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TITLE: FIBER-OPTIC CONTROL OF THE ZT-P EXPERIMENT

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Fiber-Optic Control of the ZT-P Experiment*

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The computer control system for the ZT-P experiment has been implemented using a fiber-optic link in all 161 control signal paths. Four classes of control signals are used in this design. These are: (a) digital-out, an on-off signal from computer to machine actuator, (b) digital-in, an on-off signal from machine sensor to computer, (c) analog-out, a 0 to 10 volt analog signal from computer to machine actuator, (d) analog-in, a 0 to +1 milliampere analog signal from machine sensor to computer. The digital-in and the digital-out class of signals require no control power at the machine. The analog-out and the analog-in class of signals use available machine power for control. This unique power arrangement and the use of fiber-optic links totally isolate the electrically noisy machine areas from the sensitive electronics in the computer control. Advantages of this system including low cost, small size, personnel safety, and ease of maintenance and modification are discussed.

*Work performed under the auspices of the U.S.D.O.E.

I. INTRODUCTION

The ZT-P experiment[1] provides a test bed for many engineering aspects of large air-core machine design - including experimental control in the presence of high ambient magnetic fields and transient voltages. This adverse environment dictated the need to explore the advantages of fiber-optic transmission in control systems. The ZT-P control required four classes of signals and unique fiber-optic sensors/actuators were developed and implemented using commercially available fiber-optic components. The control requirements were for a low bandwidth, short length (less than 100 meters), low cost fiber that could be used with inexpensive electro-optic devices and connectors. These requirements were met or exceeded by EOTec's plastic clad silica (PCS) fiber.[2] Amphenol type 905 fiber-optic connectors using the crimp and scribe termination technique (no epoxy, no polishing) permit quick field assembly and allows us to achieve about 10% emitter power coupled to the fiber-optic detectors. Honeywell electro-optic emitters and detectors were chosen for their low cost, high efficiency, and compatibility with the PCS fiber. The fiber-optic emitter power used in the different signal classes varies from 150 to 650 microwatts with 15 to 65 microwatts available at the detector. The hardware control originates in an unshielded control room about 30 meters from the center of the ZT-P machine. The control room contains the CAMAC[3] hardware, fiber links to the control computer, and fiber links to the distributed machine sensors and actuators. A 2.5 MHz byte-serial CAMAC highway links the control computer to the CAMAC crates. Operator data terminals are connected to the control computer by 9600 baud optic links. The CAMAC hardware consists of four types of commercial modules that perform the analog to digital, digital to analog, and digital sensing/actuating functions. Coupled to these commercial modules and also housed in CAMAC crates are optic modules that perform digital to optic, optic to digital, frequency to voltage, and voltage to frequency functions. These optic modules drive the fiber links to the machine control.

II. DIGITAL-OUT CONTROL

This class of signal is used where on-off control is required. The control computer actuates the modified solid state relay (Fig. 1) by a CAMAC housed digital to optic converter. This small (3 X 4 X 7 cm) relay can be mounted next to the controlled load and requires only optic power from the control system. The relay is immune to transient voltages and will operate in magnetic fields approximately ten times higher than the 36 gauss field which causes its magnetic counterpart to fail.[4] Other attractive characteristics of the relay are: (a) low optic control power (less than 10 microwatts), (b) zero crossing detector (this feature prevents turn-on transients in adjacent circuits), (c) dual control inputs (manual control can be exercised locally using the metallic circuits input, (d) high power switching (with proper heat sinking, loads up to 25 amperes can be controlled).

III. DIGITAL-IN CONTROL

An optic microswitch (Fig. 2) allows the computer to detect mechanical position of the ZT-P machine sensors. This switch breaks the optic path that originates at a source in the control room, couples across a movable vane, and reaches a digital-input detector at a CAMAC crate. Careful mechanical fabrication and alignment produce microswitches with 3 dB attenuation across the vane gap. These digital-input signals require two fibers each and the source emitter must typically supply 650 microwatts power to allow for misalignment and less than perfect fiber terminations.

