DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

TIME COMPATIBLE ACCELEROGRAPH POWER SUPPLY

BY

JOHN NIELSON AND ARNOLD ACOSTA [1]

OPEN-FILE REPORT 88-564

[1] U.S. GEOLOGICAL SURVEY
15000 AVIATION BLVD MS 6113
LAWNDALE, CALIFORNIA 90261

SEPTEMBER 1988

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INTRODUCTION

This report describes a time compatible accelerograph power supply (Power Supply) that serves as an interface between interruptible AC or solar power sources and calibrated Greenwich time systems and several model accelerographs. The Power Supply may be used in combination with numerous instruments including 1) triaxial analog recorders, the RFT-250/350, TTA, and SMA, 2) triaxial digital recorders, the DCA, DSA, A-700, PDR-1, and SSA and 3) multiple sensor recorders, including the CRA and multiplexed versions of the previously mentioned digital units. The Power Supply incorporates a selected regulator circuit, depending upon the power source, (110 volt AC or an array of solar cells and panels), which allows easy maintenance of the following components: the recorder operational mode, standby or active; a system for recording Greenwich mean time; remotely located sensors, including downhole transducers; and a wide range of rechargeable batteries. The entire system, including Greenwich time generators, TCG-1A/B time generators, and WWVB radio receivers, are incorporated in a single weather-resistant easily transportable unit and may be field installed under most environmental conditions. This power supply design has been adopted as the standard for new USGS strong-motion stations and is being retrofitted to existing stations as time and funding permits.

GENERAL DESCRIPTION

When new accelerographs, such as the Kinemetrics SMA-1 and CRA-1, are received from the factory the unregulated power supply systems and world time generators are mounted inside the recording unit. If a power supply fails or an electronic malfunction occurs after an event has been recorded, the accelerograph must be opened to replace the faulty component; because the recording media cannot be advanced, invaluable event data may be lost. To circumvent this problem, the unregulated power supply components are removed from the recorder, re-designed, and integrated in an external configuration. Some advantages of this Power Supply include the use of higher capacity and greater reliability batteries, more effective utilization of solar panels, capability of externally reading and synchronizing the Greenwich time generator, safer vandal-resistant housing, and better access to electronic components.

The Power Supply design includes a sealed battery, a regulated charger, choice of 110 volt (220 volt optional) or an array of solar cells, voltage and current measuring modules, a digital counter, instantaneous fuses, and a synchronized Greenwich time generator (figure 1). When two or more recorders are connected for simultaneous triggering and timing, a fail-safe interconnect switch and warning lamp are installed. Power, time code, and threshold trigger pulses are routed into the recorder from the Power Supply utilizing a seven-conductor cable mated to a connector on the recorder. All items in the Power Supply are mounted on a metal plate and wired to terminal boards designed for easy module replacement.

To meet a variety of demands, there are 12 variations of the Power Supply, six that use solar cell chargers and six that use an AC regulated float charger. Solar cell models vary in the following ways: (1) no timing generator or interconnect circuits, (2) with interconnect circuits, (3) with a time code generator (synchronized world timing), (4) with timing generator and interconnect circuits, (5) with WWVB radio timing generator, (6) with WWVB radio timing generator and interconnect circuits.

The Power Supply fiberglass housing is approx. 30.5 cm (12 in.) high, 25.4 cm (10 in.) wide, and 12.7 cm (5 in.) deep. It is easily secured, is water tight, and is virtually vandal proof. Mounting holes allow installation in any structure or housing used as a strong-motion recorder site, with the door opening in any position for easy access.

POWER COMPONENTS

The following paragraphs describe the various components and their functions in the Power Supply. See wiring diagram in figure 1 for details of components described in this section.

BATTERIES

Although a range of batteries are adaptable, tests have shown that a 12 volt 6.5 amp hour (AH) rechargeable lead/lead dioxide gel-type are preferred (20 AH at remote sites). These batteries are virtually leak proof because of the lead/lead dioxide system in which dilute sulphuric acid electrolyte is immobilized in a gel mixture (Globe-Union Inc., 1973). Should the battery be accidentally overcharged, producing hydrogen and oxygen, special one-way valves allow the gases to escape, thus avoiding excessive pressure build-up. Otherwise, the sealed battery is maintenance free, leak proof, and usable in any position. Specified operating temperature range is from -4° F to +122° F (Power Sonic Corp., 1973).

BATTERY CHARGERS, GENERAL

Two types of battery chargers are used, a 110 volt regulated float charger, or a sun-powered solar cell charger. The float charger is mounted inside the housing whereas the solar cell must be mounted outside the recorder building and wired into the Power Supply housing.

