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A LIQUID-NITROGEN MONITOR FOR LITHIUM-DRIFTED GERMANIUM DETECTORS

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SYNOPSIS

An instrument has been developed that makes use of a load cell to monitor the liquid nitrogen in the Dewar flask of a lithium-drifted germanium detector. The contents are recorded on a chart recorder, and an alarm is sounded when the previously set content has been reached. A signal switches off the high-voltage power supply 30 minutes after the alarm is triggered.

The calibration of the load-cell monitor is described in an appendix.

SAMEVATTING

Daar is 'n instrument ontwikkel wat van 'n lassel gebruik maak om die vloeibare stikstof in die Dewar-fles van 'n Ge(Li)-detektor te moniteer. Die inhoud word op 'n kaartregistreerder geregistreer en 'n alarm word aangeskakel wanneer die inhoud 'n voorafbepaalde peil bereik. 'n Sein skakel die hoogspanningskragtoevoer 30 minute nadat die alarm gesneller is, af.

Die kalibrering van die lasselmonitor word in 'n aanhangsel beskryf.

CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

Lithium-drifted germanium (GeLi) detectors used in gamma-ray spectroscopy are expensive and must be maintained at liquid-nitrogen temperature at all times to prevent the lithium drifting out of the germanium crystal. It is therefore imperative that the supply of liquid nitrogen in the Dewar flask of the instrument should be monitored.

2. EXISTING MONITORS

The most commonly used monitor has a temperature sensor mounted on a stick that is immersed in the liquid nitrogen at a certain depth. When the liquid nitrogen has boiled off below this set level, an alarm is triggered. This method has several disadvantages. For the liquid nitrogen to be replenished, the measuring stick must be removed from the Dewar flask containing the liquid nitrogen and exposed to the air. As a result, the ice that forms on the surface of the stick is introduced into the flask when the stick is replaced. Furthermore, icing-up of the sensor may occur, which results in inaccurate sensing.

A very simple, but rather crude, method employs a bathroom scale to weigh the total mass of the detector. The main disadvantage of this method is that the detector is subject to movement of the scale caused by boiling-off of the liquid nitrogen, and there is a change in the geometry when a sample is counted.

3. THE LOAD-CELL MONITOR

The problems discussed in Section 2 are eliminated when a load cell is used.

As load cells have no moving parts, the detector is stationary, and, as the sensing device is applied externally to the Dewar flask, no problems are experienced due to icing-up of the measuring stick or increased rate of boiling-off of the nitrogen.

The contents of the Dewar flask can be monitored by a chart recorder or moving-coil meter. A chart recorder has the advantage that any deterioration of the vacuum in the Dewar flask due to increased rate of boiling-off of the liquid nitrogen can be observed, and corrective action can be taken in good time.

3.1. Status Indicators

The monitor is equipped with the following additional indicators.

a. A green lamp indicates a safe condition.

b. A yellow lamp gives warning that the set level (i.e., 20 per cent of the total liquid nitrogen in the flask) has been reached.

c. A red lamp indicates that the high-voltage power supply has been switched off.

d. An audio alarm is activated when 3 to 5 per cent of the liquid nitrogen has boiled off. When the set level has been reached, the yellow lamp is lit.

e. A timer starts when the alarm is triggered and switches off the high-voltage power supply to the detector 30 minutes later. (The 30-minute delay permits the user to finish the experiment and to refill the detector with liquid nitrogen.)

3.2. The Instrument

The load cell to monitor the mass of the detector is mounted under the wooden platform supporting the detector (see Figure 1). The platform is held in position by two knife-edge hinges, the third supporting point being the load cell.

The load cell (type LM 20 KA made by Kyowa) that is used in this instrument has a sensitivity of approximately 0,965 mV/V. The input voltage to the cell is 5 V direct current and the maximum loading 20 kg. The offset to be compensated for under no load was found to be 1,3 mV/V.

In this application, the instrument is required to offset a mass of 14 kg and to indicate a change of 2 kg. The voltage output of the load cell at 14 kg is given by

$$0{,}965\ \text{mV}/20\ \text{kg} \times 5\ \text{V} \times 14\ \text{kg} + 5\ \text{V} \times 1{,}3\ \text{mV} = 9{,}88\ \text{mV}.$$

The maximum signal to be amplified is given by

$$0{,}965\ \text{mV}/20\ \text{kg} \times 5\ \text{V} \times 2\ \text{kg} = 0{,}482\ \text{mV}.$$

As can be seen from these calculations, the overall voltage input to the amplifier is relatively low compared with the offset resulting from the imbalance of the bridge of the cell and the dead mass of the detector. For this reason, the offset–zero adjustment is introduced at the supply circuit of the load cell (see Figure 2), thus eliminating unnecessary amplification of any unwanted voltage and enhancing the overall stability of the circuit.