IV. ANALOG-OUT CONTROL

Computer control of the high voltage bank is asserted with an analog ramp which originates in the control room. The ramp is voltage to frequency converted, transmitted 30 meters to the power supply room and presented at the optical input of the bank charge circuit (Fig. 1). The bank charge circuit performs frequency to voltage conversion reconstructing the analog ramp which establishes the bank charge rate and final voltage. Two to five microwatts of optic power is required to switch the digital optic receiver (SD4324) at the maximum frequency of 50 kilohertz. The optic emitter for this signal class is operated at 400 microwatts peak to compensate for coupling and transmission losses.

V. ANALOG-IN CONTROL

The circuit in Fig. 4 allows computer

monitoring of high voltage values. The energy to drive this current to frequency converter is supplied by the monitored source. A battery in the circuit serves only as a reference voltage with a current drain of less than one microampere. The circuit uses a relaxation oscillator based on a programmable unijunction transistor (2N6028). The threshold voltage of the 2N6028 is reached at a rate dependent on the current which is charging the input capacitor. The pulse produced at the 2N6028s threshold triggers an SCR and dumps the stored charge through an optic emitter (SD4352). About 320 microwatts peak optic power is produced by this circuit. This optical information is transmitted 30 meters to the control room where it is frequency to voltage converted and presented to the control computer.

VI. SUMMARY

The ZT-P computer control design has several advantages over previous wired designs. The CAMAC optic modules were designed with analog test points and digital indicators for ease of maintenance and fault isolation. In many cases visual inspections are sufficient to locate the fault. Since only fiber-optic cable enters the control room, no hazardous voltages can be encountered because of a wiring mistake, large magnetic fields, or a machine fault condition. Large numbers of signals (520 for the four CAMAC crates of ZT-P) can be concentrated in a small control area. Current per-channel cost for the optic design (dominated by fiber cost) is about the same as per-channel cost for a wired design ($125/channel). As less expensive fiber-optic cable becomes available the final advantage of cost reduction will also be realized.

REFERENCES.

1. Kurt F. Schoenberg, et al., "ZT-P: An Advanced Air Core Reversed Field Pinch Prototype, "Los Alamos National Laboratory report LA-10593-MS (January 1986).

2. EOTec Corporation's plastic clad silica fiber, part number 471001, core/clad diameter of 200/380 micrometers, numerical aperture of 0.4, 3 dB bandwidth of 25 MHz-km, and 6 dB/km attenuation at 820 nanometers.

