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Summary

A pulsed power supply has been developed which is suitable for powering electroluminescent lamps at frequencies up to 5 kHz. A distribution system for driving 90 or more lamps simultaneously and a programmed data-lamp array utilizing this power supply are also described.

Introduction

High-energy physics experiments employing spark chambers, frequently use fiducial lights of some type to provide positional and event data on film or vidicon readout system. One recent experiment at the Lawrence Radiation Laboratory in Berkeley employed about 90 electroluminescent (EL) lamps. In the past, incandescent, fluorescent, and Xenon flash lamps have all been used in various combinations to provide fiducial marks. The EL lamp system offers the advantages of light weight, flexibility, and insensitivity to magnetic fields. Typical energy output of the pulse burst generator developed to power the EL lamps is 0.5 joule per pulse. During a beam spill, the supply provides 1 kW to the EL panels. The power supply described here is adequate for 10 ft^2 of EL material (90 panels of the chosen size).

EL Power-Supply Requirements

The EL material, as opposed to the other lights mentioned, emits light only in a changing or alternating electric field.[1, 2] In fact, the intensity and to some extent the color of the EL lights change with frequency.

Commercially available EL lights were used which were originally intended for 60-Hz 120-V operation. Figures 1 and 2, drawn from data presented in references 3 and 4 respectively, show typical parameters of presently available material. These graphs of their light output indicated more efficient operation at about 5 kHz, the design frequency of the power supply described here. However, it should be noted that the supply can operate over a large frequency variation by adjusting the master oscillator.

Power requirements for EL panels on house lighting circuits are about 3.5 $\mathrm{W/ft}^2$ at 60 Hz; in the present application, where they must suitably expose photographic film, they require about 200 $\mathrm{W/ft}^2$ during the "on" time. The lamps are essentially lossy capacitors in the load they present to the power supply. To avoid a specialized circuit design and to add greatly to the flexibility of being able to add or subtract large numbers of EL panels to any display system, it was felt that shunting the EL panel load resistivity was worth while, even at the expense of some power loss. The result is that about 40% of the generated power burst is actually dissipated in the lamp. The other 60% is dissipated in the resistors used to make the system fairly insensitive to the exact number of connected loads.

Matched-Impedance 5 kHz Distribution System

As shown in Fig. 3, the output of the power supply is resistively split and sent to each EL lamp. Relatively long cable lengths are permissible in the present system because an approximately resistive impedance match is maintained. Such condition is only approximate, of course, since lamps may be added or taken off from time to time, but in general, a 50 Ω impedance is the aim. Thus, readily available cables and connectors can be used with no sacrifice in performance.

The overall power-supply system concept that results is that of a constant-voltage "mains" supply which feeds parallel lines running out to the various lamps. This is illustrated in Fig. 4. Owing to the pulsed nature of the light requirement, the power "main" is turned on for a pulse burst length adjustable in the range of 5 to 50 msec. Each burst of course, follows immediately after a successful spark-chamber event, and hence the timing of bursts is quite irregular. To fill our needs, an EL supply must operate well under conditions of either regular or statistically fluctuating burst rates. The present supply was designed with this requirement as a major consideration.

5-kHz Circuit Description

Examination of Fig. 5 reveals that the burst power-supply circuit design centers around the use of a six-section, lumped LC pulse line. Each section is made up of 17 μH and 1 μF, giving the pulse line a characteristic impedance $(L/C)^{1/2} \approx 4\ \Omega$ and a delay or discharge time $12(LC)^{1/2} = 50$ μsec. Figure 6 is a top view of the power supply showing its construction.

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* This work was done under the auspices of the U. S. Atomic Energy Commission.

High-Speed Line Charging

The applied supply voltage is doubled in the pulse line by using the resonant charging choke, L2. Note the use of six charging diodes, one to each section of the pulse line, in place of a single diode usually used. This permits the parallel charging of the LC sections with no waiting for the transit time of the line, thus providing repetition-rate capabilities not ordinarily obtainable in a line-type pulser. An input from a gated-pulse oscillator triggers SCR2, discharging the pulse line into a 4:1 step-up, tetrafilar-wound autotransformer. An oscillator capable of driving 50 Ω at 4 V was used. Since the power-supply output load is nominally 50 Ω, the reflected impedance presented to the pulse line through the transformer is 50 Ω/16 = 3.1 Ω.