A.C. Regulated Float Charger. After extensive testing by the U.S. Geological Survey and the Calif. Division of Mines and Geology, a Globe/Union model CDF regulated float charger was selected as the standard unit to provide precise voltage maintenance of batteries in standby float service. To accommodate long periods of unattended service the charger is designed to operate in a continuous short circuit without damage. The charger holds a constant 13.5 to 13.8 volts across the battery (Globe-Union Inc., 1973). When held at this voltage, the battery will recharge to its maximum level and maintain itself in a fully charged condition (see figure 2).

Solar Cell charger. Solar cell chargers that convert light energy into direct current electricity are available in different voltage and current ratings and physical sizes. The voltage and current required is dictated by the type of instrumentation used at each project.

The silicon solar cell circuit is encapsulated between a top layer of glass protected by shock proof polycarbonate and a corrosion-resistant metal backing for moisture protection and strength; the latter two items were installed by the USGS after field testing. The solar charger operates most effectively when it receives direct sunlight but can provide an adequate power source under a wide variation of weather conditions.

After the solar cell charger is mounted and adjusted for latitude, the output cable is connected into the Power Supply (figure 3). Because the solar cell has no output at night, a blocking diode (1N4001) is placed in the positive wire circuit to prevent current from flowing away from the battery and back to the solar cell, discharging the battery. The solar cell must be kept clean for optimum charge capability.

CHARGE CURRENT MEASURING CIRCUIT

A circuit that allows the measurement of the battery charge current under both instrument standby and operation load is built into the Power Supply. The positive lead from the charging device is connected to the main terminal board (TB-1) at screw 2 (figures 2 and 3). The current passes through the blocking diode (1N4001) or a shorting wire to screw 1 of TB-1 and then to the center contact of a fail-safe single-pole-double-throw momentary switch (S-1). During normal operation current flows from the center of switch S-1 to contact 2, to the black jack, through the red wire to screw 3 of TB-1, and then to the battery.

To measure current to the battery, an ampmeter is placed between the yellow and black jacks. When switch S-1 is activated, the current flows to contact 1, through the meter, to the battery. Releasing the spring-loaded switch (S-1) returns the charge circuit to the normal standby condition.

VOLTAGE MEASURING CIRCUIT

A voltmeter across the red and black jacks measures voltage across the battery. Checking this voltage while the recorder is operating indicates the condition of the battery under load. A drop of more than 0.5 volts indicates a problem with the charger, battery, or related circuits.

OPERATIONAL FUNCTIONS

INTERCONNECT DISCONNECT SWITCH AND WARNING LAMP

To prevent spurious operation at remote units when two or more recorders are interconnected for common trigger and time, a fail-safe circuit has been added that permits opening the interconnection between instruments. This circuit contains a 3-position double-throw switch and a red indicator lamp (figure 1). When one of the interconnected recorders is being serviced, its trigger output line is opened at switch S-2 to prevent operation of the other recorders. The red indicator lamp is a warning that the trigger line is open and must be closed upon completion of the servicing. The trigger line from the other recorders is connected to TB-1 (screw 6) to the bottom contact of switch S-2, then through the switch to the top contact (TB-1 screw 12) to the recorder. When switch S-2 is set to the OPEN position, the contact between the top and bottom is opened and the secondary contacts between top and center are closed, allowing battery voltage from the power fuse, F-1, to flow through the lamp. Returning switch S-2 to NORMAL will turn the lamp off and close the trigger line.

FUSES

Two fast blow 2 amp fuses protect all circuits and the recorder from current overload. Fuse F-1 protects the recorder, battery, and charging circuits; fuse F-2 protects the timing device. Both fuses are in clip type holders for ease of replacement (figure 1).

DIGITAL COUNTER

The counter, used to indicate how many times the accelerograph has been triggered, is an electro-mechanical device connected to battery voltage and to the trigger circuit of the recorder. When the recorder starts, a relay in the recorder closes and allows voltage to flow through the counter solenoid, and then through a mechanical linkage that rotates a numbered disc half through its first position. When the recorder stops, all relays open and a spring pulls the numbered disc into its first position, allowing the number '1' to appear in the window. When this recorded event has been removed, the counter is then cleared by the servicing technician.

TIMING COMPONENTS

GREENWICH TIME DEVICES

Two types of time devices are used with the Power Supply: a synchronous time code generator and a WWVB radio receiver, each of which encodes time in seconds, minutes, hours, and day of year on the recorder film in a serial binary-coded decimal display.

