Auroral all-sky camera control system

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Publisher’s version / Version de l'éditeur:
https://doi.org/10.4224/21276062
Report (National Research Council of Canada. Radio and Electrical Engineering Division : ERB), 1969-01

ERB-806

UNCLASSIFIED

NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

JHC-3 All-Sky Camera Control System

- M.J. Neale -

OTTAWA

JANUARY 1969

ABSTRACT

A new control equipment for the NRC auroral all-sky camera, replacing the earlier system put into service in 1957, is described. Use has been made of solid state counters, glow type indicators, and more liberally rated components. The use of separate units to perform each of the various functions permits the choice of a suitable group of units to satisfy the requirements of each installation. The basic instrumentation camera controlled may be a 35-mm PSC Mk VII, a 16-mm Kodak K100 or both may be operated together. The equipment can be operated on time-stabilized 60 Hz power, or provision can be made to use reliable but poorly regulated 60 Hz power. The use of a battery, float-charged, permits the timekeeping and control circuits to maintain synchronization on power systems with frequent short interruptions. A set of circuit schematics are included.

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*Schematic Diagram number.
A set of 11 schematic drawings accompanies this report and forms a part of it.

AURORAL ALL-SKY CAMERA CONTROL SYSTEM

– M.J. Neale –

This camera control system (ASC Mk II) replaces the original one built for and used during the International Geophysical Year (IGY). The latter was designed around a mechanical digital drum clock and a mechanical day counter, driven by the clock, and included auxiliary cams and switches to provide cyclic control of the camera and to switch it on during the dark hours.

The revised system was intended

a) to replace some of the mechanical items by more reliable solid state elements,

b) by fragmenting the various functions into separate units, to provide more flexibility in the choice and mounting of the equipment to suit various different all-sky camera installations,

c) to remove as many of the components as possible from the base of the camera system to a remote equipment rack, from which two cameras might be operated, and

d) to facilitate operation and maintenance.

BASIC GENERAL DESCRIPTION

The block diagram (UAR-413-01) represents a very complex setup, most unlikely to be encountered in fact, but shows all the many alternatives possible.

The two instrumentation cameras, a 35-mm PSC*Mk VII for the black and white film, and a 16-mm Kodak K100 for the colour, are carried over unmodified from the previous system. The display units – the chassis mounted in the bases of the tetrapods – have a row of glow type indicators (nixie tubes), just below the data window in the bases. These indicate the last digit of the year, the day, and the time, as well as a station-identification and exposure-duration indication. Of these, the day and time indicators are slave to a master electronic clock, which counts the minutes up to 366 days, making use of solid-state integrated circuit components.

The control unit for the black and white camera is a repeat-cycle timer with a 50-sec period, started by each minute pulse. It supplies signals to the display system and camera to open and close the camera shutter, to turn on the display indicators momentarily, and to set up the proper exposure length indicator. Provision is made to select all long, all short, or alternate long and short exposures. A 24-V dc power supply, required only for the operation of the Mk VII camera, is provided as an auxiliary chassis. The control for the colour camera is a repeat-cycle timer with a 320-sec period, started by every sixth minute pulse. During its cycle the camera is turned on for three periods, of increasing length, with momentary operation of the display indicators.

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*Spar Aerospace Products

These camera controls, while they continue their cycles 24 hours a day, turn on their camera units with power from a separate relay unit. This relay may be operated by the timer unit, the light sensitive unit, or an external isolated contact, to operate the cameras during dark periods.

The minute pulses for the clock and camera controls may be provided from an external source (each requires approximately $\frac{1}{2}$-sec closure of an isolated contact), or from the minute pulse generator. The latter unit could be driven by the 60-Hz ac mains when the timekeeping accuracy is adequate, or by the 60-Hz power supply unit. When the likelihood of power interruption is too high, this 60-Hz unit, which supplies power for the minute pulse generator and the cycling portions of the camera controls, as well as for the clock, can be powered from the float-charged 12-V battery.

DISPLAY CHASSIS

Schematic Diagram – UAR-413-20C

The eight numeric nixie tubes are grouped on two printed-circuit boards to which they are permanently wired, while the three alphanumeric units are plugged into sockets. The control of the proper symbol displayed by each, determined by the presence of a ground on the corresponding cathode, is not the same for all. The control for the three digits identifying the numerical day, and the four digits for the hours and minutes of the 24-hour clock come from the clock unit through a multiple connection cable. The last digit of the year is controlled by the position of a plug in a 10-jack field, the station code is controlled by two printed-circuit boards with suitable wired-in jumpers, and the exposure nixie indicates L or S under the control of the camera control unit. This also turns on the whole group of nixie tubes for a second or so, and at the same time turns on the altitude lamp on each tetrapod leg. For test and monitoring purposes, the nixies and these lamps may be turned on continuously when the chassis is dropped, an interlock switch preventing this when the chassis is raised. The display chassis also acts as a junction panel for leads to the camera from other chassis of the system, many of the connections to it serving no internal function.

