20-kW X-Band Uplink Transmitter Development

R. B. Kolbly
Radio Frequency and Microwave Subsystems Section

The 20-kW X-band transmitter Power Amplifier and its related control and monitor cabinet are described, along with the circuitry for the monitoring and protection of various transmitter components.

I. Introduction

A future requirement exists for a 20-kW X-band (7145-7235 MHz) uplink transmitter for utilization in the Deep Space Network (DSN). A developmental model is being designed and built for installation at DSS 13, where this transmitter will be evaluated for possible application in the Deep Space Network (Ref. 1). A major portion of any transmitter design is the system for protection, monitor and control of the various subsystems associated with the transmitter, the Power Amplifier (PA) Assembly and its related support equipment which is located in an adjacent rack. Also, the protective interlock logic and transducer conditioning circuits will be described.

II. Power Amplifier Assembly

Figures 1 and 2 show the actual PA Assembly that contains the klystron, focus magnet, filament circuit, and buffer amplifier units. A simplified schematic diagram is shown in Fig. 3. The PA Assembly is designed for maximum RF shielding. All electrical connections through the klystron compartment are filtered, and box joints are metal-to-metal for best shielding integrity. Three of the box sides are removable for ease of klystron removal. The fourth side of the PA Assembly serves as a mounting surface for the output waveguide assembly (consisting of the harmonic filter, arc detector, water load, switch and directional coupler) as well as a heat sink for the buffer amplifier. The cathode cooling air is routed over this plate and out the top of the power amplifier. All coolant connections for the klystron pass through the top of the PA on AN-type flare bulkhead fittings. This top plate is also removable for klystron replacement. The lower section is for the filament transformer, cathode blower, and associated circuits. The filament transformer divides the lower (cathode) compartment into two sections, one of which has all of the high-voltage connections. The other compartment has the filament control circuits and a card cage for interlock and monitor circuits. The filament transformer has both current and potential monitor windings for supplying operating conditions to the PA controller, These ac monitor signals are conditioned in the PA card cage to provide 0 - 5 volt dc analog signal, and the limit conditions are tested by the conditioning circuitry to provide the filament hardware interlocks. The filament circuit is started by a “step-start” circuit, with the final voltage set by an adjustable autotransformer in the filament primary circuit. After 5 minutes, the series resistor is switched out by a time-delay relay, applying full voltage to the klystron filament. After another 5 minutes, a second time delay relay provides a “filament ready” signal to the PA controller.

Protection for the beam operating conditions (beam overvoltage/current, excess body current, etc.) is provided by the power supply, so it is not necessary to provide beam or body current monitors in the PA Assembly. However, a local beam voltage and beam current monitor is provided for local diagnosis. A 50-millivolt shunt and 5000: 1 voltage divider are used for these local indicators.

III. Power Amplifier Monitor Control Rack

Figures 4, 5 and 6 illustrate the PA monitor-control rack that is mounted next to the PA in the feedcone. This rack contains the PA controller, magnet power supply, control monitor interface, buffer control chassis and power supplies.

The PA controller is mounted on tilt slides for ease of access to the system interconnect terminal strips. This controller is in a standard industrial chassis with the interface panels mounted on a separate chassis under the controller.

The control monitor interface contains the analog conditioning cards and the summing logic for the protective hardware interlocks. In addition, local indicators for the analog signals and interlock status annunciators are provided to assist in failure diagnosis.

IV. Flowmeter Signal Conditioning Circuit

The 20-kW X-band uplink transmitter will use turbine flowmeters to sense coolant flow in the various parts of the klystron, the magnet and water load. The turbine flowmeter is linear in output, highly accurate, and lends itself to remote readout. In addition, the turbine flowmeter has been used extensively in industrial applications, providing a high confidence in the reliability of these units.