TIME CODE GENERATOR, TCG-1. The time code generator (TCG-1) is an accurate, ultra low power Greenwich time instrument that outputs a serial binary coded decimal (BCD) time signal suitable for recording on such equipment as Kinemetrics SMA-1, DSA-1, SSA-1, PDR-1, and CRA-1 (figure 4). With appropriate circuit modifications it may be used with Teledyne RFT-250 and RFT-350 and the Terra Technology TTA and DCA recorders.

The TCG-1 is available with the standard crystal oscillator (TCG-1A) or a more stable version (TCG-1B) that is two orders of magnitude more accurate in terms of crystal stability than the standard oscillator.

The crystal oscillator output (figure 5) is broken down by frequency dividers into a 1-Hz pulse that increments the time-keeping counters via a control gate. Other timing pulses are derived from the frequency dividers to obtain a selectable time code frame period from 1 to 1600 seconds. Each frame consists of 50 indexes of BCD (1-2-4-8) data including a reference marker, five position markers; seconds; minutes; hours; day of year; and a low battery indicator (National Bureau of Standards, 1979; see figure 5).

The TCG-1 time data is displayed and synchronized with a calibrator -- the time display controller (TDC-1 or TDC-2), which has a high-precision time generator, is portable, and has a low power demand (Kinemetrics Inc., 1986). When a TCG-1 is first connected to power, the time-keeping system starts at zero seconds. The TCG-1 must be synchronized to the correct Greenwich time, using the time display controller. The controller display is set to the correct Greenwich time by using signals from WWVB radio, which is a voice and pulse broadcast from the National Bureau of Standards, Fort Collins, Colorado. When the calibrated controller is connected to the TCG-1, the TCG-1 output will be displayed as a "slave" read-out on the LCD display. The operator may then observe the "master" and the "slave" displays and use the controller to synchronize the TCG-1 with the master display. The TCG-1 correction is measured at every maintenance visit and recalibrated to Greenwich time.

When the TCG-1 is mounted inside the recorder, the correction measurement after an earthquake requires opening the recorder with an inherent danger of zeroing the TCG-1 counting circuit. With the TCG-1 mounted inside the Power Supply the correction can easily be made with little chance of losing Greenwich time or of exposing the recorded event.

WWVB RADIO RECEIVER. The National Bureau of Standards (NBS), through the WWVB radio station located in Fort Collins, Colorado, broadcasts Greenwich time signals in a binary coded decimal (BCD) format at a carrier frequency of 60 kHz.

A WWVB radio receiver provides a BCD time code that indicates the current second, minute, hour, and day. Once this time code is recorded, a WWVB time decoder chart is used to convert the code to local time (Specific Products, 1965; see figure 6).

A WWVB radio receiver is used to record Greenwich time at closely spaced arrays where precise timing is required for wave propagation and ground response studies. The radio requires an outside antenna to receive the signal from the broadcast station; therefore its use is limited in comparison with the time code generator. The antenna must be clear of power lines, large buildings, hills, or dams that could block the incoming signal. Advantages of the WWVB radio receiver are that it will not lose time during a power outage, has virtually no timing error, and does not require a controller to synchronize the time before or make corrections after a recorded event.

The physical size and mounting of the WWVB radio receiver is similar to the time code generator, making both timing devices compatible with the Power Supply.

The WWVB receiving antenna must be mounted outside metal buildings or on the roof of high rise structures, but may be mounted inside most wood or fiberglass structures. The antenna is installed as far above the ground as practical and should be clear of obstructions. The newest model antenna used with the WWVB radio receiver has a built-in pre-amplifier line driver that increases the strength of the incoming signal to the receiver, insuring a clearer time code.

When a WWVB radio-equipped accelerograph starts, an electronic pulse from the recorder is sent to the output transistor of the radio receiver, activating the output. The BCD signal is then routed to a modified relay (secondary time mark generator) inside the recorder, moving the relay so that positive trace deflections are recorded on the film. A complete time frame, which is 60 seconds duration, may be compared with a WWVB decoder chart to determine the Greenwich time of the recorded event (figure 6).

SUMMARY

The time compatible accelerograph power supply, with its 12 variations, is compatible with numerous different strong-motion earthquake recording systems. Mounted above the floor, this unit provides easy access to all components, ensuring they remain dry, clean, and secure. This Power Supply has been adopted as the standard for USGS strong-motion stations, replacing units that have been in operation the past 15 years.

REFERENCES

Globe-Union Inc., 1973, gel cell battery charger CDF series for battery systems in "float" service: Globe Battery Division, Madison, Wisconsin.

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National Bureau of Standards, 1979, NBS time and frequency dissemination services: U.S. Department of Commerce Special Publication 432, p. 6-7.