CLOCK

Schematic Diagram – UAR-413-40E

For our application the clocked ring counter offers certain advantages and was chosen as the basic counting circuit. The digital integrated-circuit elements are dual master–slave JK flip-flops of the DTL type, with the C (Clock) and R (Direct Reset) inputs to the two flip-flops common. These, and the individual S (Direct Set) inputs, are inhibited when made Hi (the $+V_{cc}$ or 1 state). Since a ring counter has the 1st (the 0 flip-flop) in the set condition (Q = Hi) to indicate zero, resetting a counter to zero requires a signal to all R inputs, followed by a signal to the S input of the 1st flip-flop.

Each counter, whether a DECADE, a SIX, or a THREE count, is mounted on a plug-in printed circuit board, along with transistor buffer circuits, of rather long time constant, at the input. The 'carry' output of each, which serves as clock pulse for the following counter, is the differentiated Q of the 0 flip-flop.

A SIX counter, needed for the tens of minutes, is also used for the hundreds of days to reduce the number of different printed circuit boards. Thus the day count can be driven up to 599, though for all counts in excess of 399 no indication is shown on the hundreds day nixie tube. The THREE counter used to count tens of hours has a transistor AND gate which, on the combination of a 2 in the count on this counter and a 4 in hours count on the preceding board, provides a zeroing signal for the latter. The resulting carry output advances the tens hour counter to 0.

Operation of the nixie indicators is achieved by 300-V transistors. These are mounted on plug-in printed circuit boards, one board per digit being provided with 10, 6, 4 or 3 transistors assembled on boards wired for 10. The terminals are chosen so that a board with an excess number of transistors may be used as a spare.

An 8-position switch allows each counter to be selected for correction purposes. The return of the selector switch to its OFF position will prevent incorrect settings caused by accidental or unauthorized push-button operation. One of the decks allows a zeroing push-button switch to restore the counter to logic 0, a second makes another push button a source of clock pulses, while a third permits suppression of the carry output if desired. The spring-loaded toggle switch which effects this suppression also turns continuous power to the set of seven numerical nixie tubes, which serves as a local monitor of clock output, their cathodes being in parallel with those in the display or displays. No counter can be advanced by the push-button switch during a clock pulse.

The flip-flops and transistors in this chassis operate on +4.2 V. A rectifier power supply, or the standby battery, supplies 12 V to a zener stabilized regulator. Overvoltage protection is provided by an SCR crowbar circuit and a 'fast-blo' fuse. Protection against complete loss of count, which would occur during even a second's power cut, is provided by a 1 A-hour nickel-cadmium battery, connected to the 4.2-V bus by a reversed transistor. When the power is off, this causes minimal drop at 1 ampere, but limits the charging current to 200 mA even into a completely discharged battery. All transistors, except the voltage regulator, and most of the rest of the components are mounted on a plug-in printed circuit board. Reasonably long battery life is obtained by careful adjustment of the regulator output so that a fully charged battery draws only 5 to 10 mA. The tip jack permits monitoring of the output voltage; the break jack permits charging current measurement and, by the insertion of the dummy plug, isolation of the battery during test or other shut down periods (see appendix A).

CAMERA CONTROL (Black and White)

Schematic Diagram UAR-413-60D

This unit is driven by a synchronous motor operating at 3/5 rpm on 60 Hz. When started by a minute pulse, it drives the cam system till it is stopped by the operation of a microswitch, rotating 180° in, nominally, 50 sec. To permit operation on pulses as short as $\frac{1}{4}$ sec, a self-locking relay is provided. This repeat cycle timer portion of the unit is supplied with power continuously throughout the 24 hours. During each of the half-revolutions of the cam system, the shutter is opened by one cam-operated microswitch and closed by another, and the identification system is turned on for a short period by a third. (The PSC Mk VII camera requires separate pulses to (*a*) open the shutter, (*b*) close the shutter and transport the film in the magazine.) An additional cam-operated microswitch operates a relay during alternate half-revolutions to allow the selection of a program for a long exposure each even minute and a short one each odd, or all long or all short exposures. One contact of this relay switches the control of the shutter closing circuit between two cam-operated microswitches. Four other contacts switch the cathodes of the alphanumeric nixie in the display to produce an L or S indication. The operation of the camera and identification system occurs only during that part of the day that the equipment has been switched on, the 24-V dc power supply which supplies power for the drive motor and control solenoids being on only then.

