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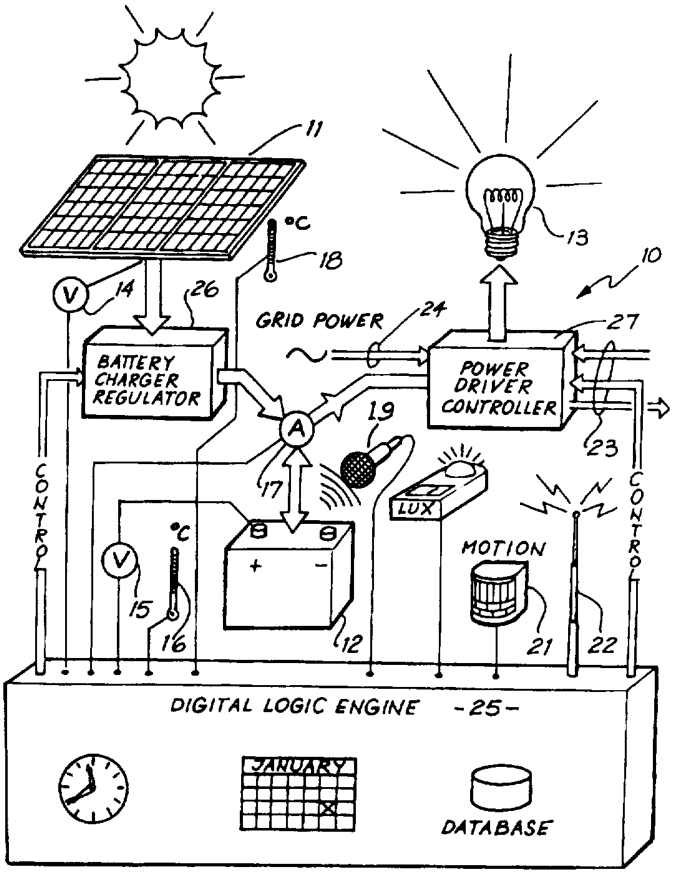
(57) Abstract

The intelligent lighting system (10) maximises available energy collected and stored whilst maximising the life of the storage batteries by monitoring battery voltage (15), PV cell voltage (14), charging current (17), battery temperature (16) and PV cell temperature (18). The storage battery (12) is computer modelled and data from the sensors is processed to ensure optimum charging rates and maximum battery life via battery charger regulator (26). The system (10) also manages utilisation of energy to provide a level of illumination commensurate with demand. Sensors detecting noise (19) and movement (21) enable the system (10) to determine the utilisation of the area being serviced by the lamp (13). The controller processes data reflecting area utilisation, ambient light levels, time-of-day, time-of-year, geographic variables, available stored energy, statistical energy usage patterns to determine how much illumination to provide and when to provide it.



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SOLAR STREET LIGHT CONTROL SYSTEM

Introduction

The present invention relates generally to solar powered lighting systems and in particular the invention provides a lighting system with intelligent power management.

Embodiments of the present invention are directed toward autonomous solar-powered footpath/park/street lamps, centrally-powered multiple lamp systems, warning/advertising signs and billboards, security lighting and emergency lighting supply.

In the prior art, solar powered lighting systems are known wherein standard solar cells, battery accumulators and lighting devices are combined in a conventional manner. However, these prior art systems generally suffer from poor efficiency and/or poor component lifetimes resulting in relatively high overall installation and maintenance cost.

Summary of the Invention

According to a first aspect, the present invention consists in a lighting system comprising photovoltaic energy conversion means arranged to convert light energy into electrical energy, energy storage means arranged to store said electrical energy and to deliver said energy as required, lighting means connected to the energy storage means via power regulating means arranged to control the delivery of power to the lighting means, control means arranged to determine a lighting demand and to control the regulating means to provide power to the lighting means in response to the lighting demand, and proximity detection means arranged to detect the presence of an object or person in or near the illuminated field of the lighting means, the control means being responsive to the proximity detection means when determining the lighting demand.

In a preferred embodiment the proximity detecting means includes a motion detection device and/or an acoustic detection device, such as a microphone, whereby any motion or any sound above a predetermined threshold detected in the vicinity of the lighting means, will create a light demand resulting in an increase in the intensity of the light output of the lamp.

In the preferred embodiment, the control means includes a stored energy monitoring means arranged to monitor flow of energy into and out of the energy storage means and to maintain an indication of currently available stored energy. The control means will preferably adjust the energy delivered to the lighting means in response to lighting demands, available stored energy and time of day in order to maintain reserve lighting capability which is a function of an expected time of remaining darkness.

In the preferred embodiment, the control means maintains lighting demand history statistics and adjusts the anticipated lighting requirement in accordance with those statistics. Preferably the control means will also maintain charging history statistics, determine an expected charging rate for upcoming charging periods and adjust energy usage to increase the probability of long term availability of lighting capability.

In accordance with a second aspect, the present invention consists in a method of controlling a photovoltaic powered lighting system including photovoltaic energy conversion means, battery accumulator means, lighting means, power regulating means for regulating power to the lighting means from the battery accumulator means, proximity detection means and control means, the method comprising the steps of maintaining the lighting means at a predetermined standby state by controlling the power regulating means to supply a standby power level, periodically or continuously monitoring the proximity means to determine if an object or person has moved toward or remains in or near the field of illumination of the lighting means to determine a lighting demand. continuously monitoring the power energy available in the accumulator, determining the demand probability to the next charging period when a lighting demand exists, calculating a maintainable usage rate that will allow the probable demand to be met with the currently available stored energy and regulating power to the lighting means in accordance with the maintainable usage rate while a demand exists.

Preferably the control means will periodically or continuously update the demand probability to the next charging period taking into account current demand and will adjust the maintainable usage rate accordingly.

Brief Description of the Drawings

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 shows a block diagram of an embodiment of the invention; and

Figure 2A-M is a set of flow charts illustrating the programme flow in the controlling programme of the embodiment of Figure 1.

Detailed Description of the Embodiment

In a solar-powered lighting system, it is firstly necessary to collect and store sufficient energy to provide the level of illumination needed for the period required. Such a system must accommodate unfavourable weather conditions and unfavourable geographic locations.

The primary function of a solar-powered lighting system becomes one of resource management, that resource being energy. Referring to Figure 1, incident radiant energy from the sun is converted to electrical energy by the photovoltaic cells 11. This electrical energy is converted to chemical energy by the storage battery 12, where it is stored until required for illumination. When needed, the storage battery 12 converts the stored chemical energy back to electrical energy. The lamp 13 converts this electrical energy back to radiant energy to provide illumination.

All of these processes of energy conversion and storage must be achieved as efficiently as possible to provide an effective solar-powered lighting system. Each of the major energy conversion devices - photovoltaic cells, storage battery and lamp/reflector - are all critical components in achieving the efficiencies desirable for a viable solar lighting system.

The responsibility of managing the energy collection, conversion and storage processes is the function of the Intelligent Solar Lighting System 10 illustrated in Figure 1.

The system 10 must accomplish these tasks while achieving maximum efficiencies, minimum energy losses and ensuring maximum system component life. The system 10 comprises two discrete elements: the system "hardware" and the embedded system "software" represented by the flow charts of Figure 2A-M. It is the controller "software" resident in the Digital Logic Engine 25 that provides the intelligence to drive the solar lighting system energy management.

Prior art attempts at providing solar-powered lighting have been far less ambitious in every major area of development than the arrangement of the present invention. In most cases, off-the-shelf components have been strung together and managed by a control system with minimal intelligence. These attempts have generally resulted in systems with poor life expectancy, frequent maintenance demands, inadequate illumination and significant periods with no illumination.

The tasks of the controller 25 may be clearly divided into two functional areas:

1. the management of collecting, storing and computing energy during daylight;
2. the management of utilising the stored energy for illumination at night.

The controller 25 must ensure that the available energy collected and stored is maximised whilst the life of the storage batteries is also maximised. The controller 25 monitors sensors for battery voltage 15, PV cell voltage 14, charging current 17, battery temperature 16 and PV cell temperature 18. "Dithering" techniques (refer Fig. 2H, item 187) are employed to achieve maximum power point tracking for the PV cells. The storage battery 12 is computer modelled (refer Fig. 2G, items 171-180) and data from the sensors is processed to ensure optimum charging rates and maximum battery life via battery charger/regulator 26. The controller 25 maintains records of energy statistics and varies the computer modelling to predict changes in performance with battery ageing. The collected energy is accurately measured and the available stored energy is computed from the dynamic computer battery modelling.

In managing the utilisation of stored energy, the controller 25 provides a level of illumination commensurate with demand. Sensors detecting noise 19 and movement 21 enable the controller 25 to determine the utilisation of the area being serviced by the lamp. The controller 25 processes data reflecting area utilisation, ambient light levels, time-of-day, time-of-year, geographic variables, available stored energy and statistical energy usage patterns to determine not only when to provide illumination, but how much illumination to provide.

Embodiments of the invention are arranged to efficiently drive any of the following lamp types with variable luminance: Induction, fluorescent, low/high pressure vapour, resonant-transformer metal halide. This range of lamps will provide solutions to lighting applications which have the following disparate demands:

maximum service life, best colour rendering index, lowest capital cost, highest efficiency.

The induction lamp represents a revolutionary new lamp technology. The lamp employs the combination of electromagnetic induction and gas discharge. A ferritecore inductor is excited at a frequency of 2.6 MhZ. The resulting electromagnetic field causes eddy currents to flow in the low-pressure gas, producing ionisation. The resulting recombination radiation in the ultraviolet spectrum causes a coating on the inside wall of the glass envelope to fluoresce.