The output signal from a turbine flowmeter is a low-level (approximately 1 to 10 millivolts) sine-wave ac signal ranging from 100 to 2500 Hz. This signal must be converted to a 0 - 5 volt dc signal with a hardware underflow interlock signal. The frequency of the ac signal is proportional to the flow, so a tachometer circuit is required. A commercial linear integrated circuit (National Semiconductor LM2907) is well-suited for this application, The LM2907 has provision for sensing low-flow, so it is only necessary to add an output buffer amplifier and an interlock isolator. Figure 7 is a schematic diagram of this flowmeter conditioning circuit; U1 is the LM2907, with the associated discrete components to set the operating conditions, and U2 is an optical isolator to provide isolation from the interlock circuits and to reduce ground current noise. A light-emitting diode (CRI) provides a local indication of low-flow condition. The simplicity of this circuit allows eight of these circuits to be built on a standard wirewrap card.

V. Protective Logic Circuit

The protective logic circuit presently consists of 16 latched and two unlatched inputs which are logically summed into one output to enable the transmitter to operate. The latched inputs will detect and hold a momentary failure so that operators can determine the cause of transmitter tripoffs (e.g., momentary loss of flow). No provision is made for the bypassing of interlocks. The controller is provided with the status of the latched channels, and this information is also displayed on the control monitor panel.

The protective logic circuit (sometimes referred to as the "summing logic") uses complementary metal-oxidesilicon (CMOS) integrated circuits for high noise immunity and a 15-volt logic true (safe or run condition). The 15-volt level was chosen over the more common 5-volt logic level for noise immunity.

Acknowledgements

The design of the flowmeter signal conditioning circuit was done by John Daeges of Section 333. Al Bhanji designed the protective logic circuitry.

Reference

1. Hartop, R., Johns, C., and Kolbly, R., "X-Band Uplink Ground Systems Development," in The *Deep Space Network Progress Report 42-56*, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1980, pp. 48-58.