Power Sonic Corp., 1973, rechargeable gel-type battery performance and specifications: P.O. Box 5242, 3106 Spring Street, Redwood City, Calif. 94043.

Specific Products, 1965, NBS time code decoder chart: Bulletin Number 226, 21051 Costanso St., Woodland Hills, Calif.

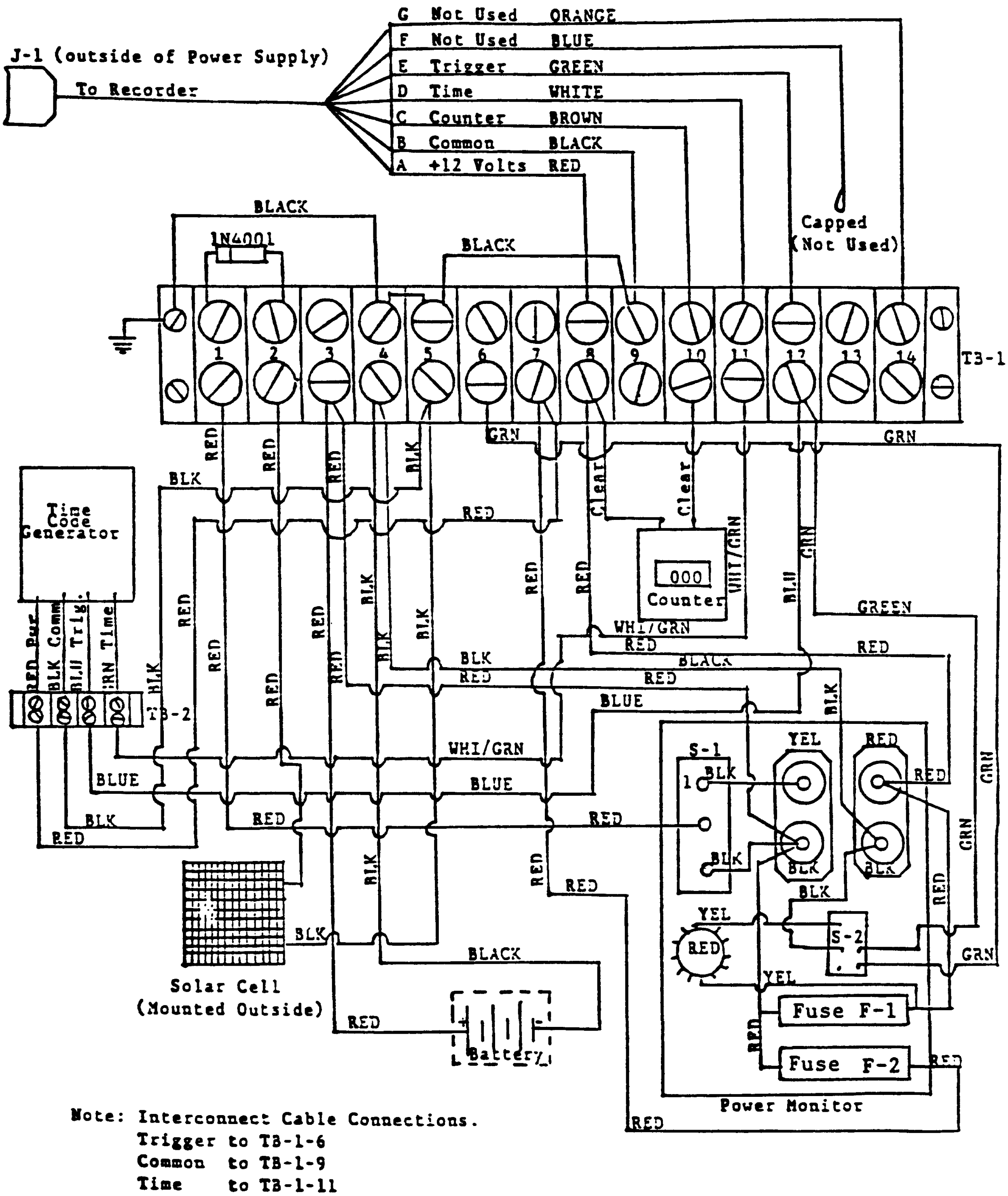

Figure 1. Time compatible accelerograph power supply wiring diagram, with solar cell charger, TMG-1, interconnect circuits, and warning lamp.