SCR Consideration

Two characteristics of high-speed SCR's of special importance in the present design are the stored charge which must be allowed to decay after each conduction period, and the fact that spurious SCR firing occurs if the anode forward recharging rate dv/dt exceeds a limiting threshold.

The design presented here achieves effective use of the SCR's despite these limitations. First, to facilitate removal of the stored charge, deliberate impedance mismatch and a time delay before recharge are built into the circuit. With this mismatch between the pulse line and the load, the voltage on the capacitors in the pulse line reverses slightly at the end of the line discharge, reverse-biasing SCR2, thereby turning if off. The pulse line is not permitted to recharge until SCR1 is triggered, 100 μsec after CR2 fires. This delay is provided by the transistor one-shot Q3, Q4, and Q5.

Capacitor Ratings

Operating experience with the pulse-line capacitors C5 through C10 of Fig. 5 shows that ordinary 600-V Mylar capacitors may be used, provided they are series-paralled as indicated. If they are not connected in series, but used individually at 400 V and 5 kHz, failures by shorting may occur. It is believed that internal corona is the cause of failure and lower operating voltage a simple cure. Special pulse-type capacitors were not investigated, as satisfactory results have been obtained with ordinary capacitors.

Program Control of Data Lamp Array

As well as fiducial marks, other pertinent data such as event numbers, run numbers, and which phototube counters were involved in any given event are recorded on the film. Figure 7 is a data-display board that contains such information and is photographed along with the spark chambers.

It is usually required that not all lamps be excited simultaneously, but rather pulsed in some predetermined pattern. A system for individually gating EL lamps on after each spark-chamber event has been worked out, as shown in Fig. 8. Gate signals from the event logic are sent to the data-display control chassis to preset the display array. These dc coupled gate signals arrive prior to a pulse burst and may, for example, come from the flip-flop stages of a binary scaler. When a pulse burst of 5-kHz arrives at the control chassis, only those lamps light whose series triacs have been enabled by the presence of the logic gate inputs. In this example, the EL lamps are automatically binary coded.

Conclusions

A physics experiment using 90 EL lamps pulsed at 5 kHz has been in operation for more than a year. During this time, each lamp has accumulated more than 10^6 pulses; 65 of the lamps have between 1.5×10^6 and 2×10^6 pulses. The known failure in this group was four lamps which failed catastrophically and were replaced. Over the entire year, there was no photographically detectible dimming of the operating lamps. Contrary to our expectations, there was no evidence of gradual dimming over this period of time.

One problem which has arisen concerns the yield of usable 60-Hz EL lamps for the higher frequency. In EL lamp purchases made two years ago, a large percentage of the lamps worked well at 5-kHz. Recent purchases appear to have 5 kHz yields as low as 5%. Communication with manufacturers indicates that the EL lamps are still under development, in particular, high-frequency dielectrics that would enable lamp operation at frequencies in excess of 10 kHz. We would conclude from this fact that flexibility in operating frequency of the power-supply system is an important consideration. One may also conclude that each lamp should be tested at the anticipated operating frequency before installation.

Certain advantages offered by the EL lamp system are worth mentioning.

1. Flexibility of the Individual Lamps

Because the lamps are light weight and mechanically flexible, they are easily bent and curved or left flat to conform with various operating positions. This factor facilitates the EL lamp use both as fiducial markers, and as data input lamps for film or vidicon.

2. Shielding for Use in the Accelerator Environment

All wiring is enclosed and shielded, providing personnel protection and protection from triggering other equipment. The lamps and supply are insensitive to stray pulses, thus permitting operation in and around spark chambers.

3. Insensitivity to 0 to 20-Kilogauss Magnetic Fields

No doubt, one of the most interesting features of the EL lamps to physics users is the fact that the lamps will operate in magnetic fields. Successful tests were performed in ambient fields from Earth's field up to and in excess of 20 kG with no perceptible change in light output of the lamps either up or down in intensity. It is clear that at a sufficiently high magnetic field, changes in lamp circuit impedance and concomitant changes in light output should be expected, but the measurements to date show that still higher fields than 20 kG will have to be explored.