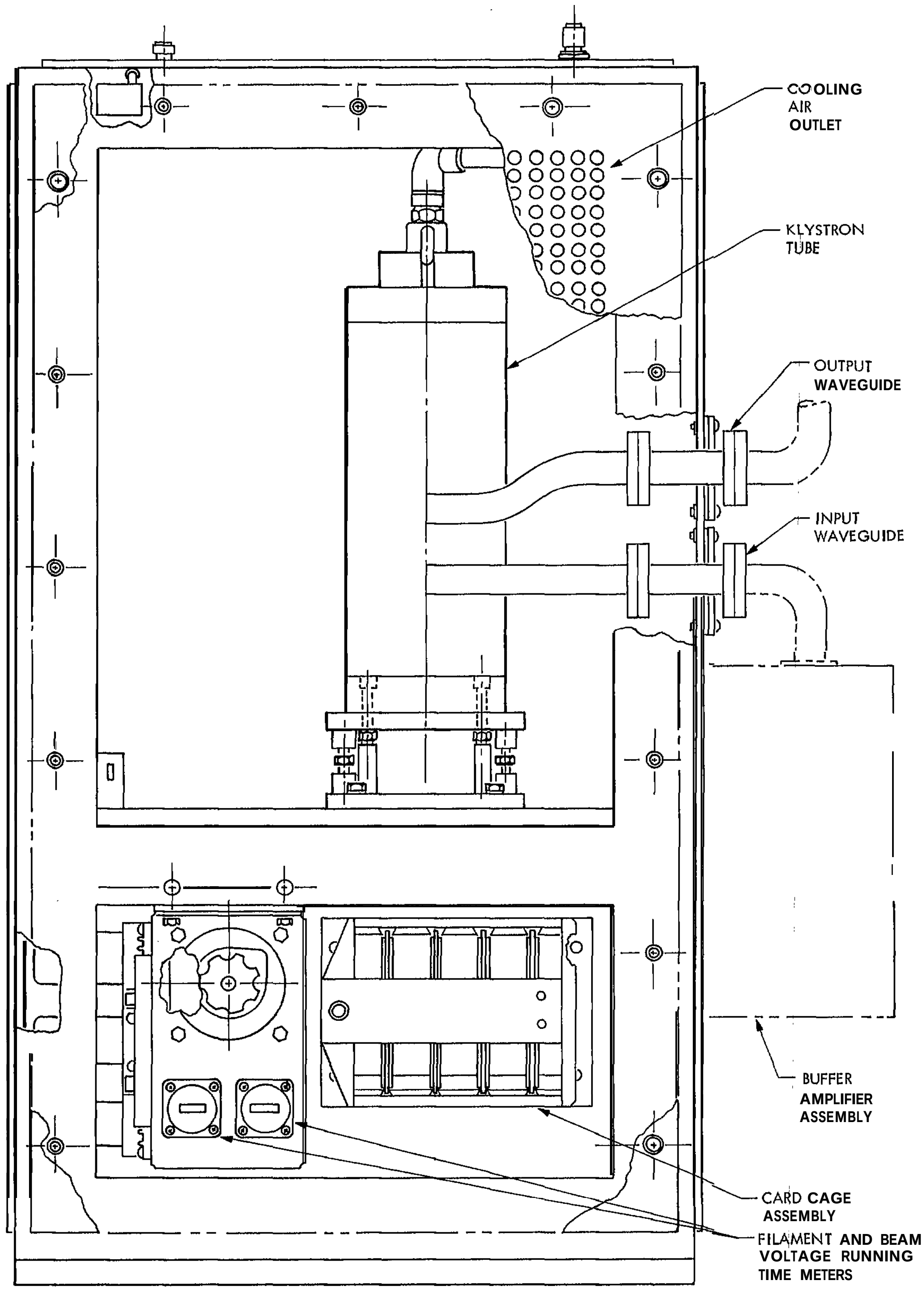

Fig. 1. Power Amplifier Assembly (front)