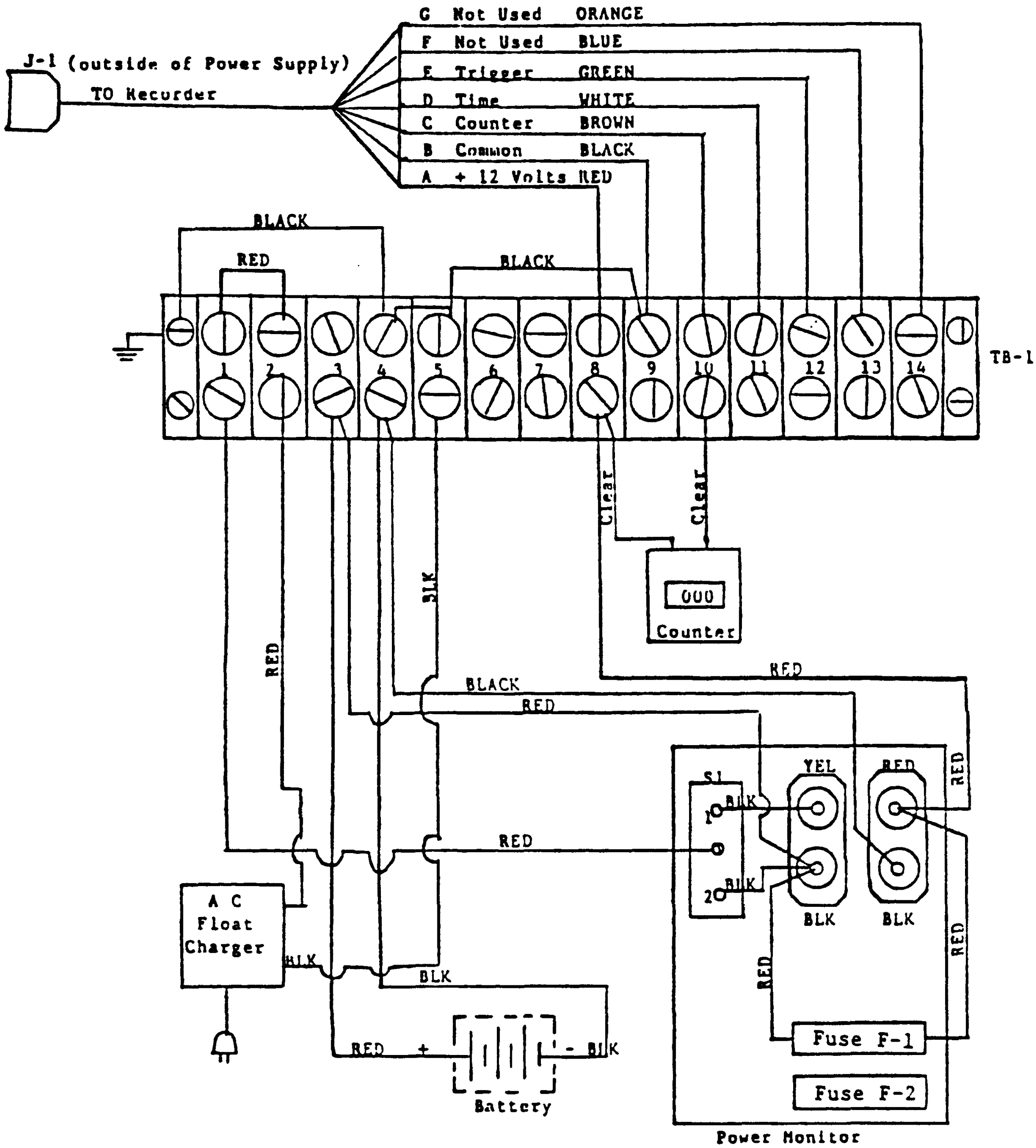

Figure 2. Time compatible accelerograph power supply wiring diagram showing the wiring of the battery and AC float charger.