As there are no filaments or electrodes in the lamp, the lifetime is governed solely by the driving electronics. It is anticipated that a lifetime in the region of 60,000 hours will be achieved. The induction lamp has the following attributes: exceptionally long life, very high efficiency, flicker-free operation, excellent colour rendering index, instantaneous start-up, constant light "quality" with varying illumination.

The extraordinary induction lamp lifetime offers the unique possibility of a hermetically sealed lamp/reflector compartment. This will permit the utilisation of very high performance reflector materials that would normally be damaged by dust or condensation. In turn, this will permit a very highly efficient lamp/optical system to be used.

In an autonomously solar-powered lamp, it is desirable to keep the size of the photovoltaic (PV) array 11 as small as possible in order to reduce the engineering complexities associated with wind loading. It is also desirable to keep the PV array size at a minimum to enable industrial designers to produce an aesthetically acceptable result.

The higher the efficiency of the PV cells 11, the smaller the area required to collect a given amount of energy. However, as the efficiency increases, so does the cost per unit of power collection (dollars/Watt - $/W). As the PV cells are a significant cost component of the system, it is necessary to compromise in maximum efficiency and make a trade off between cost and size.

Recent developments in PV cell technology have resulted in reductions in the amount of costly active material by various combinations of making the PV cells thinner, achieving active surfaces on both sides of the cell and using light concentration techniques. This latter technique is seeing significant and rapid reductions in the dollar/Watt variable.

It is ultimately intended to provide an embodiment of the invention fitted with a battery having a 15 year life, however, no current commercially available battery has characteristics which meet this specification.

The present embodiment of the present invention is fitted with less than the optimum battery but is designated to accommodate an updated battery type when higher performance batteries are available.

A "wireless" communications link 22 is provided between individual lamps in a system. This radio communications network enables:

*Synchronised lamp switch-on;

*Collection of system performance statistics;

*Reporting of system anomalies;

*Changes to system operating parameters;

*Override of system automatic control;

*Shared intelligence between lighting controllers in a network;

*Telemetry of remote sensors for system control;

*Processing of sensor triggers for security;

*Communication of text and speech messages.

In some embodiments employing a network of lamp systems a centralised "node" will enable:

*System connection to a remote monitor/control;

*Security monitoring for system tamper;

*Precision reference for synchronous switch-on;

*Distribution of central messages (see "Speech Message Annunciation").

To enable the efficient distribution of power to lamps in centrally-powered systems, embodiments of the invention will include a power transmission system 23 to transmit electrical energy between units with minimum losses. This is achieved through HF power transmission over low-loss RF transmission lines. This feature also enables a solution to the problem of differential shading in autonomous-supply lighting, by sharing collected energy between neighbouring units.

A power controller 27 is also provided to channel energy directly from the storage batteries, from the HF power network, or energy from an existing power grid 24. This approach enables solar energy to supplement existing energy supply, or to provide emergency lighting in the absence of grid supply. The controller 25 provides the "intelligence" to select the energy source and control the amount of energy delivered to the lamp(s).

As the lamps provide useful sites for speech messages, a system of speech annunciation may also be incorporated into some embodiments of the invention. This system enables pre-recorded digitally stored speech messages to be delivered upon sensing the presence of a person. Warning messages associated with environmental factors, such as UV radiation levels, could be initiated automatically local sensors.

The "wireless" communications link will support digital speech message packets, enabling real-time speech messages to be originated at a central node and distributed to the network.

Referring to Figure 2, Figures 2A-2E illustrate, Reset, Initialization and Executive functions of the controller and the operation of these functions will be readily understood by a skilled addressee. Similarly, Figures 2L and 2M illustrate simple interrupt routines which will also be readily understood.

Referring to Figure 2F, this illustrates the operation of a section of the control program known as the day/night supervisor. When control is passed to this section of the program, a test 161 is performed to test a day/night flag and if the flag is set to indicate that it is presently daytime, control passes to a first path 162. In the daytime path 162 a test 163 is performed to determine if the time of day agrees with the day/night flag and if not, the state of the flag is changed 164 to "Early Night" recognising that the time must have just passed the transition from day to early night. The night/day decision is based on stored information of year round clear sky light levels for the lamp location. In the event that the time of day test 163 indicates that it is still daytime, an ambient light test 165 is performed and if this indicates a low ambient light level (eg. due to cloud cover) then the day/night flag will again be set 164 to Early Night. In the event that the ambient light test 165 indicates a daytime light level, control is passed to the day supervisor Routine (refer Fig. 2G). Otherwise, when the day/night flag is set to early night, control signals are initiated 166 to slowly ramp the lamp output from off to the current maximum threshold. The ambient light threshold of the light detection subsystem is then increased 167 to allow for the output of the lamp and minor fluctuations in ambient illumination.

In the event that the test 161 indicates that the day/night flag is set to early night, a time of day test 168 is performed and if this test confirms that the time is early night, control reverts to the Supervisor Background Routine (refer Fig. 2J). Otherwise, the day/night flag is set to "Late Night" 169 and control signals are initiated 170 to ramp down the light output of the lamp to the current minimum threshold. Control is then handed over to the late night supervisor (refer Fig. 2I) awaiting an indication of activity in the area covered by the lamp (see later description of late night supervisor).

In the event that test 161 indicates that the day/night flag is set to late night, a time of day test 261 and ambient light test 262 are performed and if these indicate that the day/night flag is correct, control is passed to the Late Night Supervisor Routine of the program (refer Fig. 2I), otherwise the day/night flag is set to day 263 control signals are initiated 264 to turn off the lamp, the ambient light threshold is decreased 265 and control is passed to the Supervisor Background Routine (refer Fig. 2J).

Turning to Figure 2G, the Day Supervisor routine first performs a number of steps to check the status of the battery including reading the measurement of ambient and battery temperature 171; reading the measurement of battery voltage 172; reading a measurement of change in energy stored 173 and testing the computer model of the battery 174 and 175 to determine if the model is still valid. In the event that the model is not valid the model parameters are revised 176.

The battery model is then used to compute the total stored energy 177 and to determine if the battery is fully charged 178. In the event that the battery is fully charged, the state of the charger is tested 179 and if on, control signals are initiated 180 to turn the charger off and control is returned to the Supervisor Background Routine (refer to Fig. 2J).

If the battery is not fully charged, the program goes on to check the charging conditions (refer Fig. 2H). Firstly, the charge rate is checked 181 and if below maximum the current charge current is measured 182 and the optimum charge current computed 183 and compared 184 with the actual current. If the charging current is not optimum the charging rate is adjusted 185 and the charging status updated 186.

In the event that the charging rate is at maximum the PV cell voltage and temperature are measured 287, the charge current is measured 188; the maximum power point of the PV cell is computed 189 and Dither processing is performed 190. The operating parameters are then compared with the computed maximum power point 181 to determine if charging is optimal and if not the Dither flags are updated 187 and the charging rate adjusted 282. The energy storage statistics are then updated and control is passed to the Supervisor Background Routine (refer 15 Fig. 2J).

Turning to Figure 2I, the control flow for the Late Night Supervisor Routine of the program is illustrated. In this routine, the lamp status is first tested to determine if the lamp output is high or ramping up and in each case control passes immediately back to the Supervisor Background Routine.

If the lamp status indicates that the lamp output is low or ramping down the motion status, noise status and telemetry status are tested 192, 193, 194 to determine if there is any reason to increase light output, such as detection of motion or as the result of a telemetry signal requesting a change. If no change is required control reverts to the Supervisor Background

Routine (refer Fig. 2J), otherwise control signals are initiated 195 to ramp the lamp output up and the sensor block flag is set 196 before returning control to the Supervisor Background Routine.

Turning to Figures 2J and 2K, these show the flow of the controller program in the Supervisor Background Routine. This section of the program performs housekeeping tasks and switches control to other sections of the control program.

The first task that the Supervisor Background Routine performs is to transfer all real-time calls to poll service 301, after which a day/night test is performed 302 to switch control to the relevant part of the supervisor program. If it is currently night time (i.e. lights on and no charging) the energy usage is measured 303 the remaining stored energy computed 304 and energy usage projections computed 305.

A test 306 then determines whether it is currently late night or early night and energy reserves are compared with expected demand 307, 308. In the event that energy levels are good the energy use statistics are updated 314 (refer Fig. 2K), whereas if energy reserves are low the maximum light levels are adjusted 309,310 and in the case of late night operation the time-out values are adjusted 401 before control passes to the second part of the Supervisor Background Routine shown in Fig. 2K.

In the event that the energy level is critical the lamp status is tested 402, the lamp turned off 403 and the shutdown flag set 404, if necessary, before passing control to the Executive Task Supervisor Routine (refer Fig. 2C).

Referring to Figure 2K, when control is passed into point K, the lamp status is tested 311 and if not correct, relative to current maximum light levels etc, the lamp output is adjusted 312 the battery model revised 313 and the energy use statistics updated 314.

Finally the Supervisor Background Routine performs periodic housekeeping tasks 315, performs diagnostics tests, 316, 317, tests the diagnostic status 318, sets error flags 319,320 in accordance with the outcome of the diagnostic test and returns control to the Executive Task

Supervisor Routine (refer Fig. 2C). The Executive Task Supervisor Routine then responds to any error flags, if set, or if no errors exist passes control back to the Day/Night Supervisor Routine (refer Fig. 2F), the Day Supervisor Routine (refer Fig. 2G) or the Supervisor Background Routine (refer Figs. 2J & 2K).

It is also proposed to utilise a modified version of the demand management control system described herein for lighting systems not powered by photovoltaic sources but powered from the electric power grid. It is envisaged that the concept of a level of illumination commensurate with demand when applied to existing street lighting systems, could yield significant benefits via energy savings and carbon dioxide (CO^2) reductions.

It is proposed that such control systems could be retro-fitted to existing street lighting installations or supplied as component parts of new street lighting proposals.

