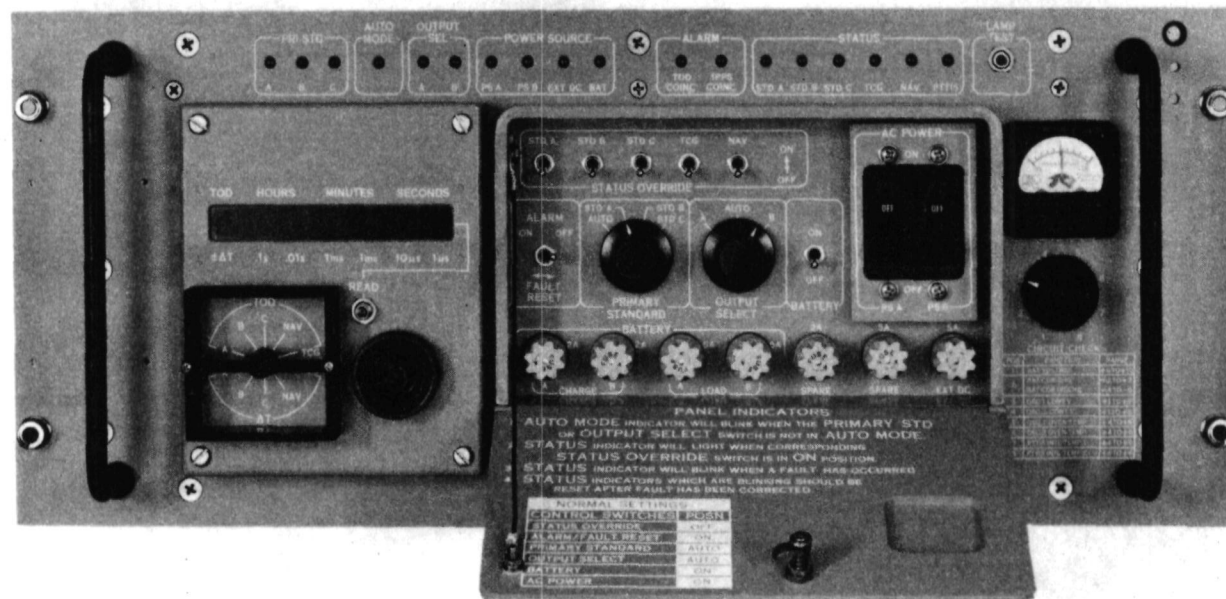


Figure 10. PTTI Switch, Front Door Open



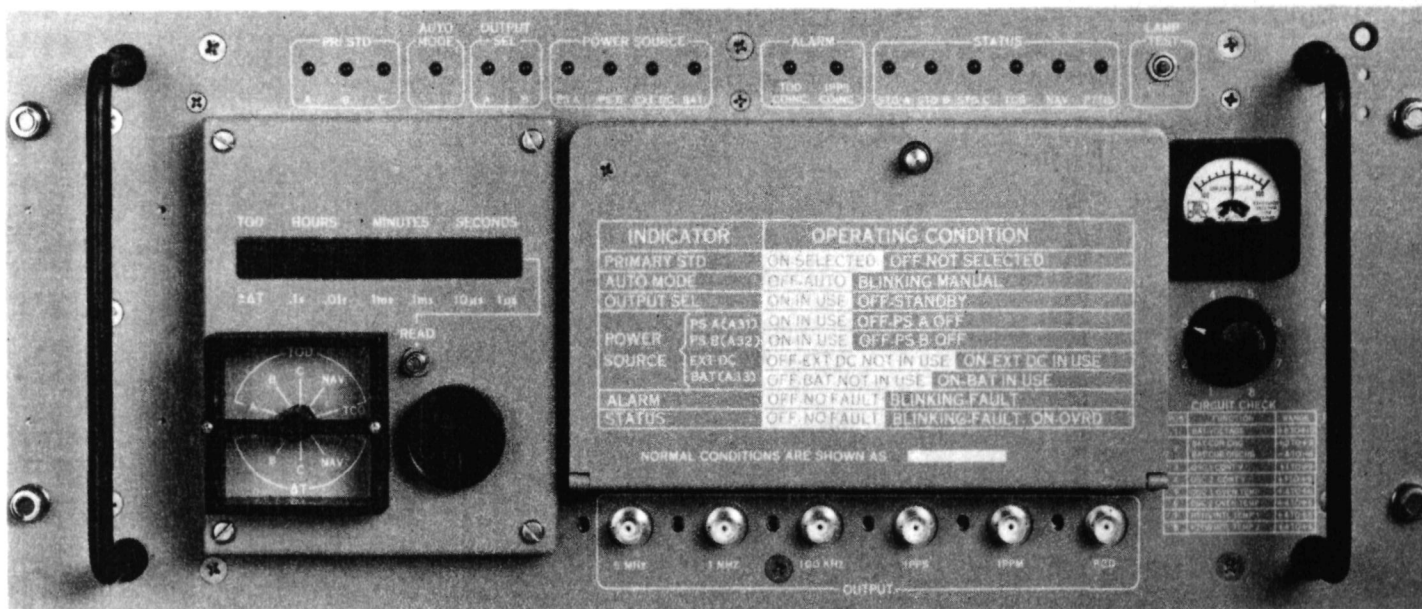