3. Computer Automated Measurement and Control, IEEE Std. 583.

4. C. R. Montoya, Lawrence Livermore National Laboratory, unpublished data, 1980.

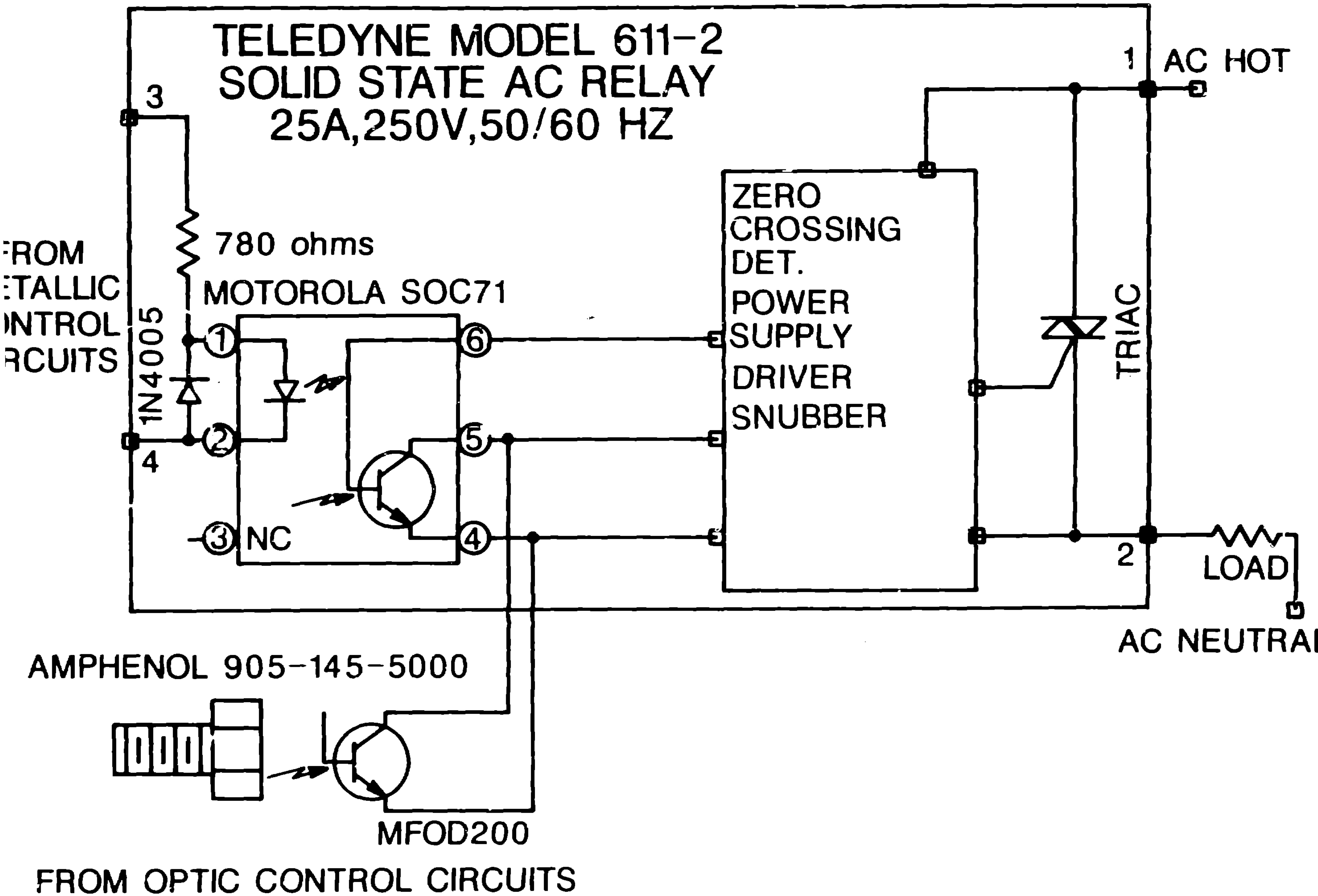
FIGURE CAPTIONS.