Referring to Figure 1, the following components would be deleted from such a mains grid powered system:

Photovoltaic array 11,
Battery charger regulator 26,
Storage battery 12,
Voltage measurement devices 14 and 15,
Current measurement device 17,
Temperature sensors 16 and 18.

Figure 1, communications (22), may be either by radio link or signalling over the existing power network.

Referring to the flow charts of figure 2A-M, the control system software would have the following modifications:

General

The 'Day Supervisor' (Figures 2F and 2H) would be deleted. Any existing calls to the 'Day Supervisor' would call the 'Supervisor background' (Figure 2J) instead.

'Supervisor Background' (Figures 2J and 2K)

After 'transfer all real time to poll flags' 301, control is transferred to (K) of Figure 2K. The remainder of Figure 2J is redundant. Functions 313 (revise battery model) and 314 (update energy use statistics) of Figure 2K would be deleted.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS:

1. A lighting system comprising photovoltaic energy conversion means arranged to convert light energy into electrical energy, energy storage means arranged to store said electrical energy and to deliver said energy as required, lighting means connected to the energy storage means via power regulating means arranged to control the delivery of power to the lighting means, control means arranged to determine a lighting demand and to control the regulating means to provide power to the lighting means in response to the lighting demand, and proximity detection means arranged to detect the presence of an object or person in or near the illuminated field of the lighting means, the control means being responsive to the proximity detection means when determining the lighting demand.

2. The system of claim 1 in which the proximity detecting means includes a motion detection device.

3. The system of claim 1 or 2 in which the proximity detecting means includes acoustic detection device.

4. The system of claim 3 in which the acoustic detection device is a microphone acoustic detection device.

5. The system as claimed in any one of claims 1-4 wherein the control means is arranged such that any motion or any sound above a predetermined threshold detected in the vicinity of the lighting means, will create a light demand resulting in an increase in the intensity of the light output of the lamp above a standby level.

6. The system as claimed in any one of claims 1 to 5 wherein the control means includes a stored energy monitoring means arranged to monitor flow of energy into and out of the energy storage means and to maintain an indication of currently available stored energy.

7. The system as claimed in claim 6 wherein the control means is arranged to adjust the energy delivered to the lighting means in response to lighting demands, available stored energy and time of day in order to

maintain reserve lighting capability which is a function of an expected time of remaining darkness.

8. The system as claimed in any one of claims 1-7 wherein the control means maintains lighting demand history statistics and adjusts the anticipated lighting requirement in accordance with those statistics.

9. The system as claimed in any one of claims 1-8 wherein the control means maintains charging history statistics, determines an expected charging rate for upcoming charging periods and adjusts energy usage to increase the probability of long term availability of lighting capability.

10. A method of controlling a photovoltaic powered lighting system including photovoltaic energy conversion means, battery accumulator means, lighting means, power regulating means for regulating power to the lighting means from the battery accumulator means, proximity detection means and control means, the method comprising the steps of maintaining the lighting means at a predetermined standby state by controlling the power regulating means to supply a standby power level, periodically or continuously monitoring the proximity means to determine if an object or person has moved toward or remains in or near the field of illumination of the lighting means to determine a lighting demand and increasing the supplied power level from the standby level as required in accordance with the demand.

11. The method of claim 10 including the step of monitoring the power energy available in the accumulator.

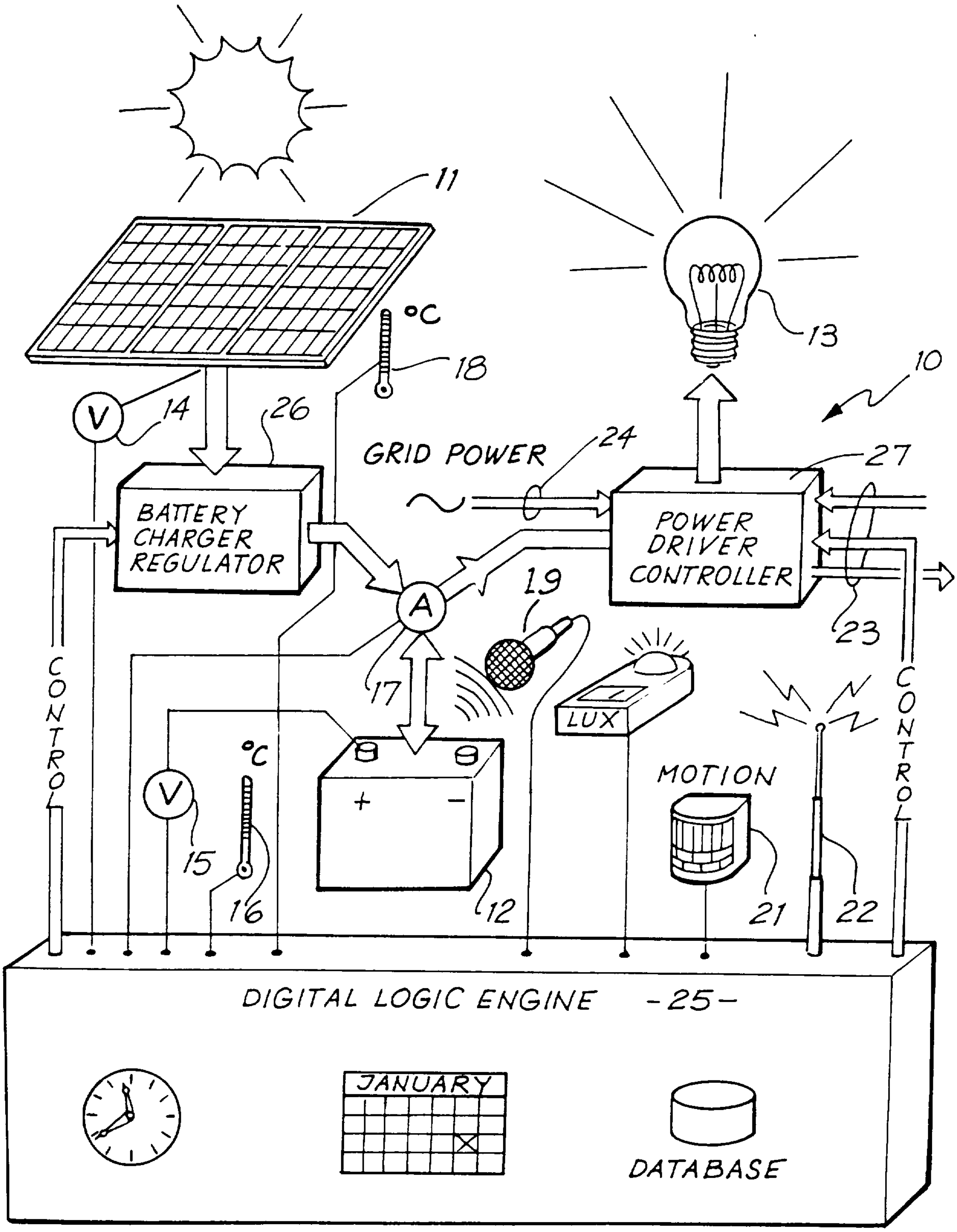
12. The method of claim 11 including the step of determining the demand probability to the next charging period.

13. The method of claim 12 including the step of calculating a maintainable usage rate that will allow the probable demand to be met with the currently available stored energy.

14. The method of claim 13 including regulating the power to the lighting means in accordance with the maintainable usage rate while a demand exists.

15. The method of claim 14 including the step of periodically or continuously updating the demand probability to the next charging period taking into account current demand.

16. The method of claim 15 including the step of recalculating the maintainable usage rate in response to the updated demand probability and adjusting the power level supplied when a demand exists.


11
°C
18
13
10
V
14
26
GRID POWER
24
27
BATTERY CHARGER REGULATOR
POWER DRIVER CONTROLLER
A
19
23
CONTROL
17
LUX
CONTROL
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MOTION
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15
16
12
21
22
DIGITAL LOGIC ENGINE -25-
JANUARY
DATABASE