Acknowledgments

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References

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2. A. G. Fisher, R. E. Shroder, and S. Larach, Luminescence of Solids, Photoelectronic Materials and Devices, (D. Van Nostrand Co., Inc., Princeton, N. J., 1965).
3. M. N. Kreisler, SLAC Report TN-65-37, 1965.
4. Sylvania Technical Data Service Series PTL175, Panelescent Tape-Lite, No. TR-105A, December 1964.
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Figure Captions

Fig. 1. EL lamp integrated light vs frequency.

Fig. 2. EL lamp brightness vs voltage.

Fig. 3. EL power-supply distribution box.

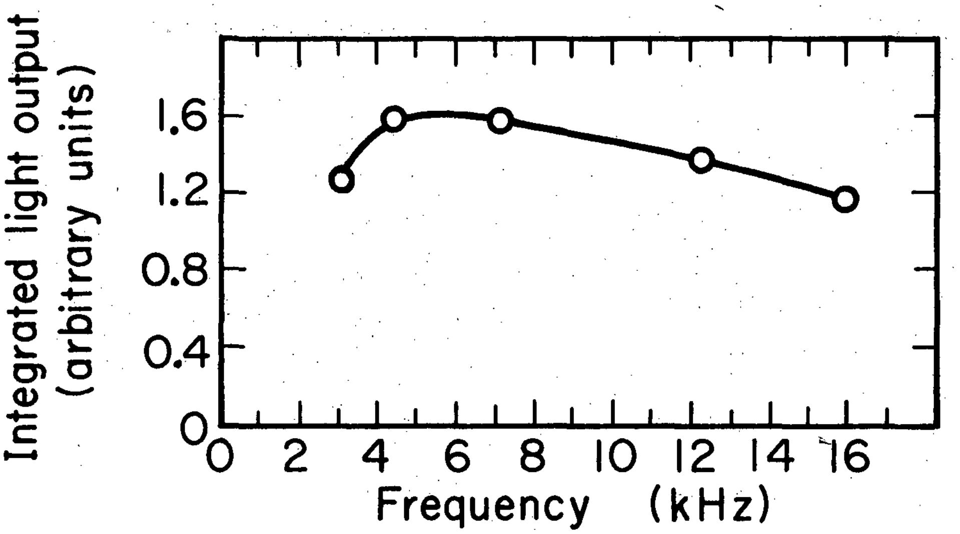
Fig. 4. System block diagram for EL fiducial lamps.

Fig. 5. Pulse burst power supply for EL lamps.

Fig. 6. Top view of EL power supply.

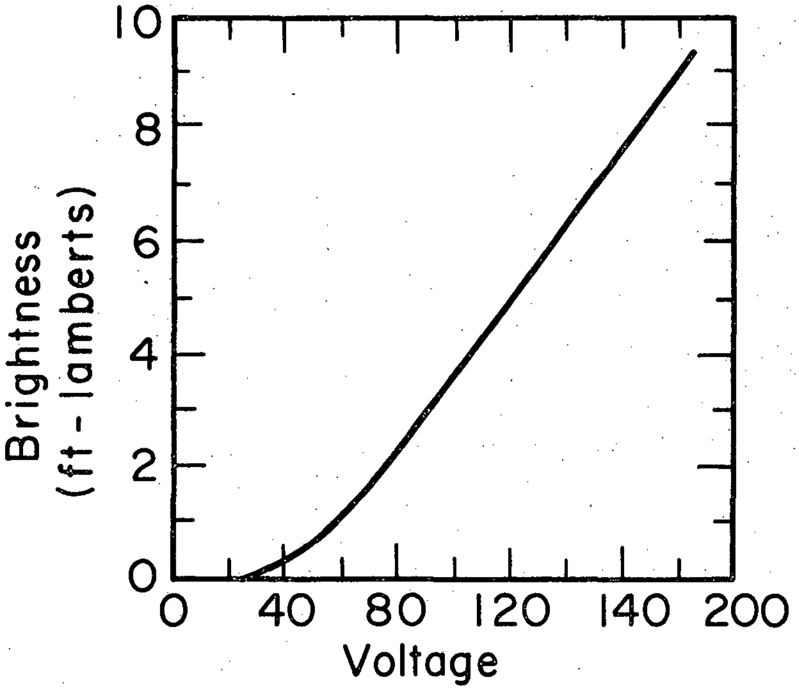
Fig. 7. Data display board.