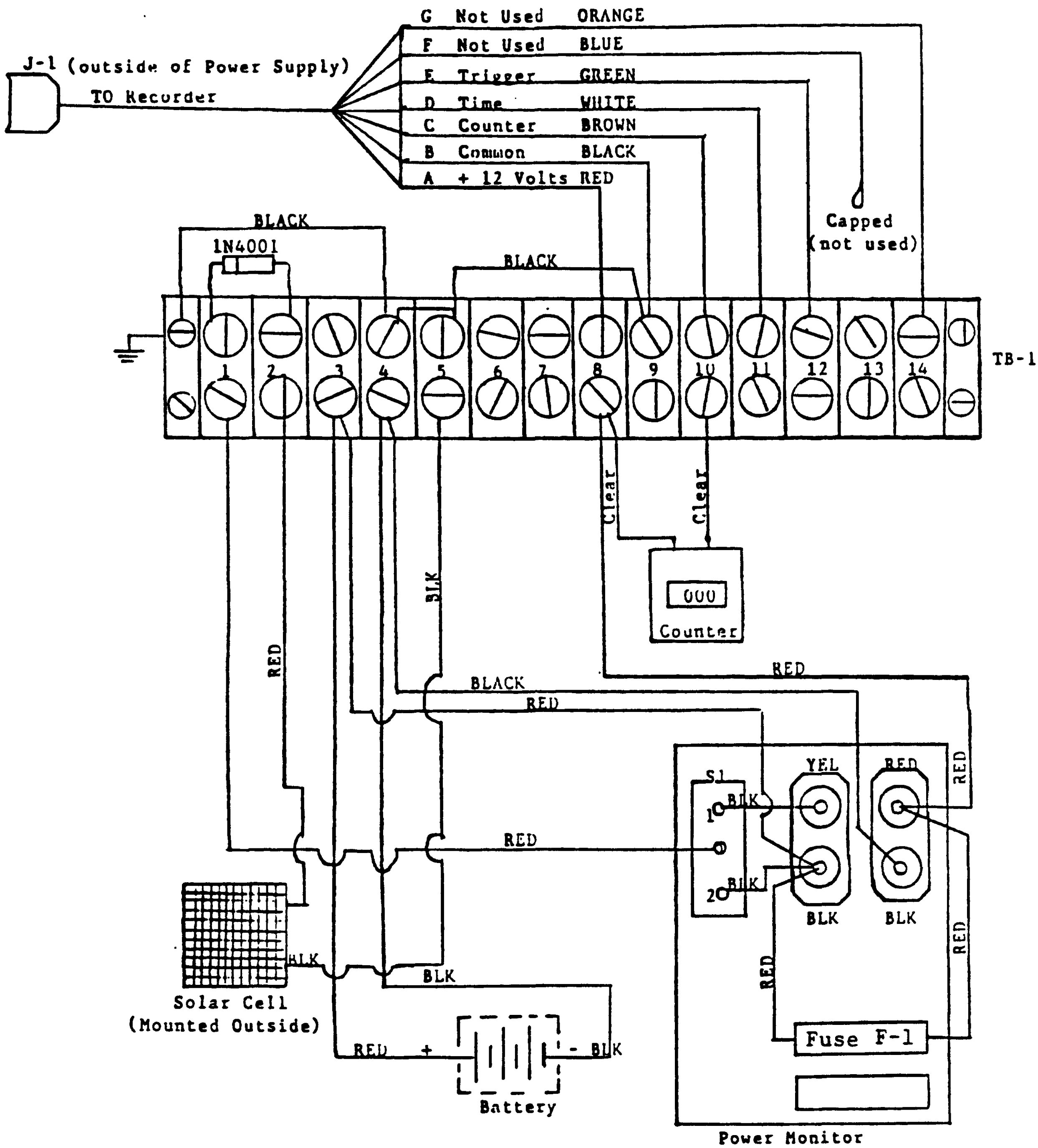

Figure 3. Time compatible accelerograph power supply wiring diagram, showing wiring of the solar cell charger and battery. Note 1N4001 diode across screws 1 and 2.