Figure 1 - Digital-Out Actuator

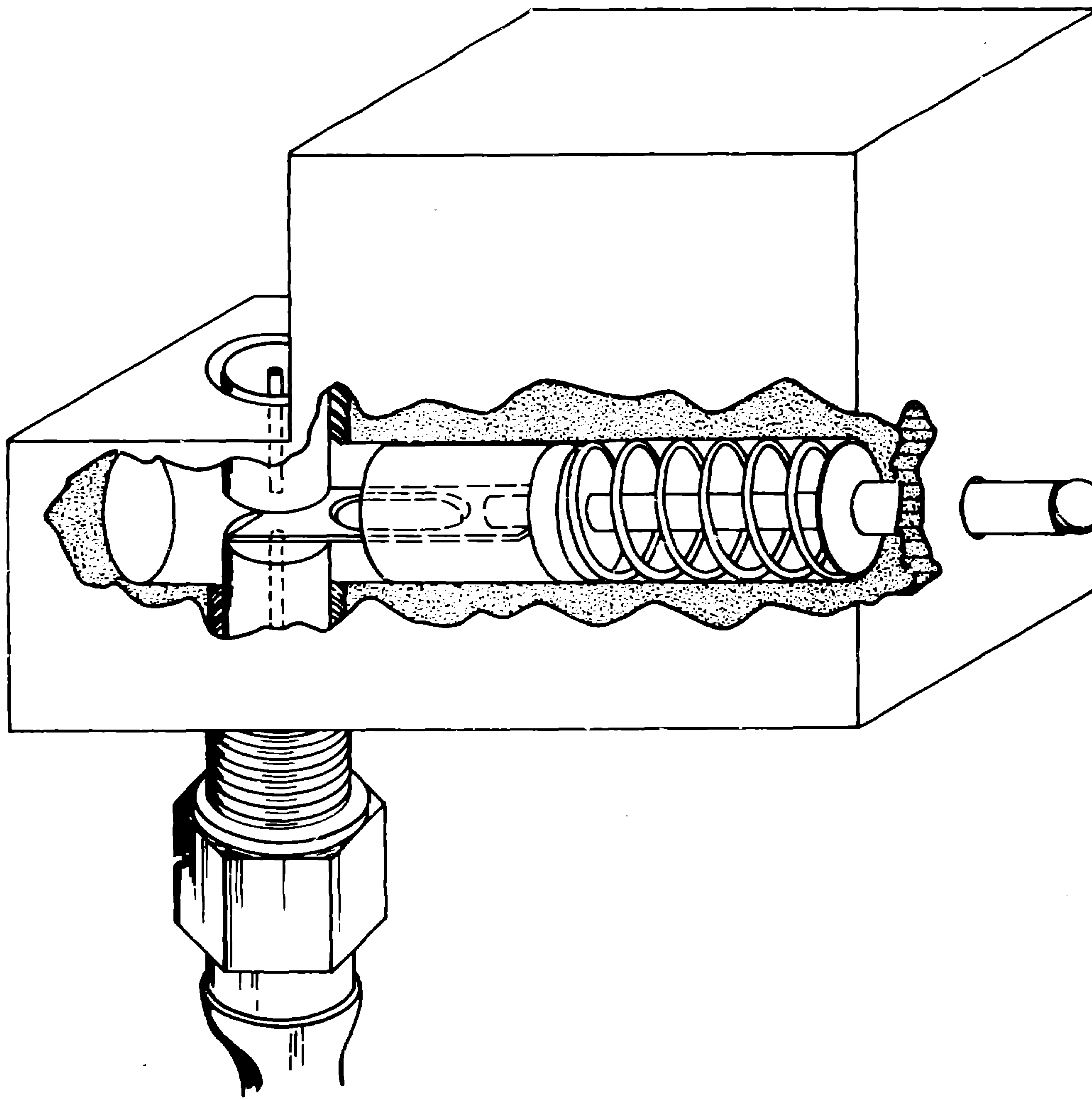
Figure 2 - Digital-In Sensor

Figure 3 - Analog-Out Actuator

Figure 4 - Analog-In Sensor



TELEDYNE MODEL 611-2
SOLID STATE AC RELAY
25A,250V,50/60 HZ
3
4
780 ohms
MOTOROLA SOC71
1N4005
ROM
TALLIC
NTROL
RCUITS
1
2
3
NC
6
5
4
ZERO
CROSSING
DET.
POWER
SUPPLY
DRIVER
SNUBBER
TRIAC
1
AC HOT
2
LOAD
AC NEUTRAL
AMPHENOL 905-145-5000
MFOD200
FROM OPTIC CONTROL CIRCUITS