Fig. 8. Data display-board gate control chassis.



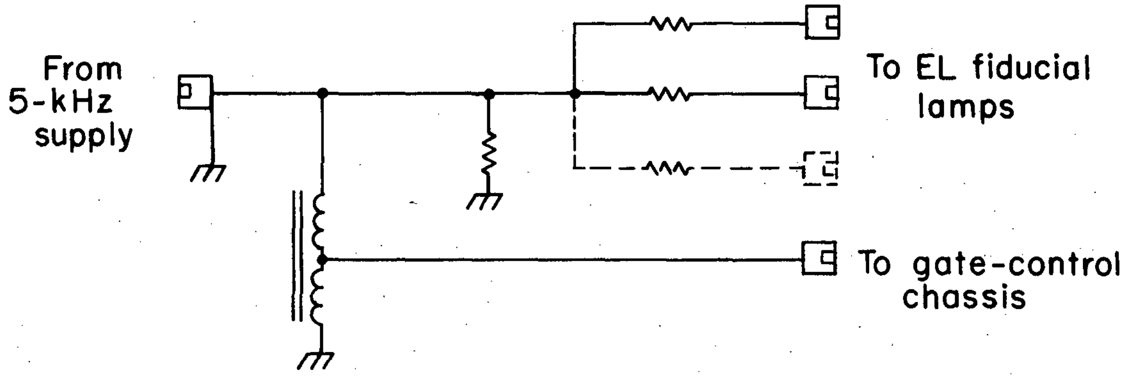
XBL670-5328

Fig. 1



XBL670-5329

Fig. 2



XBL670-5330

Fig. 3