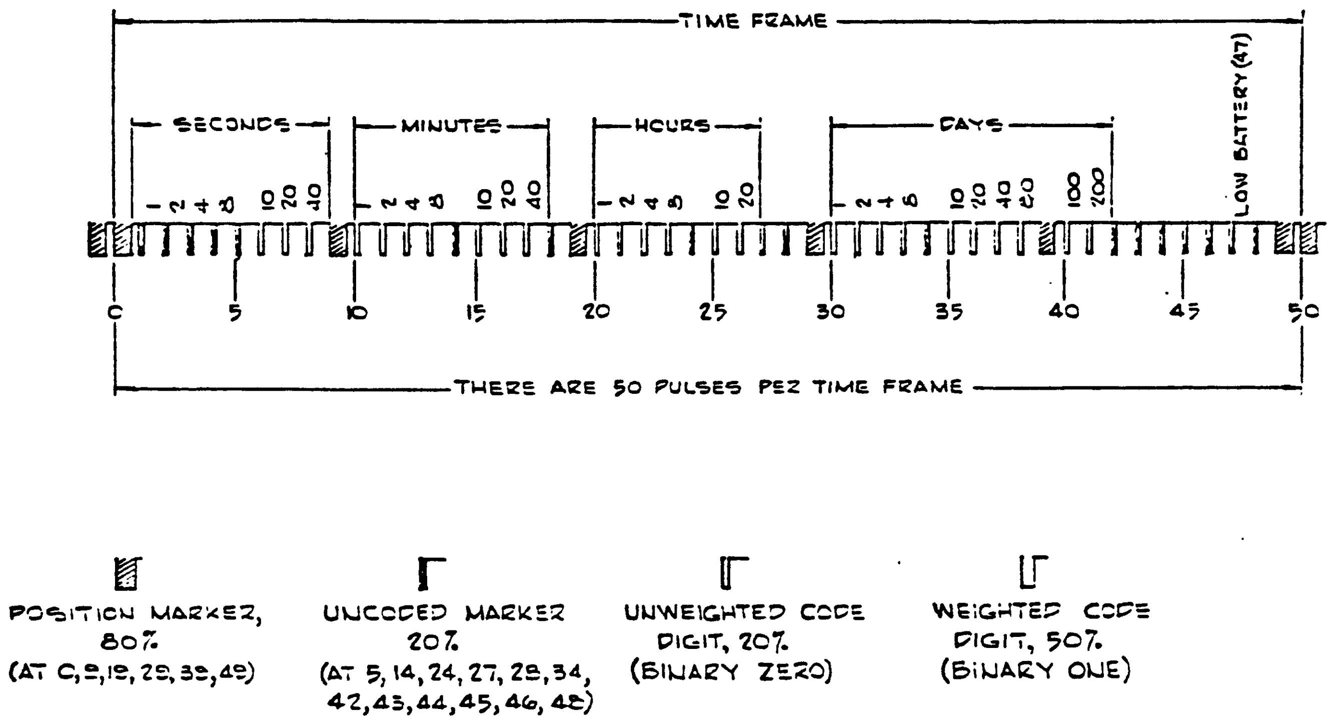

Figure 4. Time-code generator format for film or analog playback of digital data (courtesy of Kinemetrics, Inc., Pasadena, Calif.)