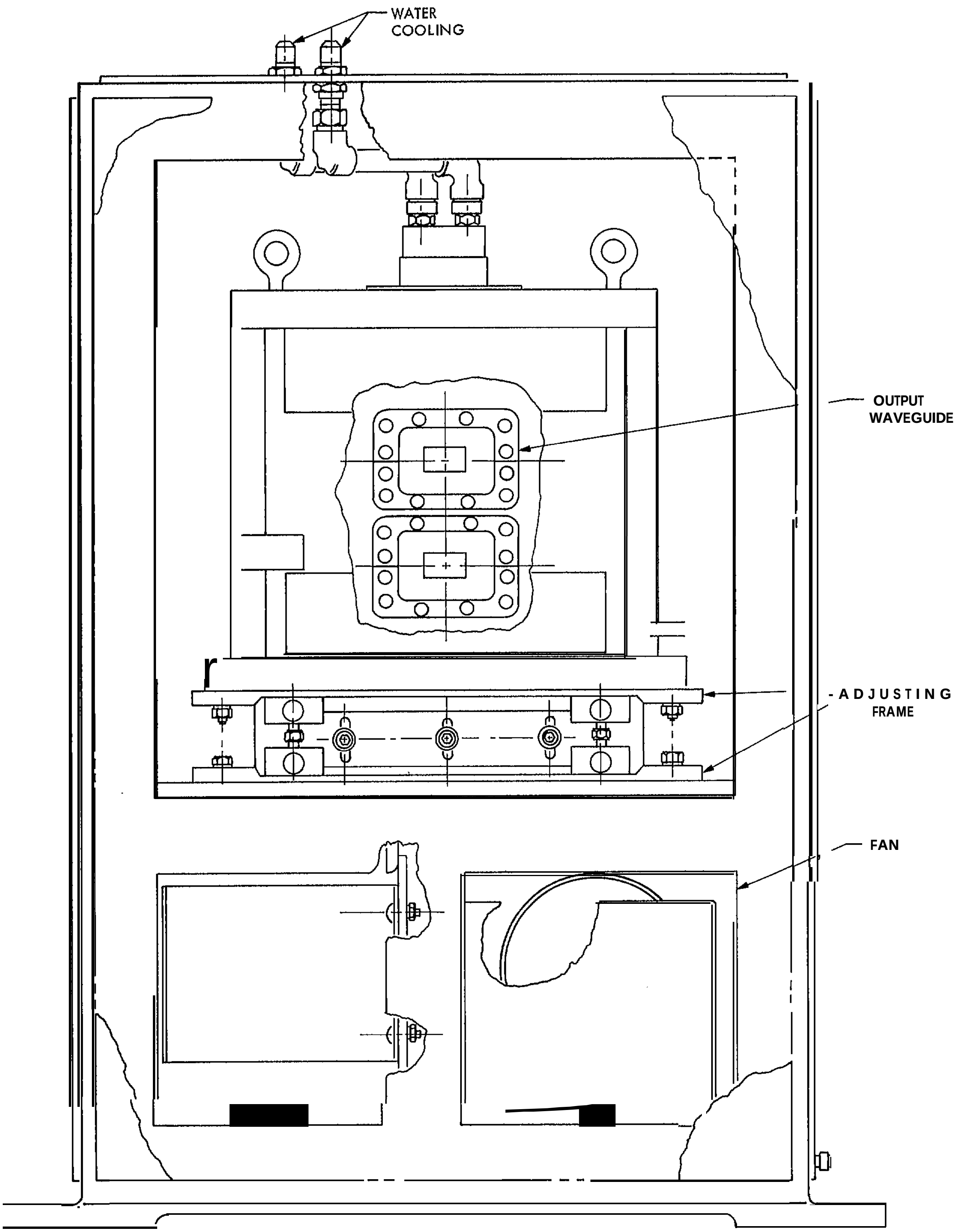

Fig. 2. Power Amplifier Assembly (side)