FIG. 1

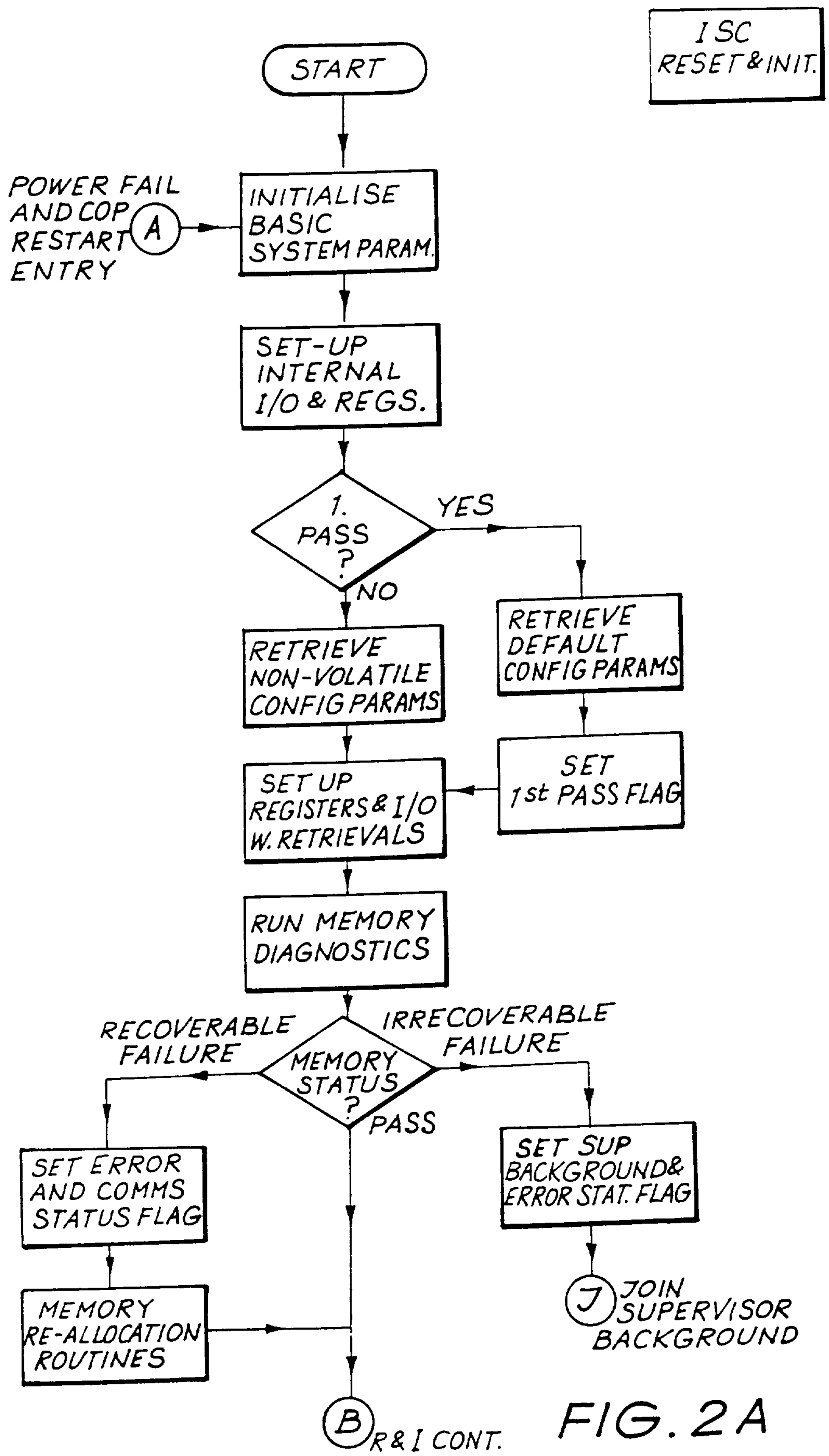

I SC
RESET & INIT.
START
POWER FAIL AND COP RESTART ENTRY
A
INITIALISE BASIC SYSTEM PARAM.
SET-UP INTERNAL I/O & REGS.
1. PASS ?
YES
NO
RETRIEVE DEFAULT CONFIG PARAMS
RETRIEVE NON-VOLATILE CONFIG PARAMS
SET 1st PASS FLAG
SET UP REGISTERS & I/O W. RETRIEVALS
RUN MEMORY DIAGNOSTICS
RECOVERABLE FAILURE
IRRECOVERABLE FAILURE
MEMORY STATUS ?
PASS
SET ERROR AND COMMS STATUS FLAG
SET SUP BACKGROUND & ERROR STAT. FLAG
MEMORY RE-ALLOCATION ROUTINES
J
JOIN SUPERVISOR BACKGROUND
B
R & I CONT.

FIG. 2A

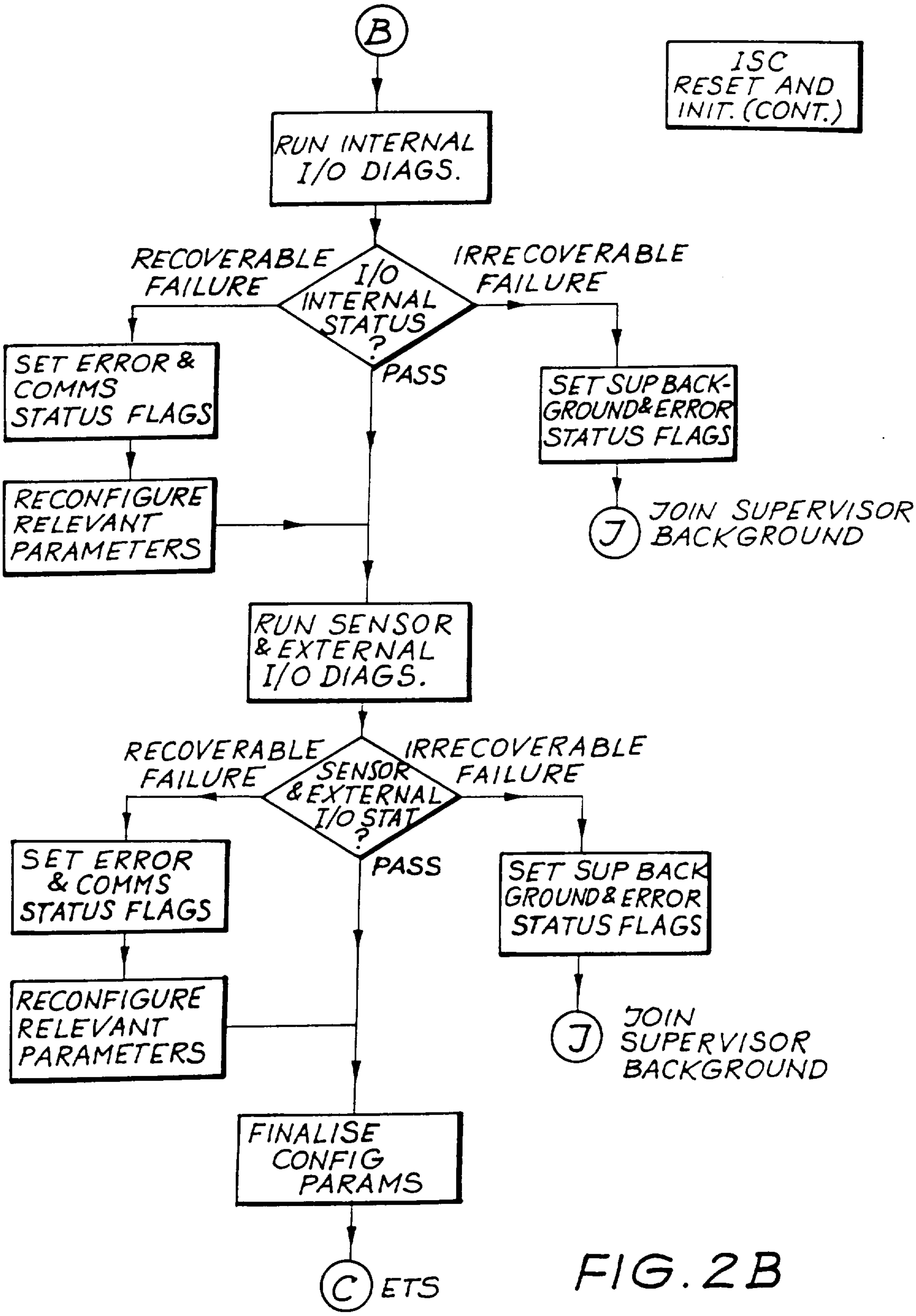
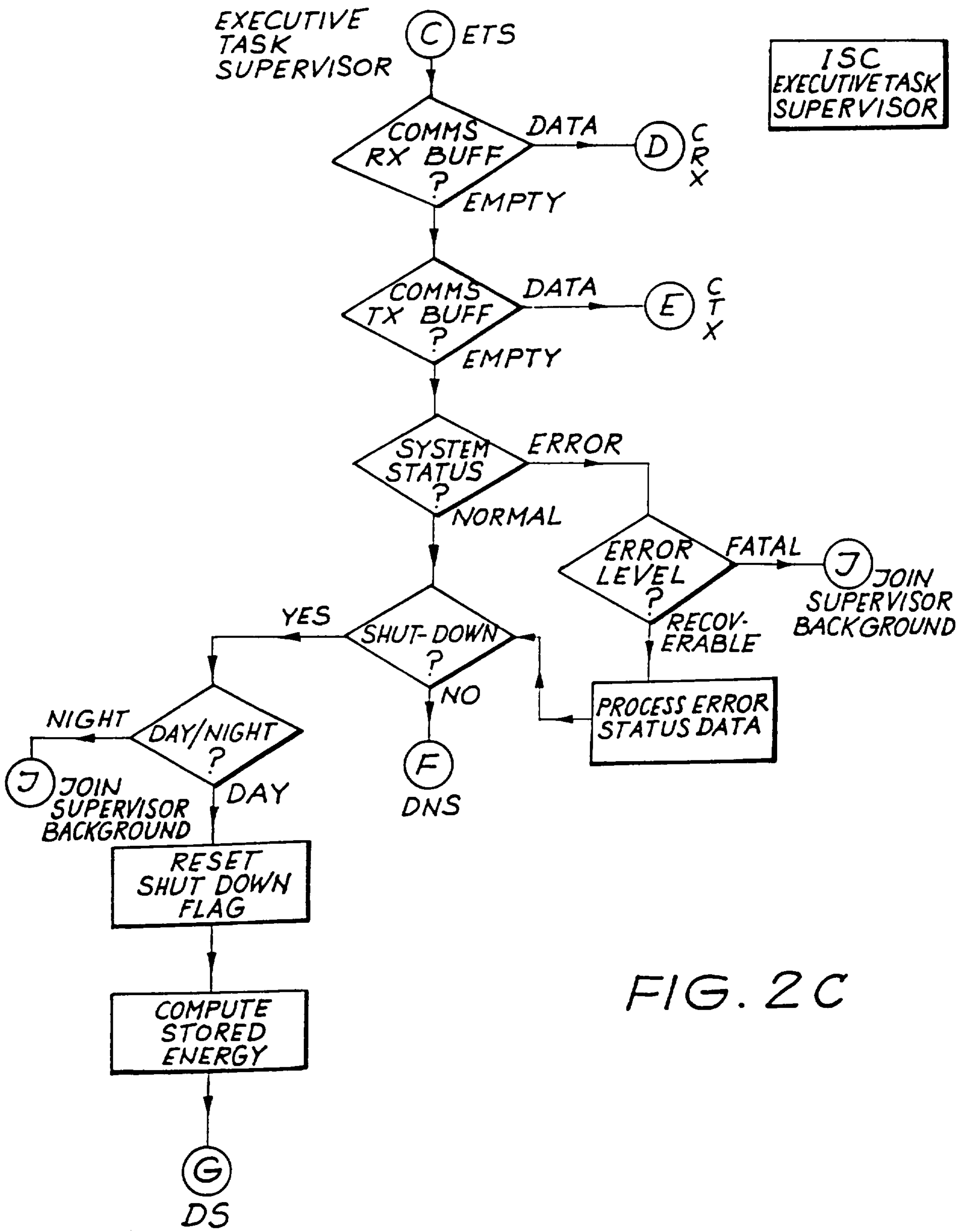