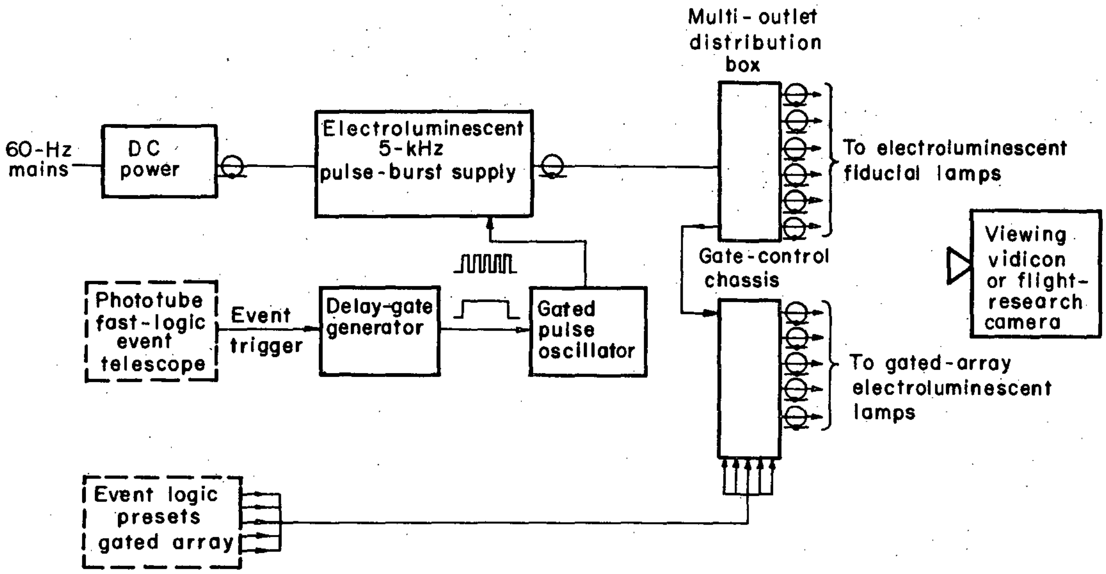


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Fig. 4

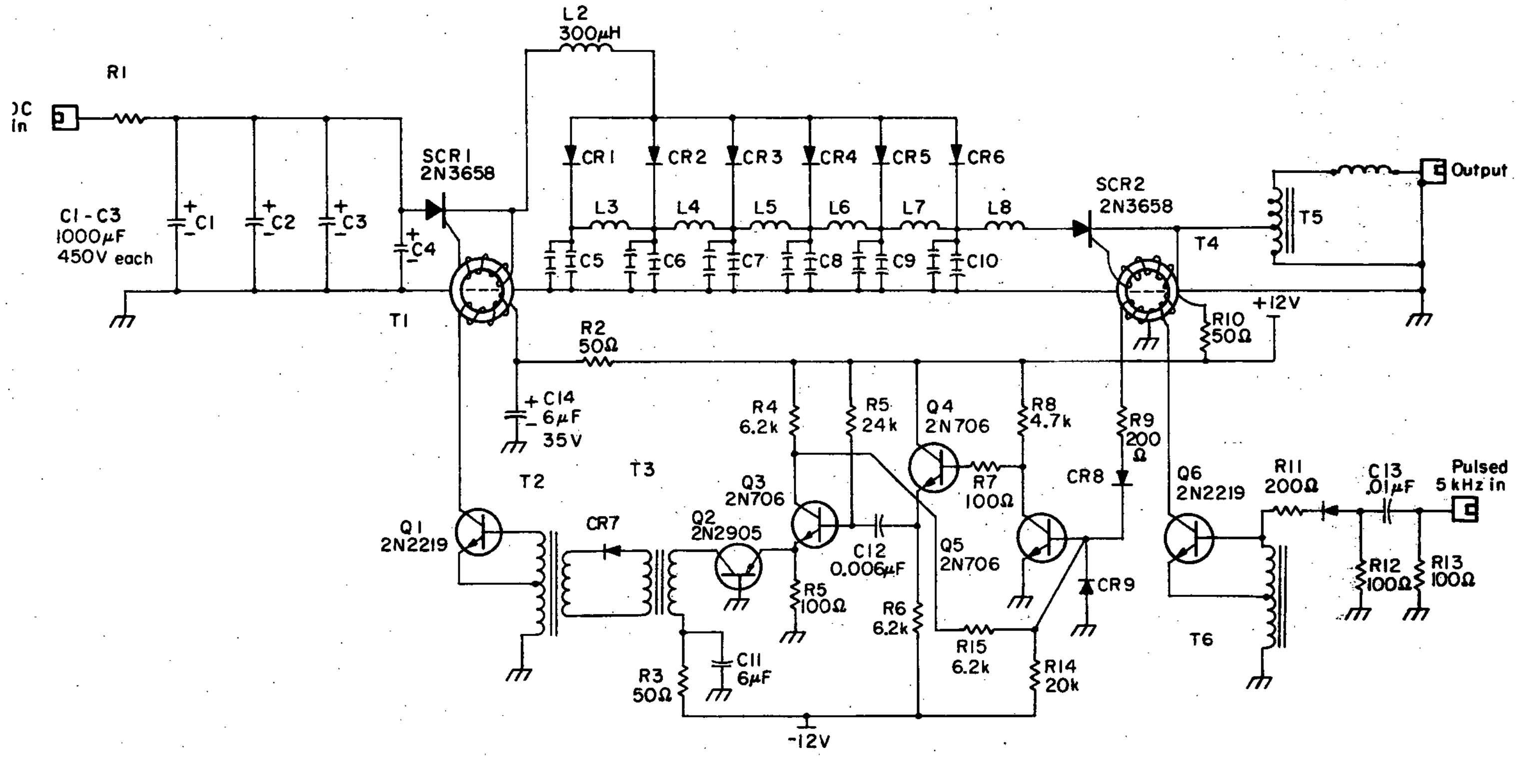

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Fig. 5