Figure 11. PTTI Switch, Front Door Closed

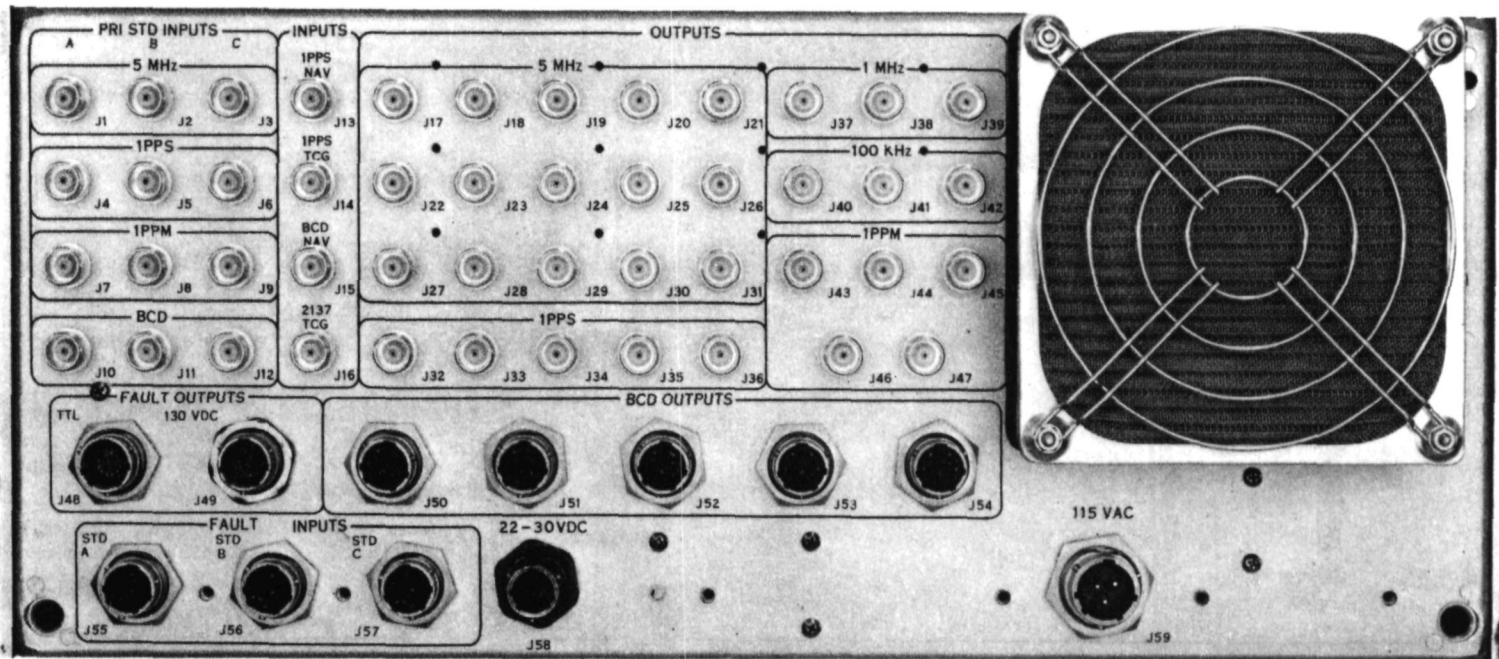