B
ISC
RESET AND
INIT. (CONT.)
RUN INTERNAL
I/O DIAGS.
RECOVERABLE
FAILURE
I/O
INTERNAL
STATUS
?
IRRECOVERABLE
FAILURE
PASS
SET ERROR &
COMMS
STATUS FLAGS
SET SUP BACK-
GROUND & ERROR
STATUS FLAGS
RECONFIGURE
RELEVANT
PARAMETERS
J
JOIN SUPERVISOR
BACKGROUND
RUN SENSOR
& EXTERNAL
I/O DIAGS.
RECOVERABLE
FAILURE
SENSOR
& EXTERNAL
I/O STAT
?
IRRECOVERABLE
FAILURE
PASS
SET ERROR
& COMMS
STATUS FLAGS
SET SUP BACK
GROUND & ERROR
STATUS FLAGS
RECONFIGURE
RELEVANT
PARAMETERS
J
JOIN
SUPERVISOR
BACKGROUND
FINALISE
CONFIG
PARAMS
C
ETS

FIG. 2B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C
ETS
ISC EXECUTIVE TASK SUPERVISOR
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DATA
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E
CTX
EMPTY
SYSTEM STATUS ?
ERROR
NORMAL
ERROR LEVEL ?
FATAL
J
JOIN SUPERVISOR BACKGROUND
RECOV-ERABLE
PROCESS ERROR STATUS DATA
SHUT-DOWN ?
YES
NO
F
DNS
DAY/NIGHT ?
NIGHT
J
JOIN SUPERVISOR BACKGROUND
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RESET SHUT DOWN FLAG
COMPUTE STORED ENERGY
G
DS

FIG. 2C

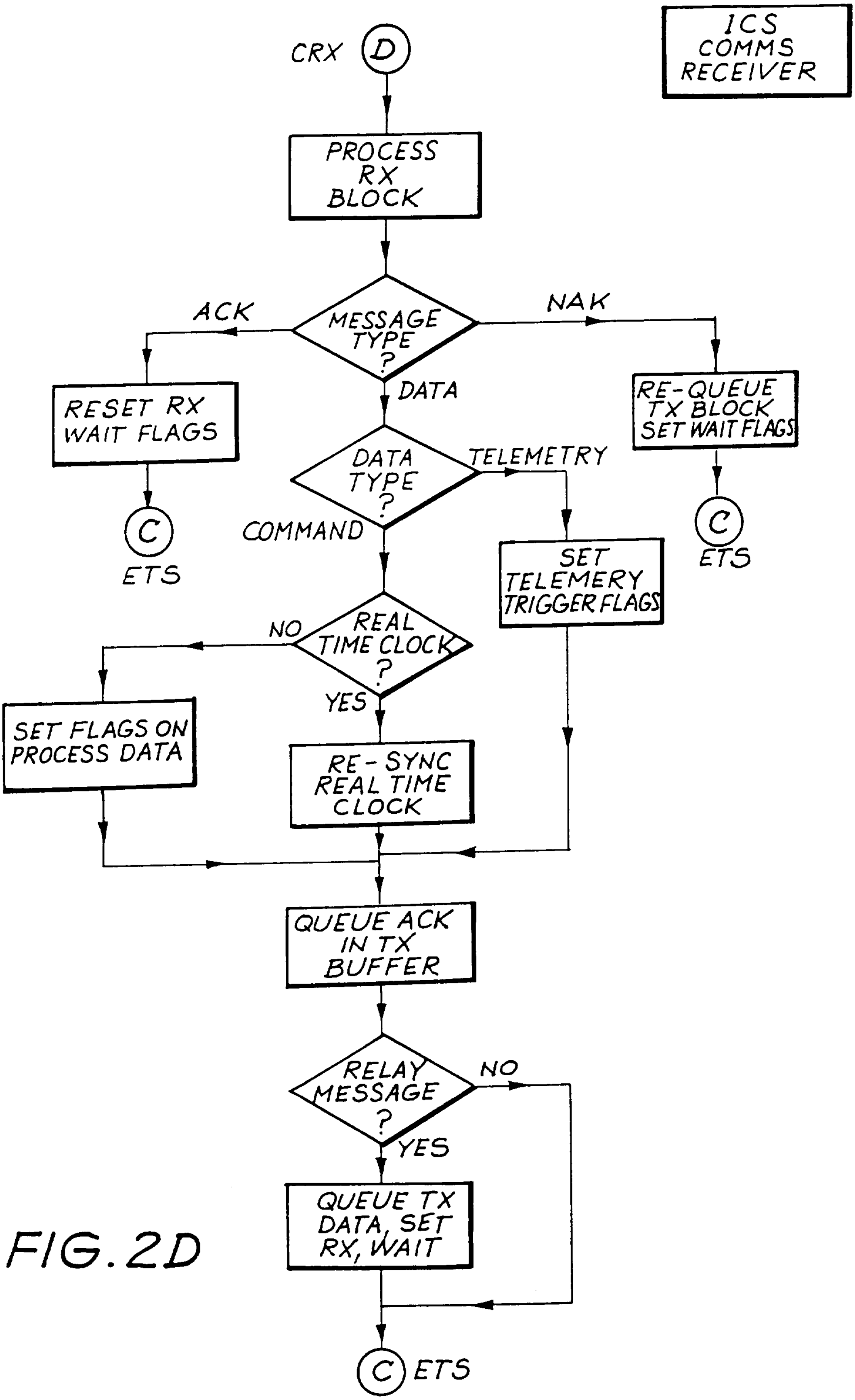
ICS
COMMS
RECEIVER
CRX
D
PROCESS
RX
BLOCK
MESSAGE
TYPE
?
ACK
NAK
DATA
RESET RX
WAIT FLAGS
C
ETS
RE-QUEUE
TX BLOCK
SET WAIT FLAGS
C
ETS
DATA
TYPE
?
TELEMETRY
COMMAND
SET
TELEMERY
TRIGGER FLAGS
REAL
TIME CLOCK
?
NO
YES
SET FLAGS ON
PROCESS DATA
RE-SYNC
REAL TIME
CLOCK
QUEUE ACK
IN TX
BUFFER
RELAY
MESSAGE
?
NO
YES
QUEUE TX
DATA, SET
RX, WAIT
C
ETS

FIG. 2D

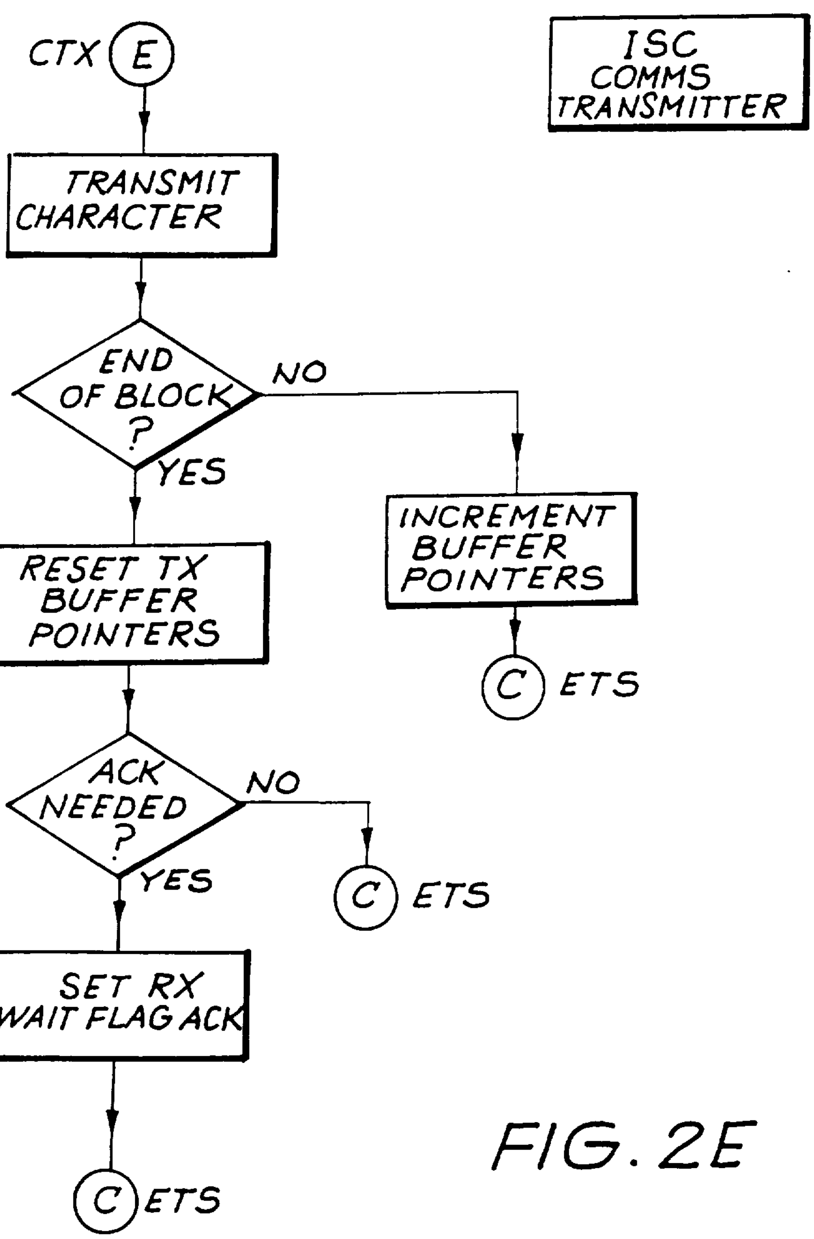
ISC COMMS TRANSMITTER
CTX
E
TRANSMIT CHARACTER
END OF BLOCK ?
NO
YES
INCREMENT BUFFER POINTERS
C
ETS
RESET TX BUFFER POINTERS
ACK NEEDED ?
NO
YES
C
ETS
SET RX WAIT FLAG ACK
C
ETS