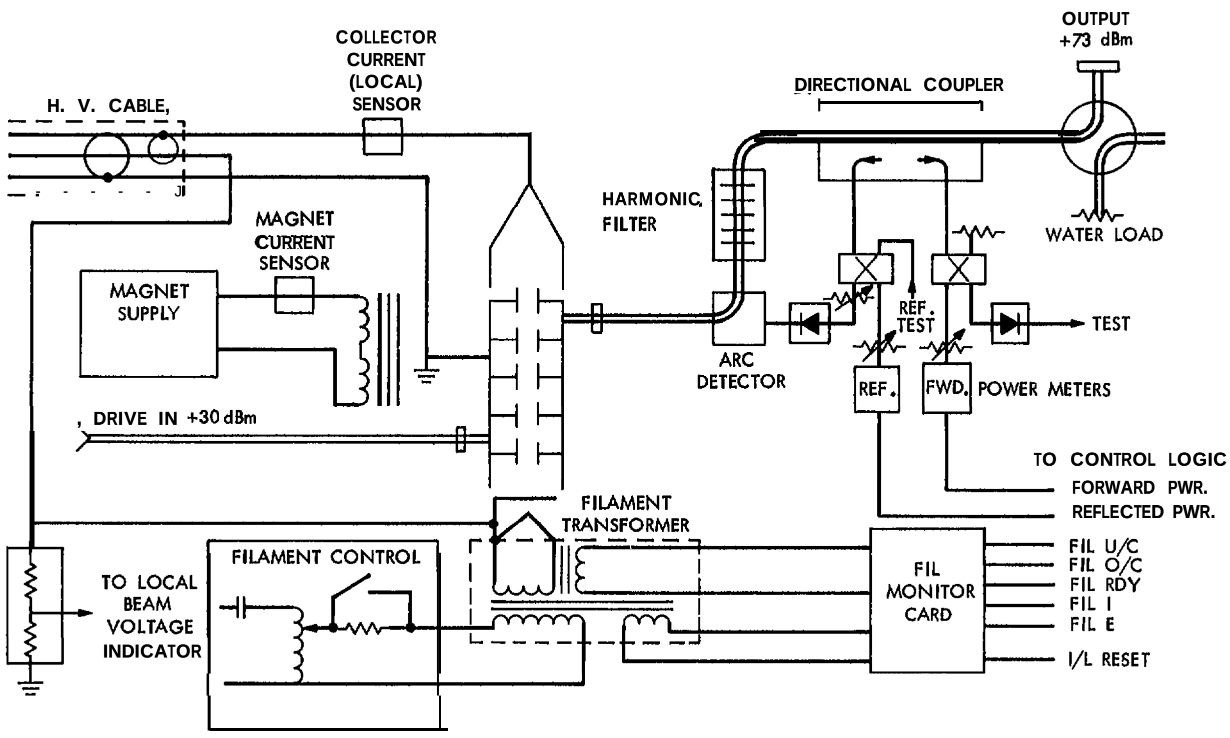

Fig. 3. Power Amplifier Assembly schematic

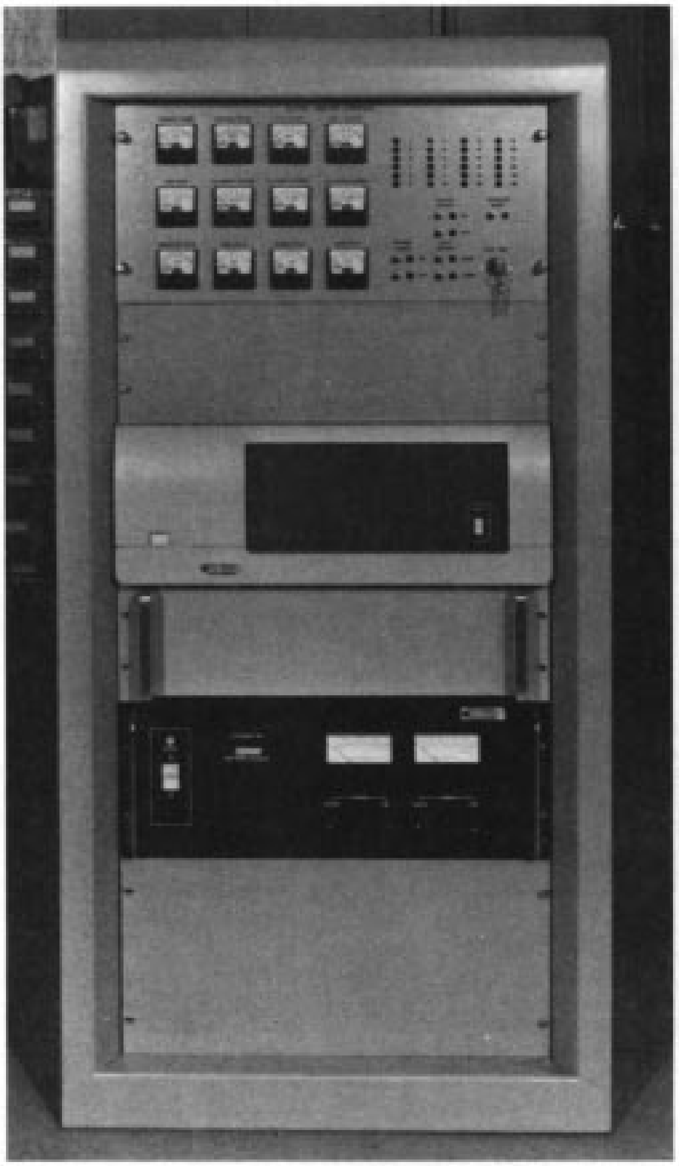