The output of the load cell is fed into an operational amplifier, type mono-OP-07, of Precision Monolithics Incorporated, which has a long-term stability of 0.2 μV per month.

The gain of the amplifier is calculated to yield an output varying between 0 and 10 mV, which is suitable to feed a potentiometric chart recorder. The same signal is also fed into a discriminator–integrator amplifier. The potentiometer P3 (see Figure 2) is used for adjustment of the set level. Once the set level has been reached, the yellow warning-light will start to glow, and, when the output reaches approximately 7.5 V, the Schmitt trigger inverter is activated, causing the flip–flop to change status. The green light then switches off and the alarm sounds.

Simultaneously, when the output of the Schmitt trigger inverter changes, a timer is started and after 30 minutes energizes the relay Re_1 and the red warning-light so that the high-voltage power supply of the detector is switched off.

The calibration of the instrument is described in the Appendix.

3.3. Multiple Detectors

For the simultaneous monitoring of four detectors, four identical circuits are built into one instrument (see Figures 3 and 4), and these outputs are recorded on a six-channel chart recorder. The fifth channel is used to record the setting of the level and the sixth channel to record the zero setting of the recorder.

3.4. Reproducibility of Operation

The yellow warning-light is activated when 20 per cent of the total liquid nitrogen (the set level) remains in the Dewar flask. Therefore, when the alarm is sounded, sufficient time is available for a new supply of liquid nitrogen to be obtained.

The stability and reproducibility of the measurements were tested at room temperature (15 to 25 °C) and showed a deviation of less than 1 per cent.

4. CONCLUSION

The load-cell system for monitoring the liquid-nitrogen content of the Dewar container of four GeLi detectors has performed satisfactorily for more than a month.

5. BIBLIOGRAPHY

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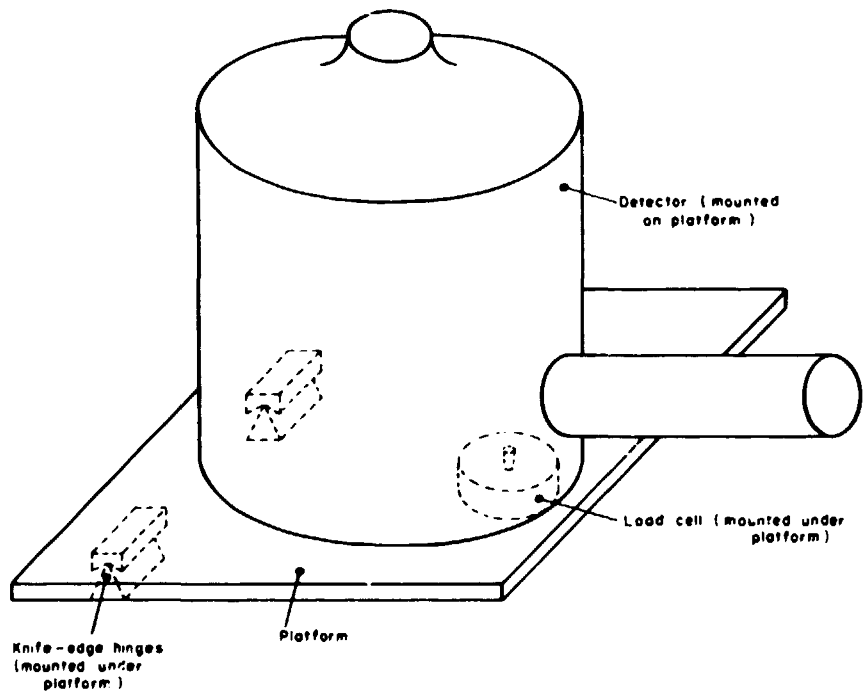