Figure 12. PTTI Switch, Rear View

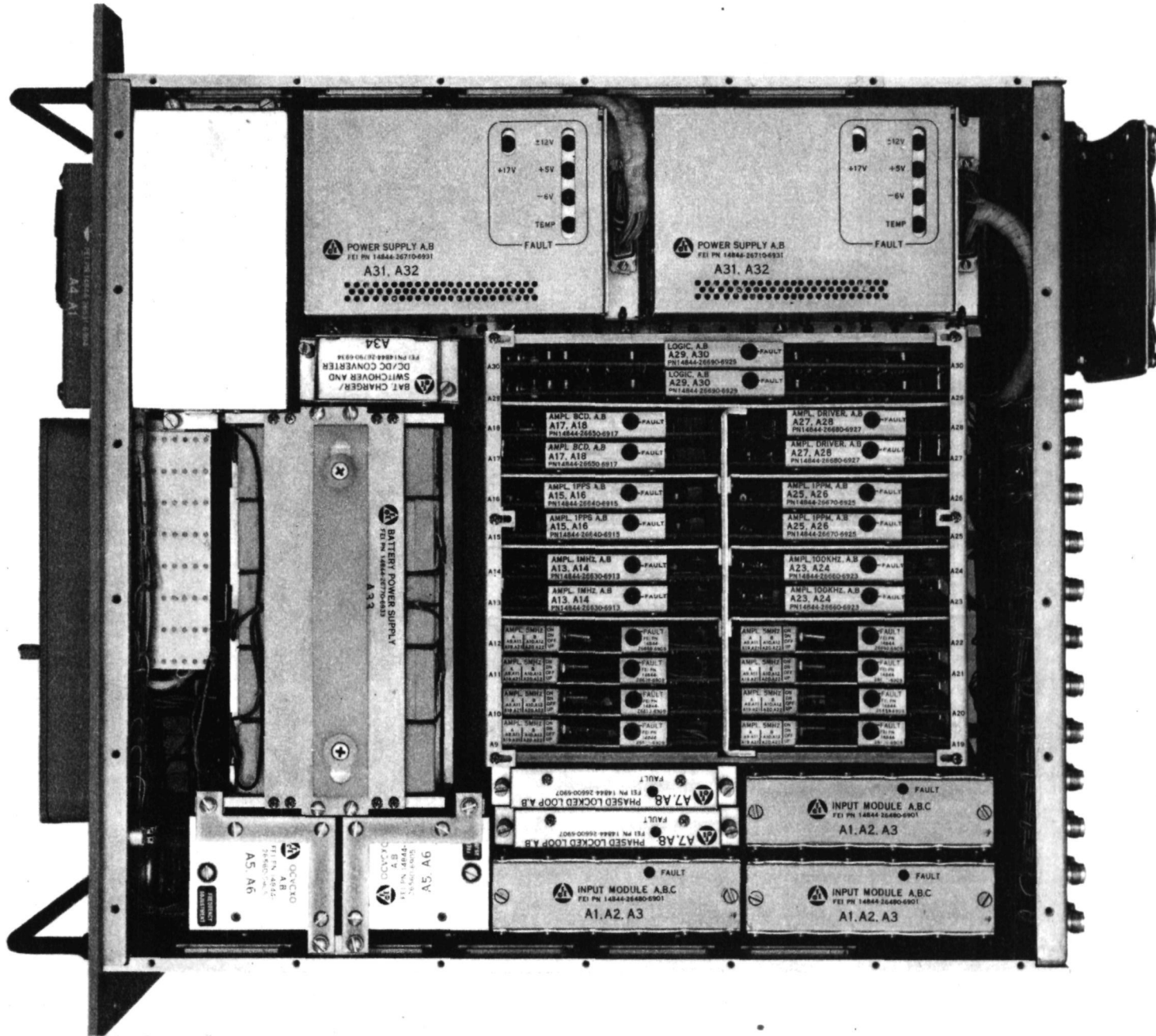


Figure 13. PTTI Switch, Top View