Fig. 4. PA monitor/control rack

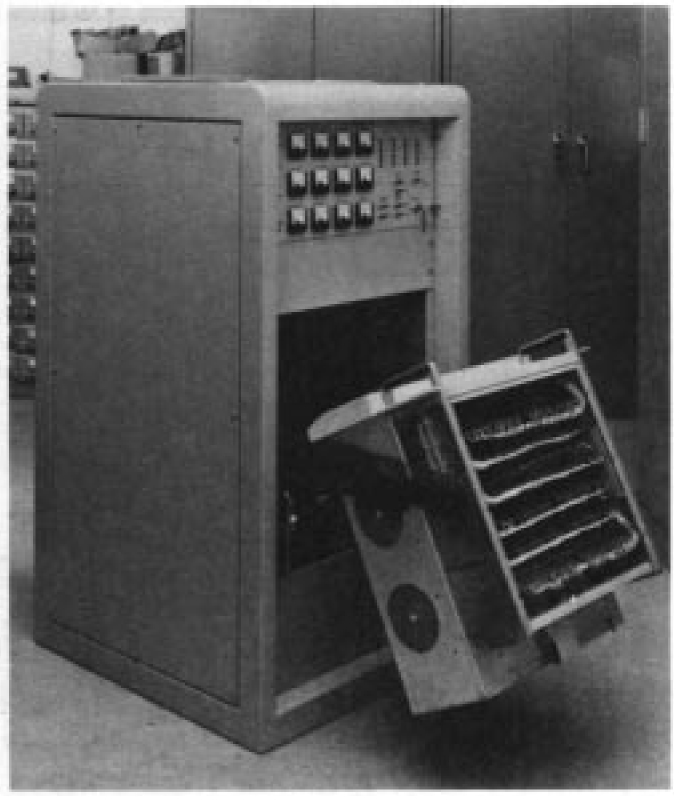

Fig. 5. PA monitor/control rack with controller extended