FIGURE 1. The mounting of the detector

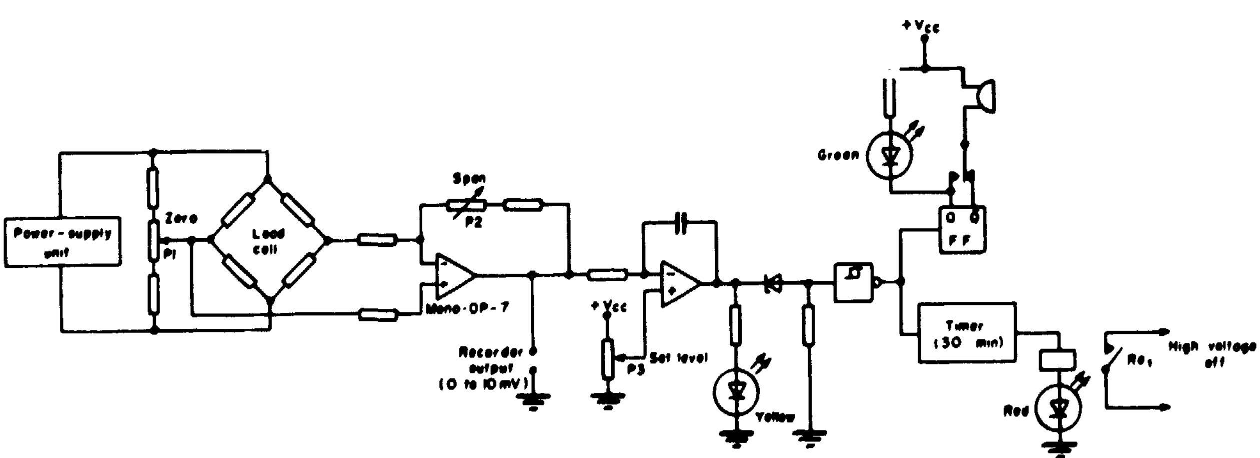


FIGURE 2. Block diagram of the load-cell monitor