FIG. 2E

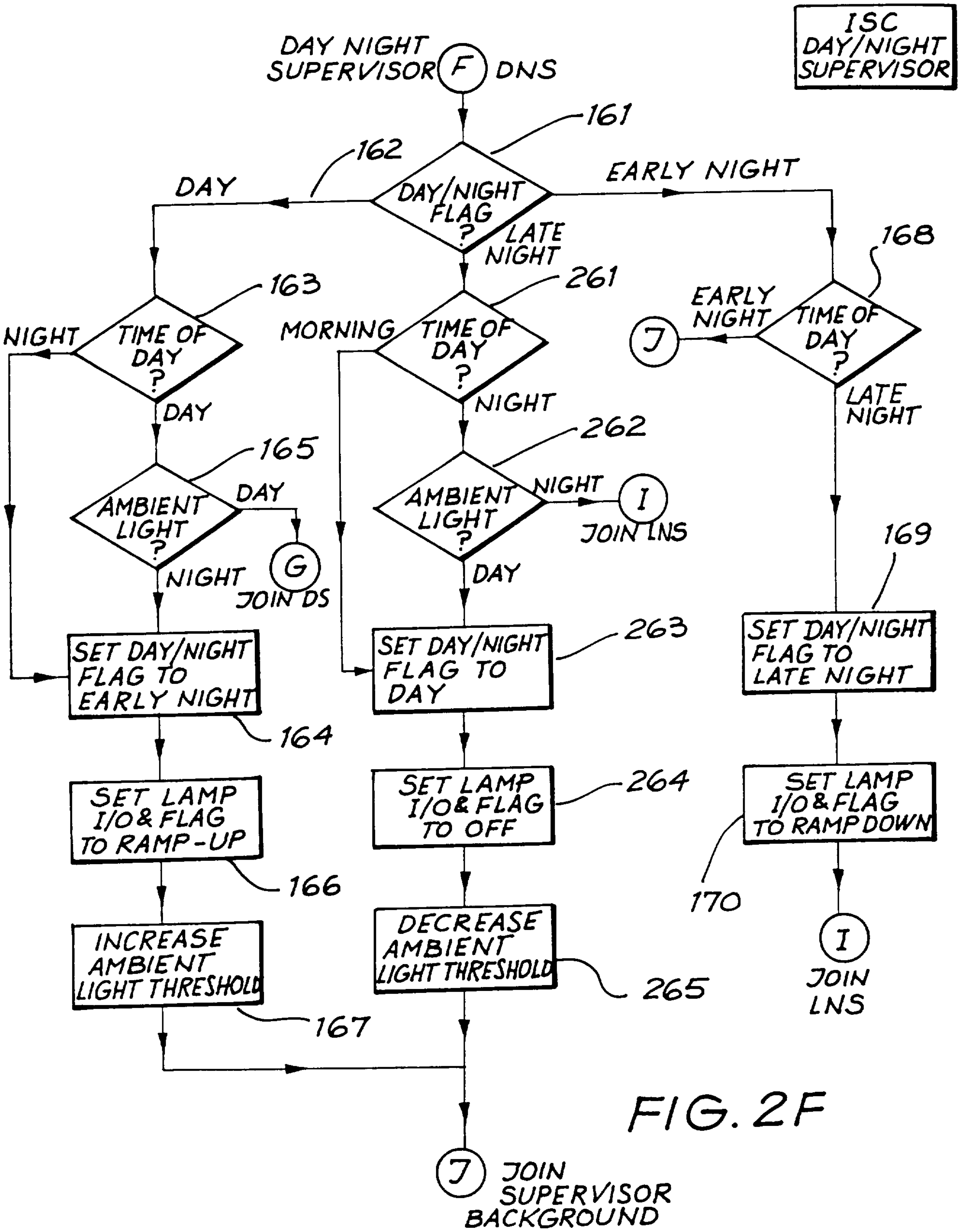
ISC
DAY/NIGHT
SUPERVISOR
DAY NIGHT SUPERVISOR
F
DNS
161
162
DAY
DAY/NIGHT FLAG ?
EARLY NIGHT
LATE NIGHT
163
TIME OF DAY ?
NIGHT
DAY
261
MORNING
TIME OF DAY ?
NIGHT
168
EARLY NIGHT
J
TIME OF DAY ?
LATE NIGHT
165
AMBIENT LIGHT ?
DAY
G
JOIN DS
NIGHT
262
AMBIENT LIGHT ?
NIGHT
I
JOIN LNS
DAY
169
SET DAY/NIGHT FLAG TO EARLY NIGHT
164
SET DAY/NIGHT FLAG TO DAY
263
SET DAY/NIGHT FLAG TO LATE NIGHT
SET LAMP I/O & FLAG TO RAMP-UP
166
SET LAMP I/O & FLAG TO OFF
264
SET LAMP I/O & FLAG TO RAMP DOWN
170
INCREASE AMBIENT LIGHT THRESHOLD
167
DECREASE AMBIENT LIGHT THRESHOLD
265
I
JOIN LNS
J
JOIN SUPERVISOR BACKGROUND

FIG. 2F

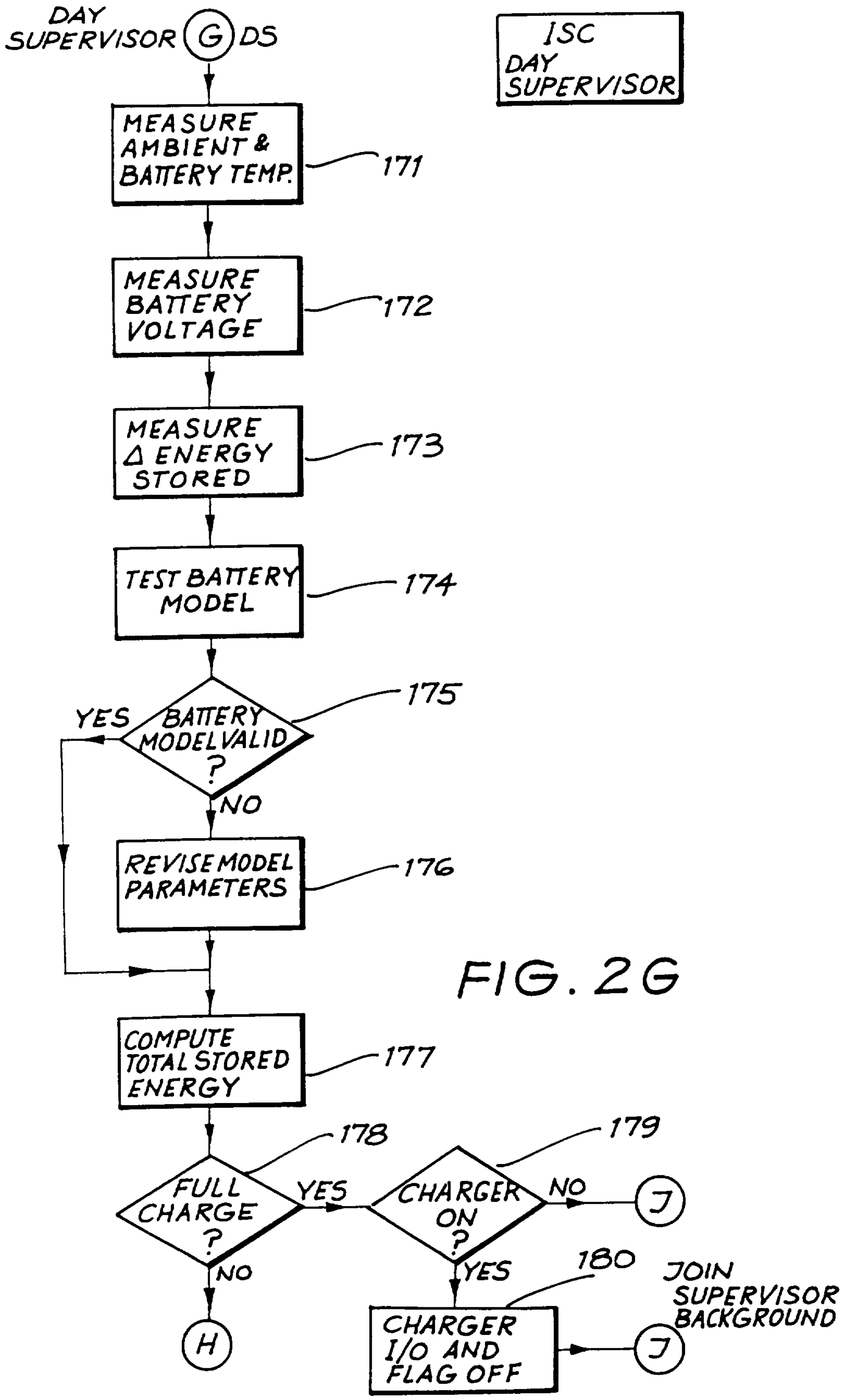
DAY SUPERVISOR
G
DS
ISC DAY SUPERVISOR
MEASURE AMBIENT & BATTERY TEMP.
171
MEASURE BATTERY VOLTAGE
172
MEASURE Δ ENERGY STORED
173
TEST BATTERY MODEL
174
BATTERY MODEL VALID ?
175
YES
NO
REVISE MODEL PARAMETERS
176
COMPUTE TOTAL STORED ENERGY
177
FULL CHARGE ?
178
YES
NO
H
CHARGER ON ?
179
NO
J
YES
CHARGER I/O AND FLAG OFF
180
J
JOIN SUPERVISOR BACKGROUND