The duration of the identification illumination pulse – a momentary completion of the ac neutral circuit of the transformers in the display – is rendered independent of the microswitch *on* time by a circuit mounted on a small plug-in printed-circuit board. A triac is turned on by the differentiation of the initiation of the microswitch *on* period. A timer adjustment is provided, and tests indicate that $1\frac{1}{4}$ sec is a suitable duration. Power is supplied to this circuit from the switched ac supply.

For test and monitoring purposes several switches and lamps are provided. The DAYLIGHT TEST switch transfers the full operation of the unit to the continuous ac power input, the START push button switch simulates a minute pulse, while the HOLD push button switch suppresses the minute pulse while it is operated. The HOLD switch provides a very simple means of switching the long pulse from the odd to the even minute after some disturbance. It should be noted that the lamps labeled LONG and SHORT switch on or off near the end of each cycle, and thus indicate the exposure which is going to occur in the next minute.

CAMERA CONTROL (Colour)

Schematic Diagram UAR-413-70D

This unit, which is very similar to the preceding one, is driven by a $\frac{3}{16}$-rpm motor nominally completing its cycle of one revolution in 320 sec; thus, only every sixth minute pulse is capable of starting it. During this revolution the actuating solenoid of the modified Kodak K100 camera is operated for three periods – 6 sec, 42 sec, 250 sec. The identification lights are turned on, by the same mechanism as is used in the controller for the PSC Mk VII, for a short time in each of these periods. (The Kodak K100, with a modified pawl system, operates as follows. When the solenoid pulls the operating lever to the single-shot position, the shutter opens and, when the lever is released, the shutter closes and the film is transported.) A DAYLIGHT TEST switch, a CYCLE ON lamp, and a SOLENOID ENERGIZED lamp, are provided, as well as START and HOLD push button switches. The last may be used to produce the proper coordination of this control unit with time, to have the start of the cycle at the 0th, 6th, 12th, etc., minute of each hour.

MINUTE PULSE GENERATOR

Schematic Diagram – UAR-414-40B

This unit is driven by a 1-rpm 60-Hz synchronous motor, thus providing minute pulses as precise as the time stability of the ac voltage supplied to it. The reed switch, operated by the field of the magnet on the rotating disc, controls a relay, using the same ac power as the motor. This prevents faulty minute pulses as long as there is continuity in the ac power supplied to the motor. A lamp indicates the *on* period of the pulse, which is helpful in resetting the clock and camera control units. Adjustments to this unit are made by rotating the friction-driven dial to any position desired.

POWER RELAY

Schematic UAR-413-80B

Power for the camera controls is supplied during the hours of darkness from this unit. A box containing a small power relay and the control, input, and output connectors is mounted on the rear of, although it is independent of, the camera control unit panel.

24-V dc POWER SUPPLY

Schematic UAR-414-20B

Rectified, unfiltered power for the Mk VII camera (black and white) is provided by this unit. The transformer, bridge rectifier, fuses, and fuse alarm lamps are contained in a small box mounted on the rear of the camera control unit panel. Input and output leads are carried on a pigtail to a plug which connects into the camera control unit.

DAWN–DUSK PHOTOELECTRIC CONTROL

Schematic Diagram UAR-414-80B

This unit and the timed dawn–dusk control provide alternative means of internal control of the power relay. The relay in this chassis is operated whenever the illumination of the photosensitive resistor is adequate, a transistor amplifier on a plug-in printed circuit board serving as a buffer. The sensitivity can be adjusted by a panel mounted control. During the day this may be overridden by a daylight test switch, and during dark periods, daylight may be simulated by paralleling a pre-set rear-mounted variable resistor with the photosensitive element by means of a panel-mounted push button switch.

DAWN–DUSK TIMER

Schematic Diagram UAR-414-60B

A 60 Hz, 1/1440-rpm motor drives this unit, operating two microswitches at presettable times during each 24-hour revolution. One of these switches is operated by the black tab and energizes a self-locking relay, the other, operated by the red tab, releases this relay.

The complete dial may be reset (to the nearest 15 minutes) by depressing and rotating it. Each of the two tabs may be set (to the nearest 15 minutes) by lifting it out from the panel. A lamp indicates that the timer has turned the equipment on, and red and black push button switches are provided to reset the relay to the OFF or ON condition. While the dawn microswitch is operated, it is not possible to latch up the relay.