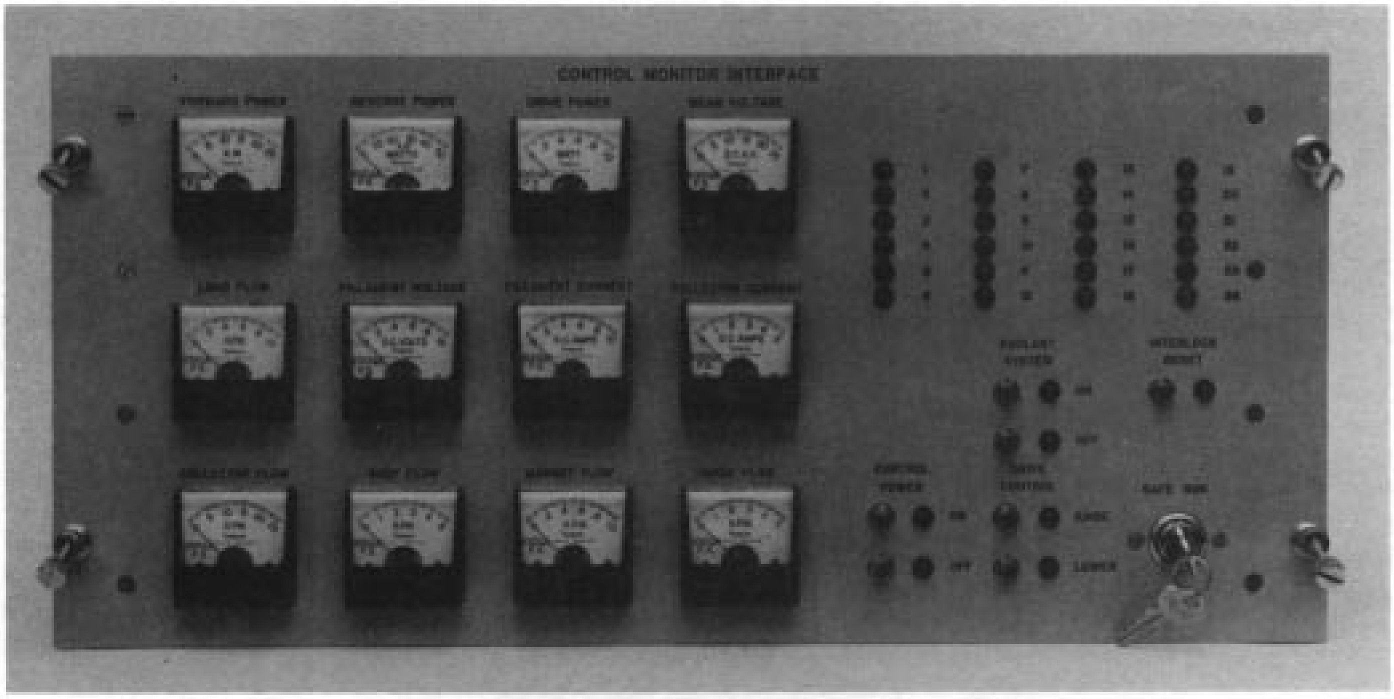

Fig. 6. Monitor/control interface

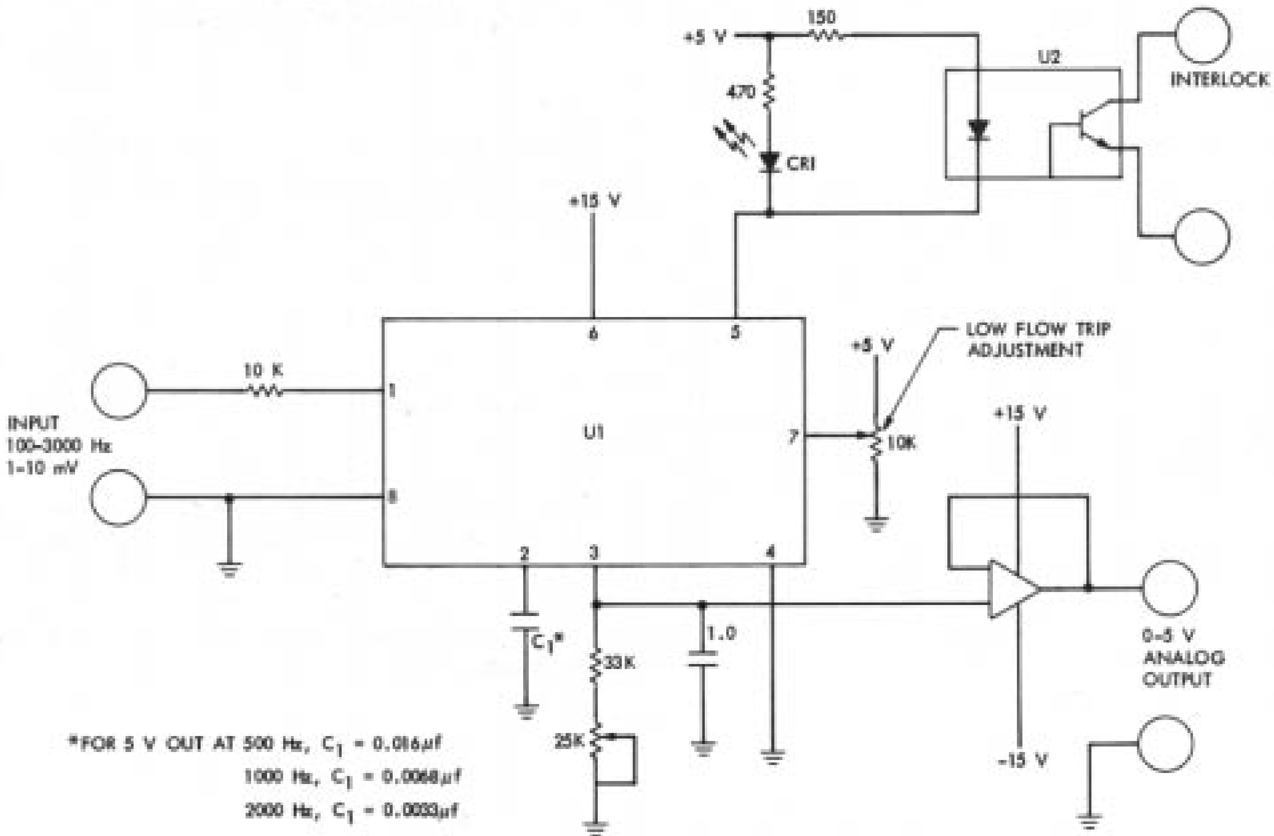

Fig. 7. Flowmeter conditioning circuit