FIG. 2G

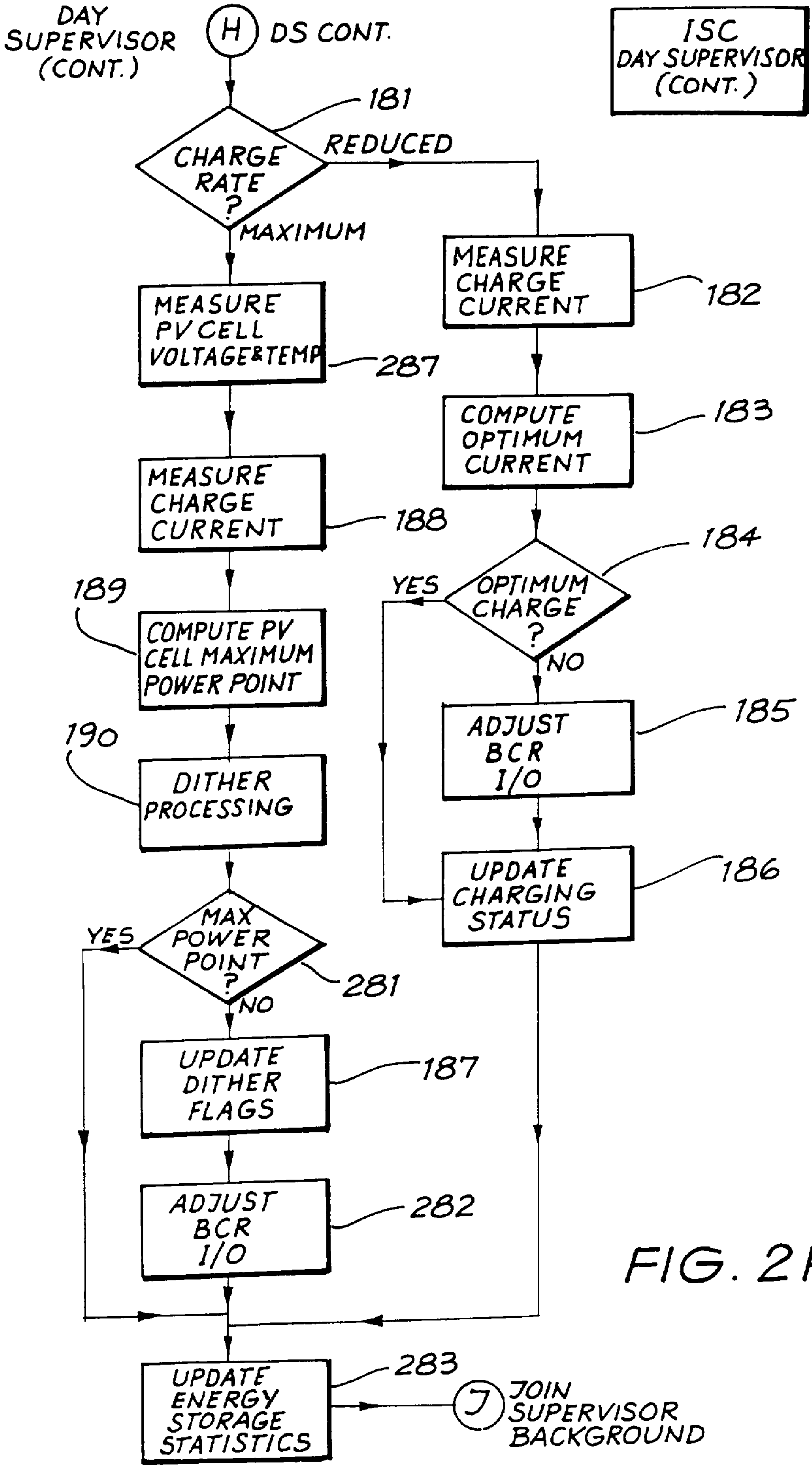
DAY SUPERVISOR (CONT.)
H
DS CONT.
ISC DAY SUPERVISOR (CONT.)
181
CHARGE RATE ?
REDUCED
MAXIMUM
MEASURE PV CELL VOLTAGE&TEMP
287
MEASURE CHARGE CURRENT
182
MEASURE CHARGE CURRENT
188
COMPUTE OPTIMUM CURRENT
183
184
189
COMPUTE PV CELL MAXIMUM POWER POINT
YES
OPTIMUM CHARGE ?
NO
190
DITHER PROCESSING
ADJUST BCR I/O
185
UPDATE CHARGING STATUS
186
YES
MAX POWER POINT ?
NO
281
UPDATE DITHER FLAGS
187
ADJUST BCR I/O
282
UPDATE ENERGY STORAGE STATISTICS
283
J
JOIN SUPERVISOR BACKGROUND

FIG. 2H

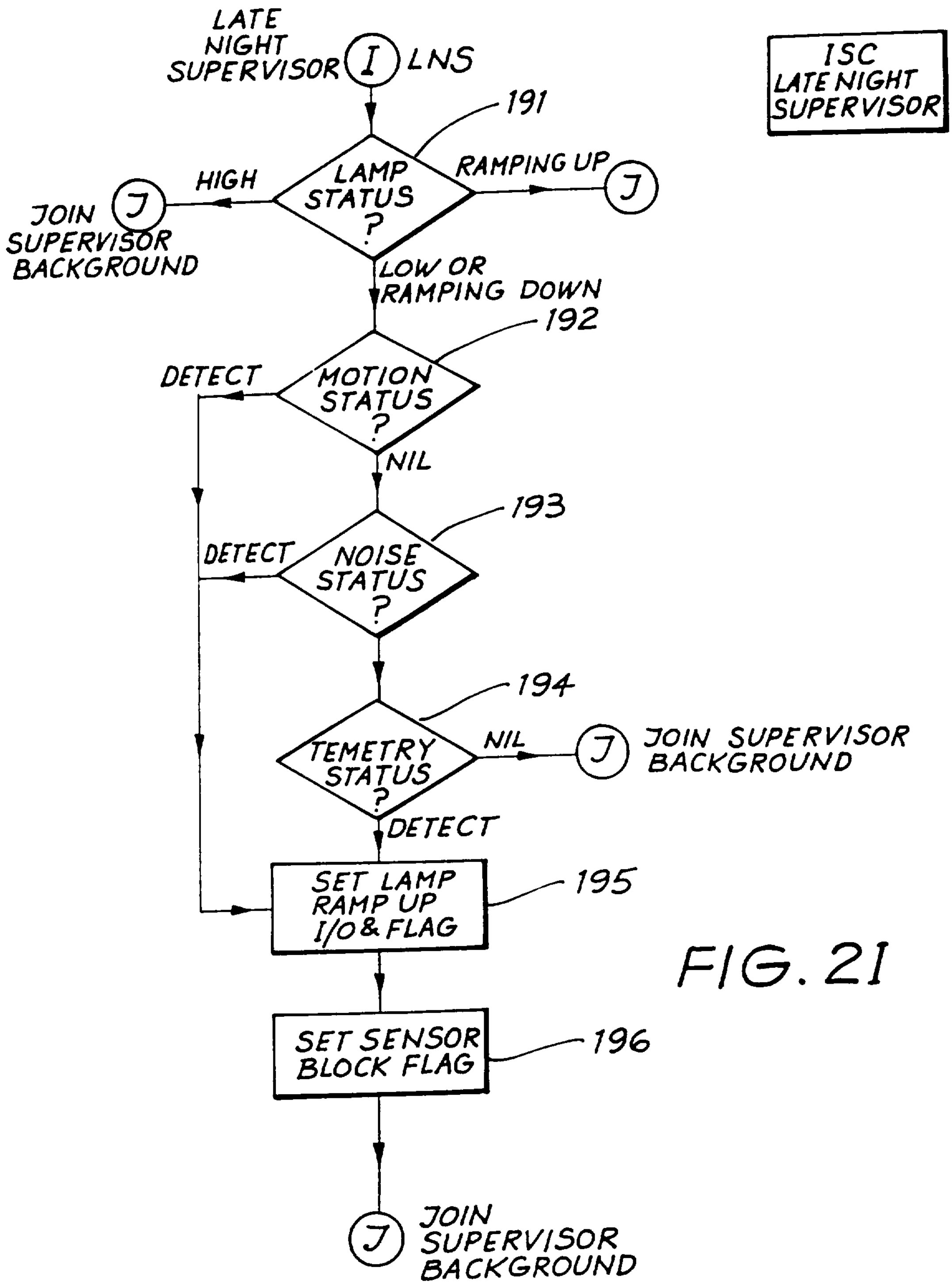
LATE NIGHT SUPERVISOR
I
LNS
ISC LATE NIGHT SUPERVISOR
191
LAMP STATUS ?
HIGH
JOIN SUPERVISOR BACKGROUND
J
RAMPING UP
J
LOW OR RAMPING DOWN
192
MOTION STATUS ?
DETECT
NIL
193
NOISE STATUS ?
DETECT
194
TEMETRY STATUS ?
NIL
J
JOIN SUPERVISOR BACKGROUND
DETECT
SET LAMP RAMP UP I/O & FLAG
195
SET SENSOR BLOCK FLAG
196
J
JOIN SUPERVISOR BACKGROUND