60-Hz POWER SUPPLY

Schematic Diagram UAR-415-20D

A bakelite box houses a 120-kHz crystal-controlled oscillator, a buffer, and a proportional temperature-control system. The frequency of the oscillator may be varied by the internally adjusted inductor or by the variable capacitor. The former provides the coarser of these two controls, and is used to set up the correct frequency with the other at the mid-point, see Appendix B. A rather massive aluminum plate is included in the assembly, both as a heat sink for the regulating power transistor, and a heat distributing mount for the heater elements. Both these circuits operate on 12-V dc, but a rear-mounted switch permits disconnection of the heating system when the power available is limited.

On a plug-in printed circuit board a limiting amplifier drives a frequency dividing system. The first three integrated-circuit elements are decade dividers, while the fourth is a JK master–slave flip-flop which produces a 60-Hz square wave. This signal, or an external 60-Hz low-level signal, as determined by the position of a rear-mounted switch and set by a panel-mounted control, is supplied as the input to the small integrated-circuit amplifier. The somewhat smoothed 60-Hz output of this amplifier drives the transistor power amplifier. Under normal conditions 20–25 watts of 110-V ac power may be drawn.

The well filtered 12-V rectifier power supply is intended to supply this chassis only, the dc jack provided being for use as an input connection from the floated-battery power supply unit. To facilitate the replacement of parts, the +4.2-V power supply, used for the divider portion of the circuit, is identical with that of the clock. Since 12 V is available from the main chassis, the 12 V rectifier power supply is unnecessary and is not connected to the ac supply. The nickel-cadmium battery serves no purpose here and may be removed from a power supply used for this unit only (see Appendix A).

FLOATING BATTERY CHARGER

Schematic Diagram UAR-415-50C

The provision of a 40–80 A-hour storage battery to supply 12 V dc power will prevent timing and control malfunctions during power interruptions lasting several hours. The clock can operate on 12 V dc (except for the monitor display illumination), and the 60 Hz supply chassis can also operate on 12 V to maintain power to the minute pulse generator, the camera control, and dawn–dusk timer. The charger for the battery may be operated in an automatic or manual control mode, selection being made by interchanging boards in sockets at the rear of the unit. In both cases, after proper adjustments are made the battery will charge up fully as the charge rate decreases to a very low value. After the discharge caused by a power failure, the output current will be limited to a safe value – approximately 8 A, which will recharge the battery while supplying full voltage to the load.

For detailed instructions regarding the adjustment of the settings of the variac and of the voltage control, see Appendix C.

APPENDIX A

Adjustment of Charging Rate of Nickel-Cadmium Batteries in 4.2 V Power Supply

The robust characteristics of the nickel-cadmium batteries are the reason for their use in this application. The type of cell chosen is little damaged by high-rate discharges, by being left in any condition of charge, or by high-rate charges when partially charged. However, when fully charged, any excess over a very small trickle charge is injurious and causes a reduction in life.

Since only short and very occasional power outages are considered normal, it is unlikely that the battery will be fully discharged. When this does arise, the limitation placed on the charging current prevents excessive drain on the rectifier system, and permits full voltage to be available for the counters of the clock immediately, when the ac power is restored. The long time required for the battery to become recharged sufficiently to provide carry-over power is less significant than this feature. The red-handled dummy plug will isolate the battery when this is desirable. However, if the clock is put back into service with this plug in the jack, no carry-over facility exists.

Since it is very difficult to assess the charge condition of these batteries, the following procedure is suggested for setting the output voltage of this power supply: (A wired plug for the break jack is provided, as well as a cable for connecting ac power to an unmounted power supply).

a) Set the voltage to 4.1 and note the charging current.

b) If this drops to below 10 mA in $\frac{1}{2}$ hour or so, increase the voltage to 4.2; if it does not, wait for a day and recheck current.

c) By this means the voltage for which the charging current levels out to 5 and 10 mA is found and this setting left undisturbed. (Use a meter with internal resistance of approximately 2 ohms, such as a Model 260 Simpson multimeter on its 100 mA scale.)

APPENDIX B

Adjustment of Crystal Oscillator in 60-Hz Power Supply

The crystal oscillator in this unit can be adjusted to a stability of a part or two per million – say a second per week. The variable capacitor can be adjusted via the covered hole in the panel. Corrections should be made only when reliable time signals adequately spaced have established that a frequency error exists. Several small discrete adjustments, from a marked position, with a few days of observation following each, should be made.

APPENDIX C

Adjustment of Floating Battery Charger

The optimum conditions are achieved when the battery voltage settles to approximately 14 V, with a charging current of 50–75 mA.

When using the variac control, make small discrete adjustments, from a noted setting. Allow several hours, more if substantial discharge has occurred, for the system to reach equilibrium.

When using the automatic control, make small discrete adjustments of the potentiometer. Note that the voltage will continue to move towards a new value until equilibrium is reached.