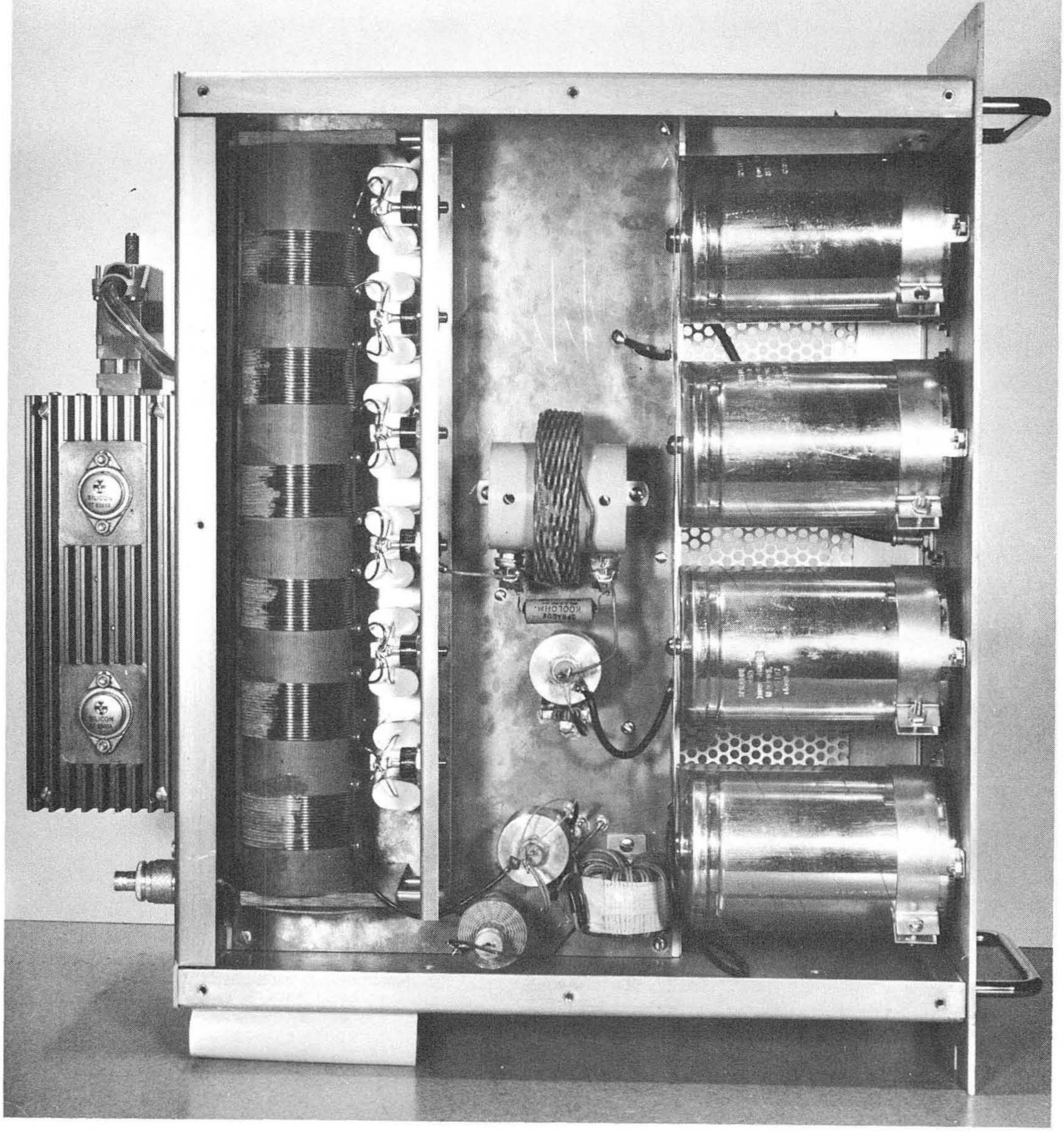

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Fig. 6

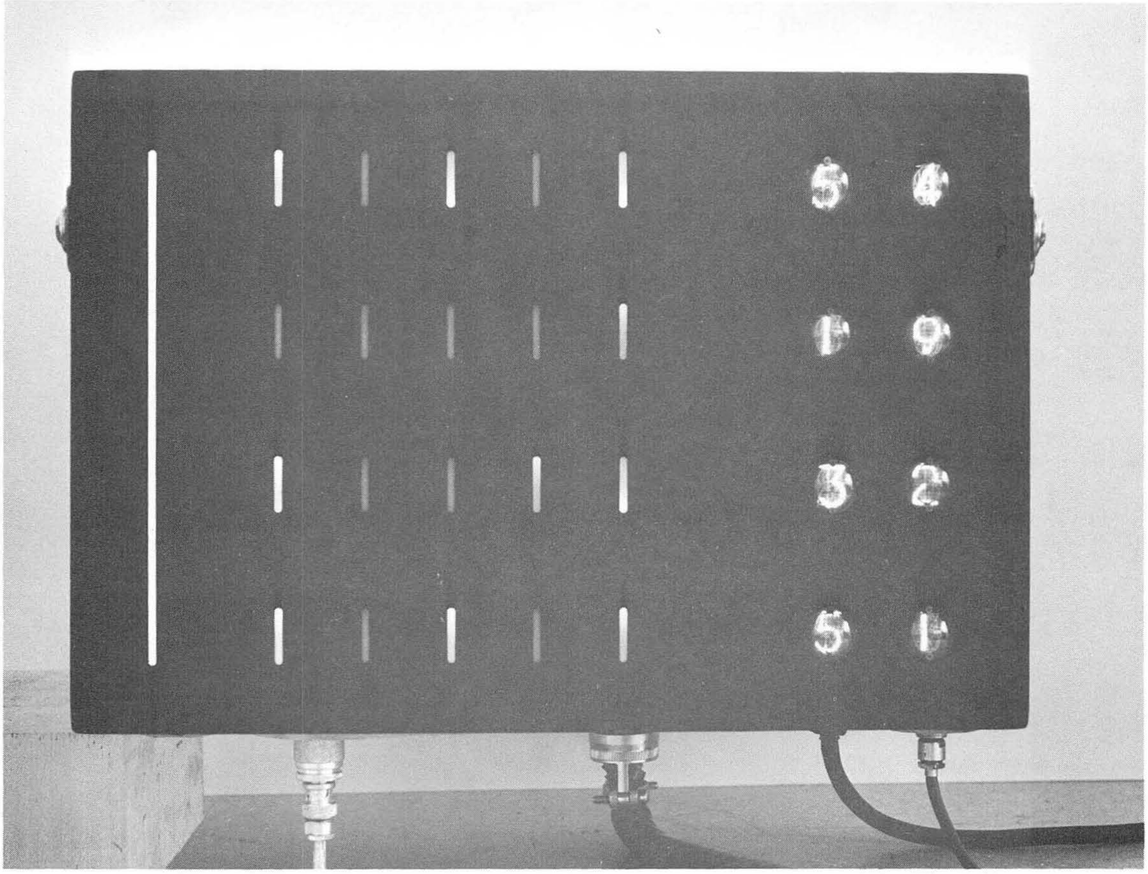

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