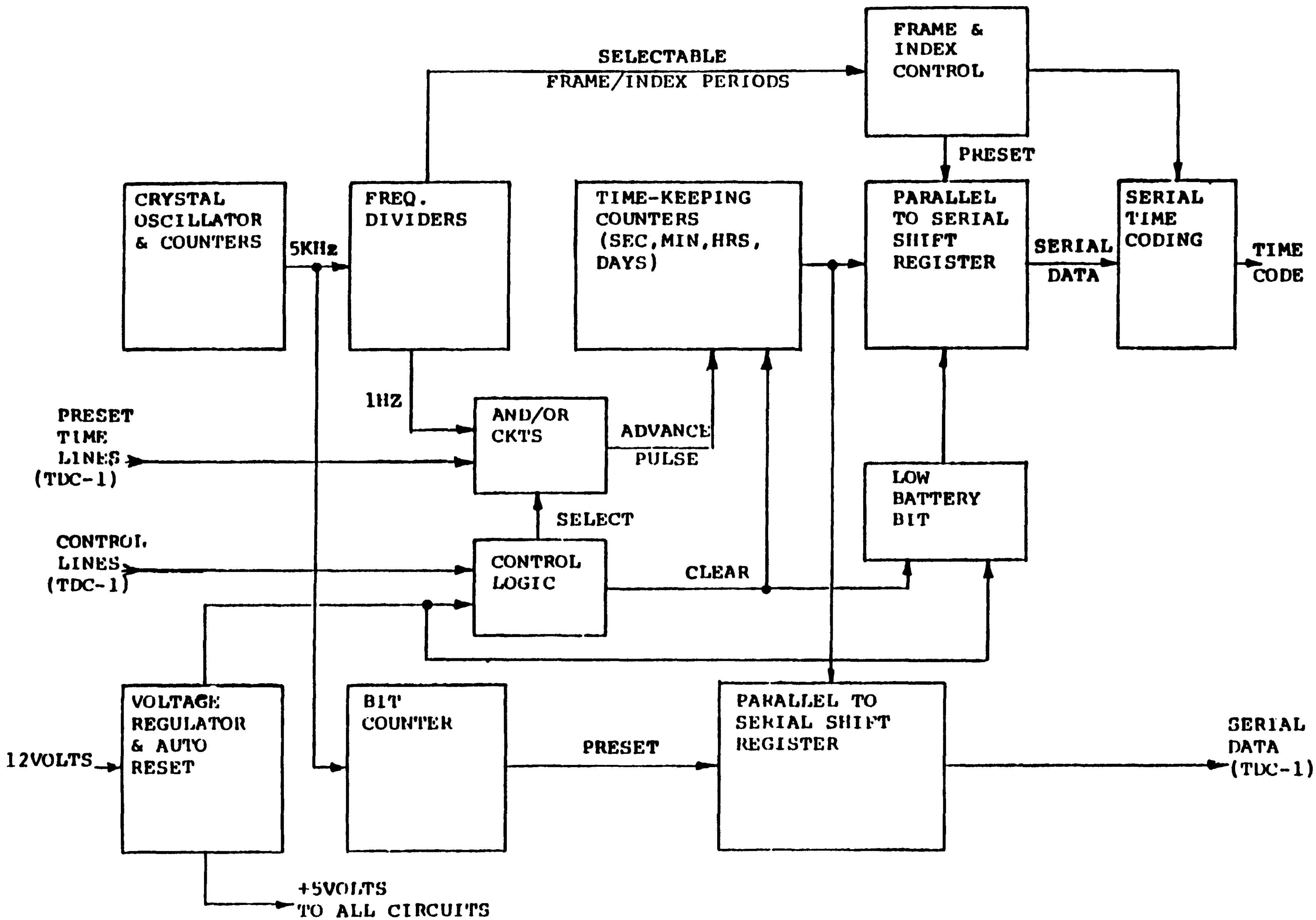

Figure 5. Time-code generator block diagram.

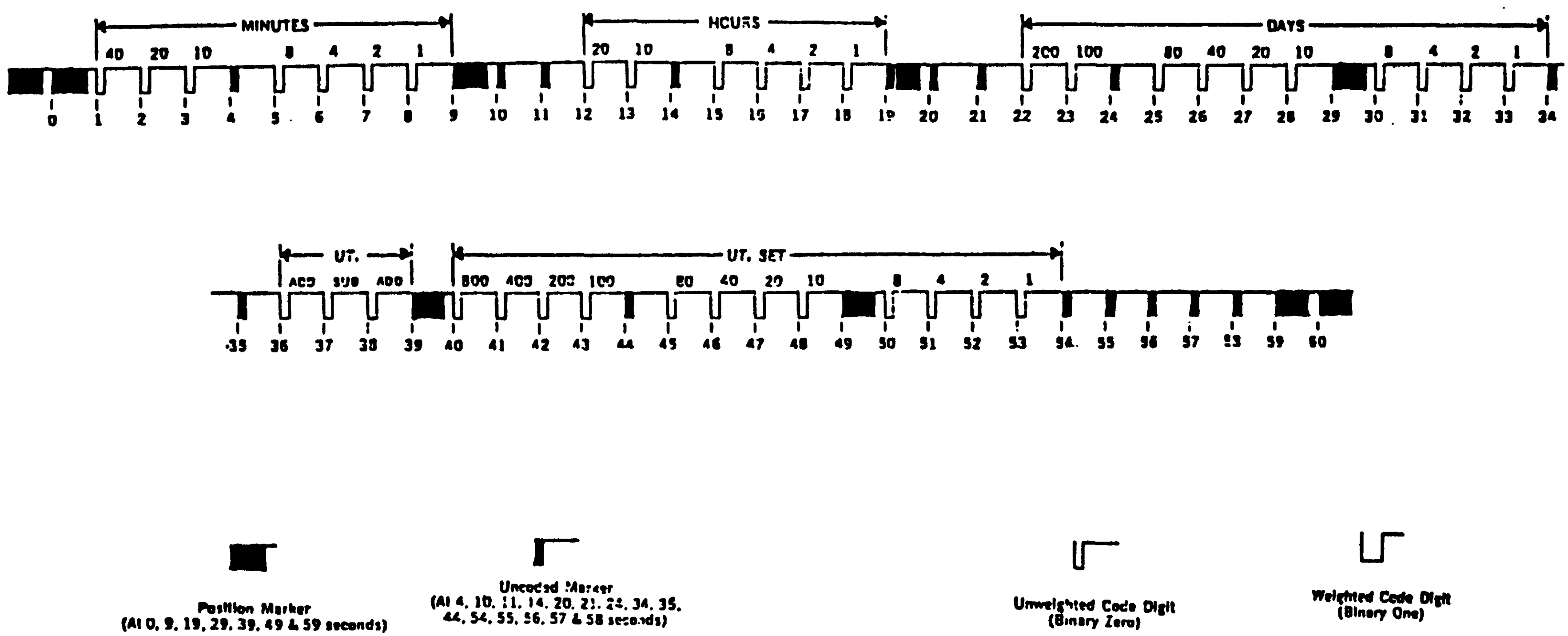

Figure 6. WWVB time decoder chart (courtesy Kinematics Inc., Pasadena, Calif.)