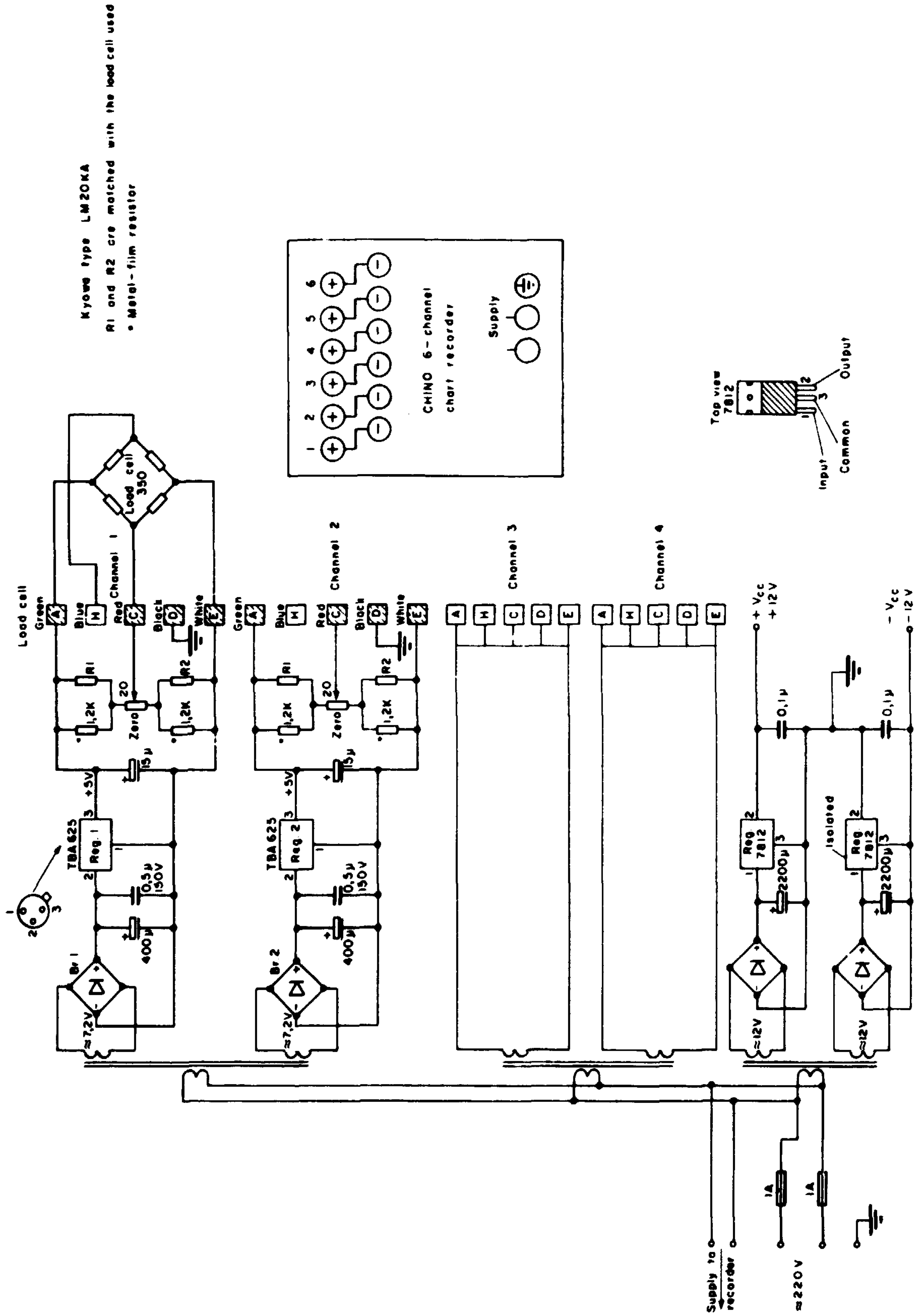
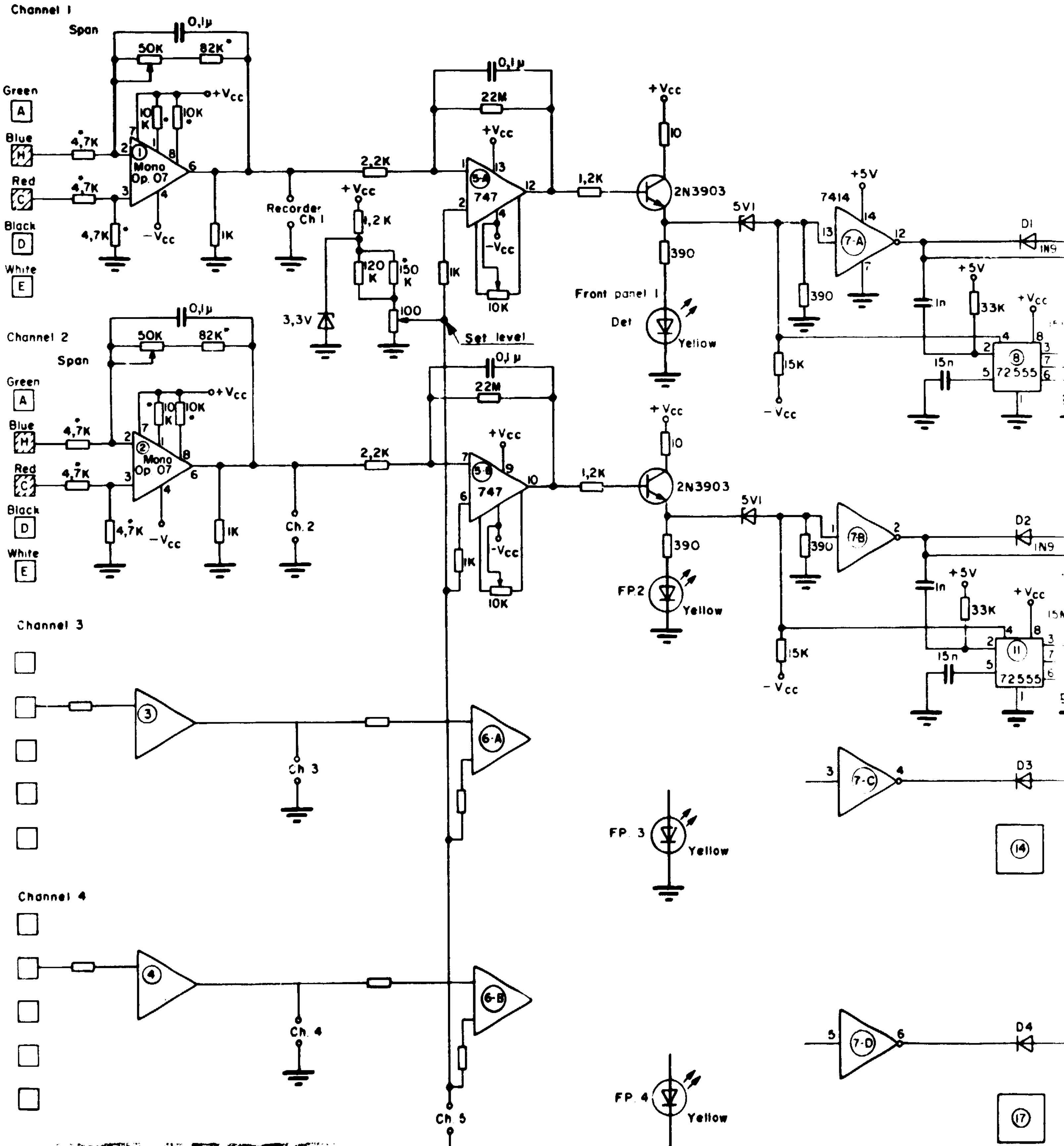
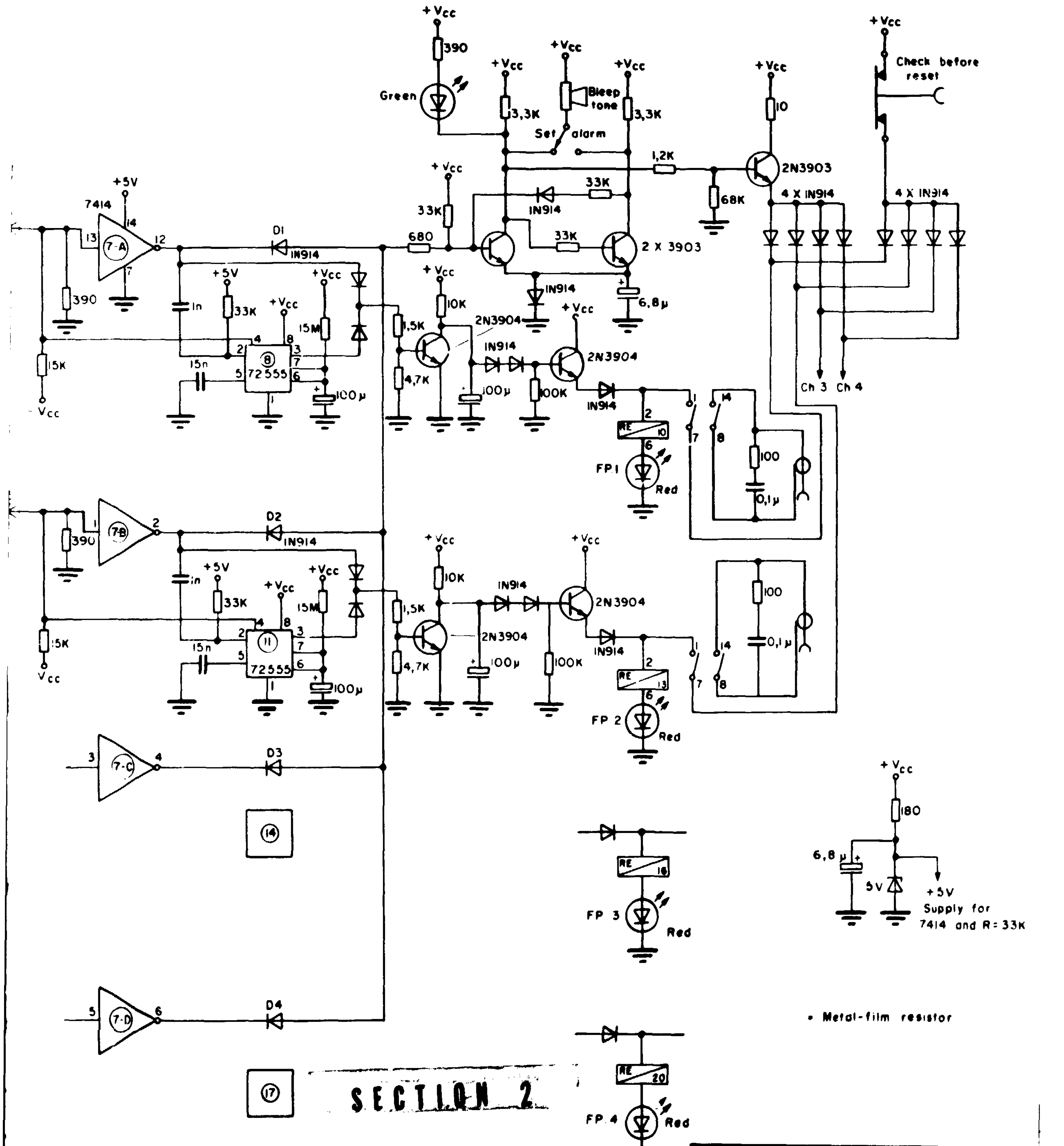


FIGURE 3. Circuit diagram for the power supply of the monitor



SECTION 1

FIGURE 4. Circuit diagram of the amplifier and



SECTION 2

FIGURE 4. Circuit diagram of the amplifier and logic