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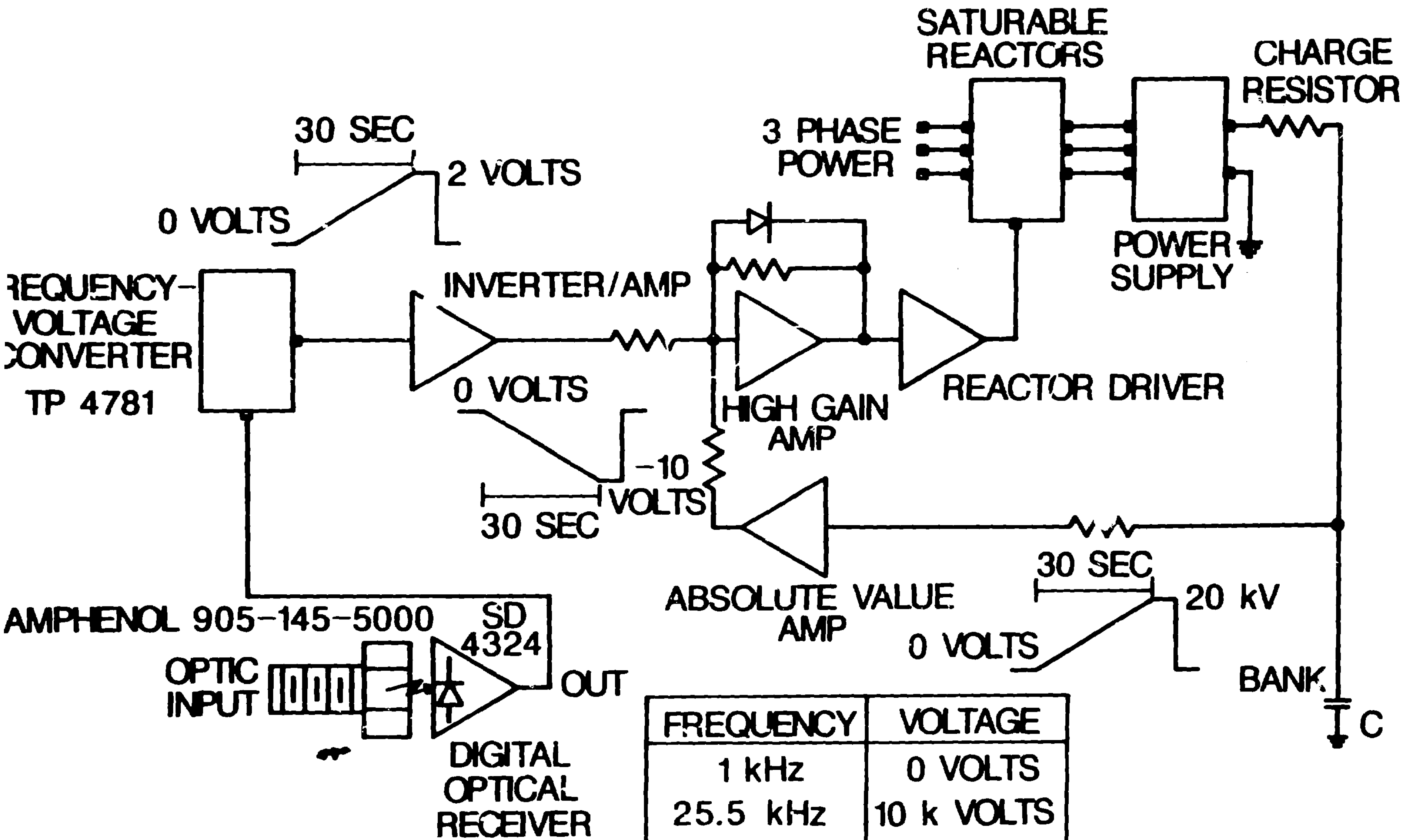
TYPICAL ZT-P BANK CHARGE CIRCUIT