Fig. 7

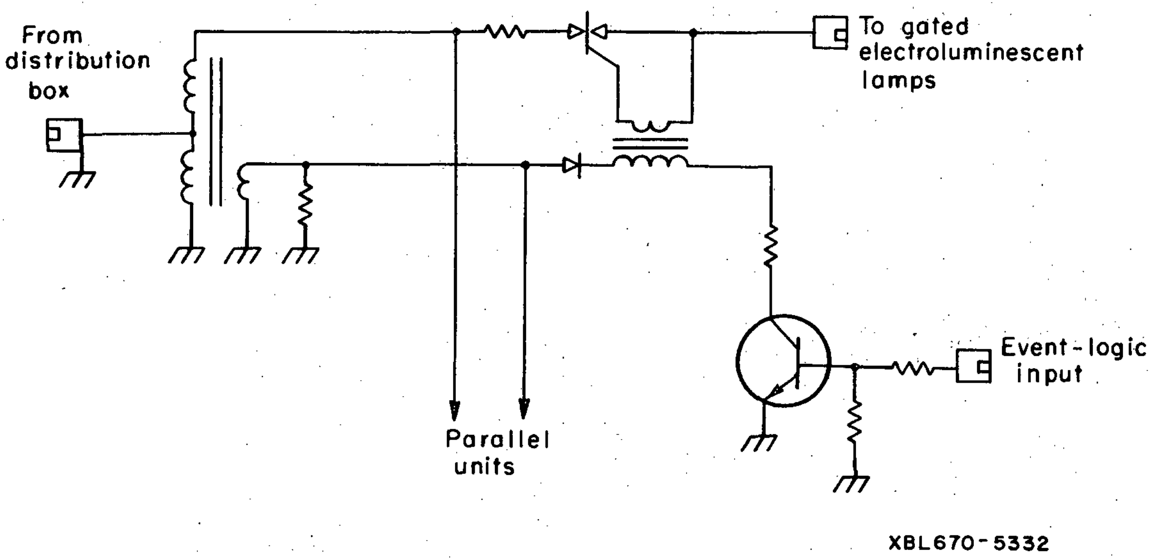
From distribution box
To gated electroluminescent lamps
Parallel units
Event-logic input
XBL670-5332

Fig. 8