FREQUENCY	VOLTAGE
1 kHz	0 VOLTS
25.5 kHz	10 k VOLTS
50 kHz	20 k VOLTS

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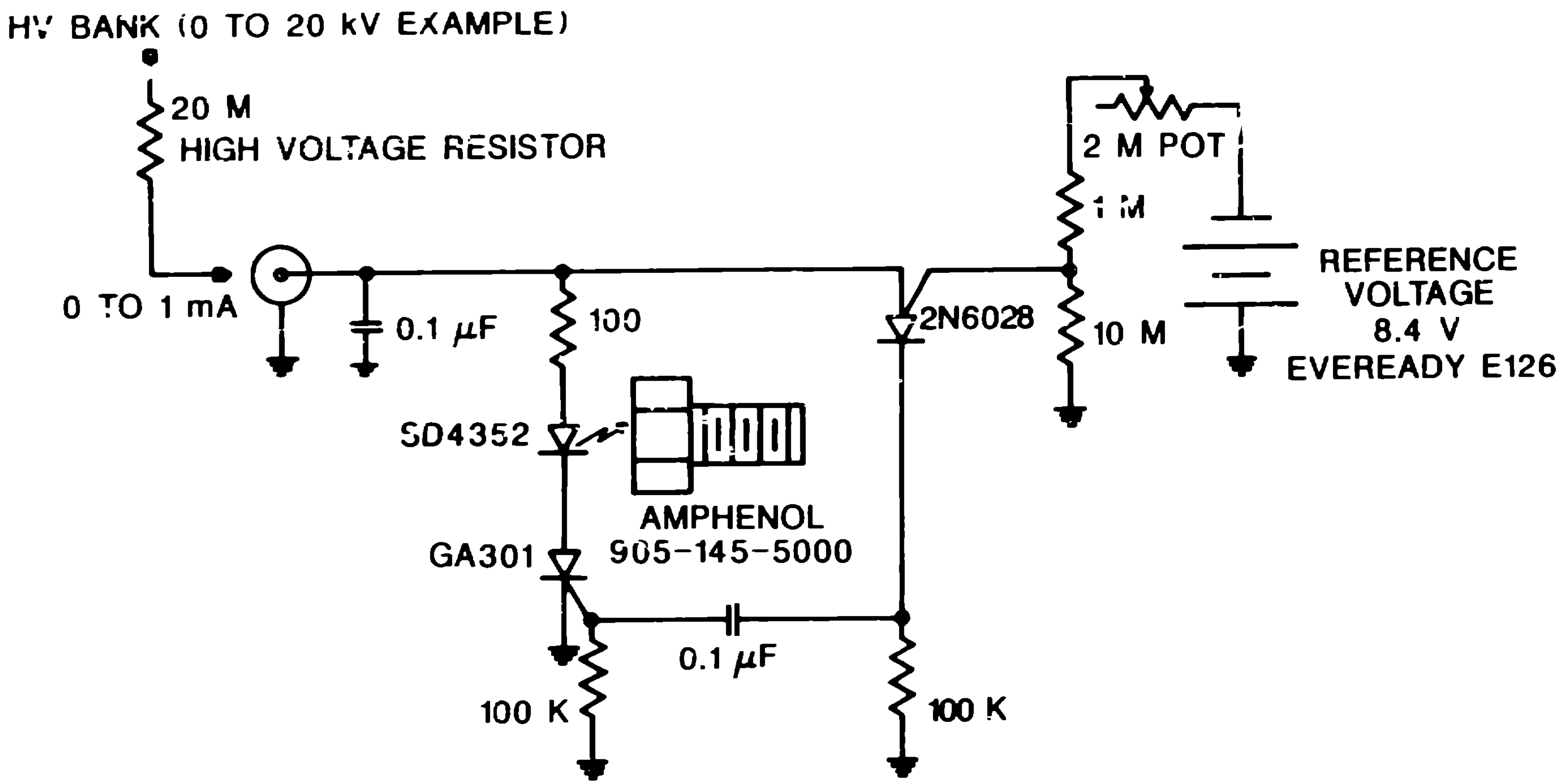
CURRENT-FREQUENCY OPTIC TRANSMITTER



CURRENT	FREQUENCY
10 μA	20 HZ
500 μA	880 HZ
1 mA	1850 HZ