FIG. 2I

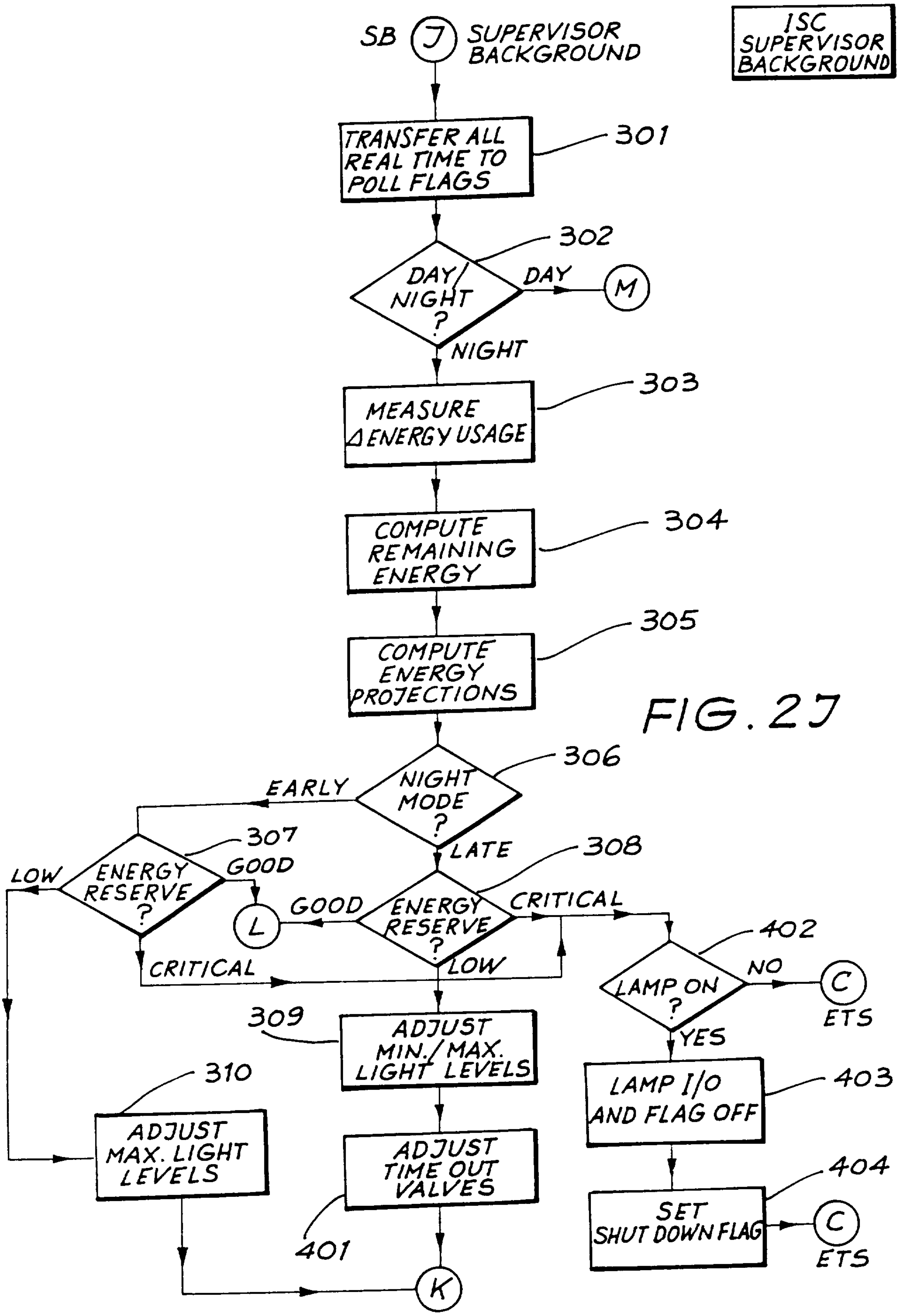
ISC SUPERVISOR BACKGROUND
SB
J
SUPERVISOR BACKGROUND
TRANSFER ALL REAL TIME TO POLL FLAGS
301
DAY/ NIGHT ?
302
DAY
M
NIGHT
MEASURE Δ ENERGY USAGE
303
COMPUTE REMAINING ENERGY
304
COMPUTE ENERGY PROJECTIONS
305
NIGHT MODE ?
306
EARLY
LATE
ENERGY RESERVE ?
307
LOW
GOOD
L
CRITICAL
ENERGY RESERVE ?
308
GOOD
CRITICAL
LOW
LAMP ON ?
402
NO
C
ETS
YES
ADJUST MIN./MAX. LIGHT LEVELS
309
ADJUST MAX. LIGHT LEVELS
310
ADJUST TIME OUT VALVES
401
K
LAMP I/O AND FLAG OFF
403
SET SHUT DOWN FLAG
404
C
ETS

FIG. 2J

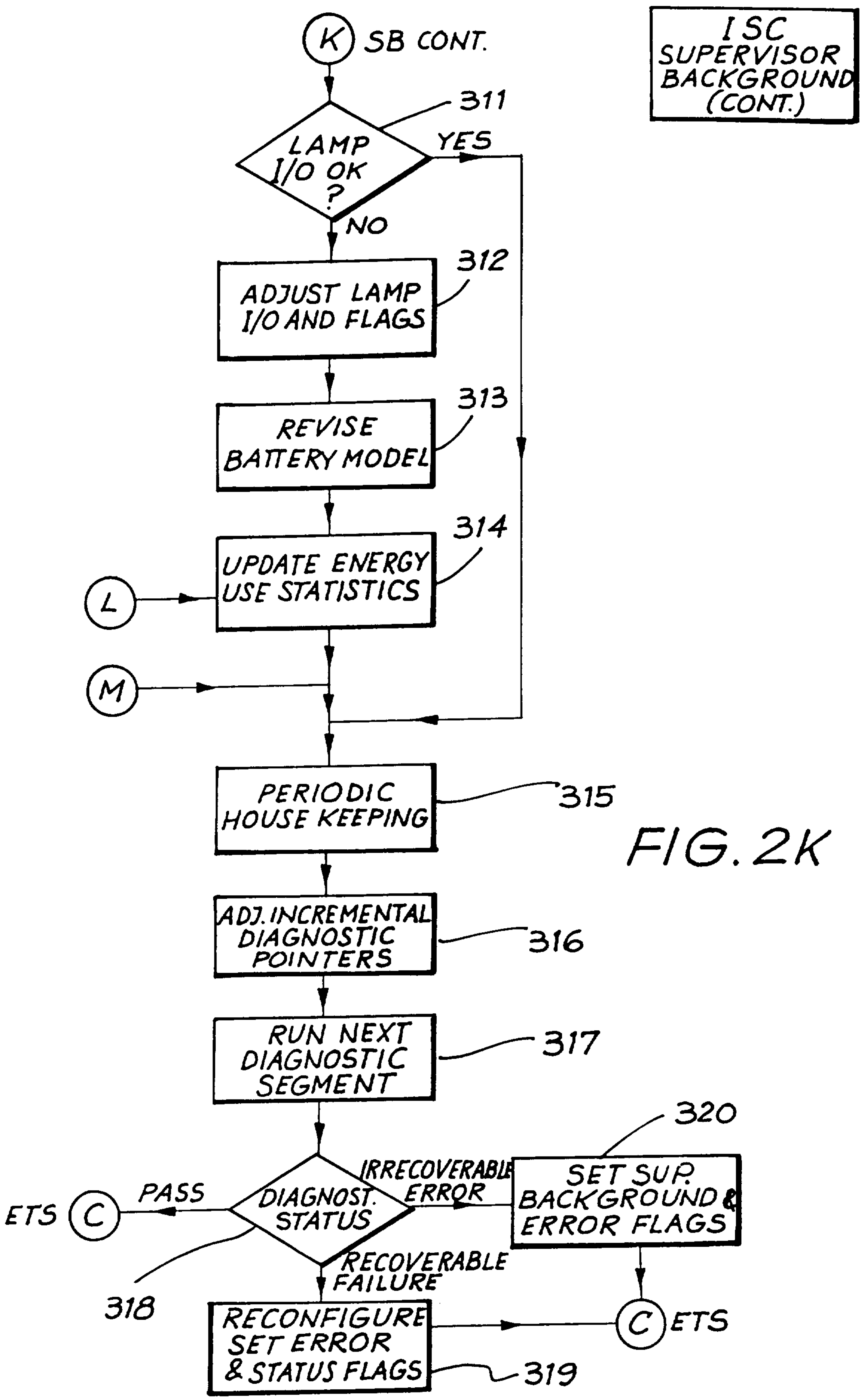
ISC SUPERVISOR BACKGROUND (CONT.)
K SB CONT.
311
LAMP I/O OK ?
YES
NO
ADJUST LAMP I/O AND FLAGS
312
REVISE BATTERY MODEL
313
UPDATE ENERGY USE STATISTICS
314
L
M
PERIODIC HOUSE KEEPING
315
ADJ. INCREMENTAL DIAGNOSTIC POINTERS
316
RUN NEXT DIAGNOSTIC SEGMENT
317
DIAGNOST. STATUS
318
PASS
ETS C
IRRECOVERABLE ERROR
SET SUP. BACKGROUND & ERROR FLAGS
320
RECOVERABLE FAILURE
RECONFIGURE SET ERROR & STATUS FLAGS
319
C ETS

FIG. 2K

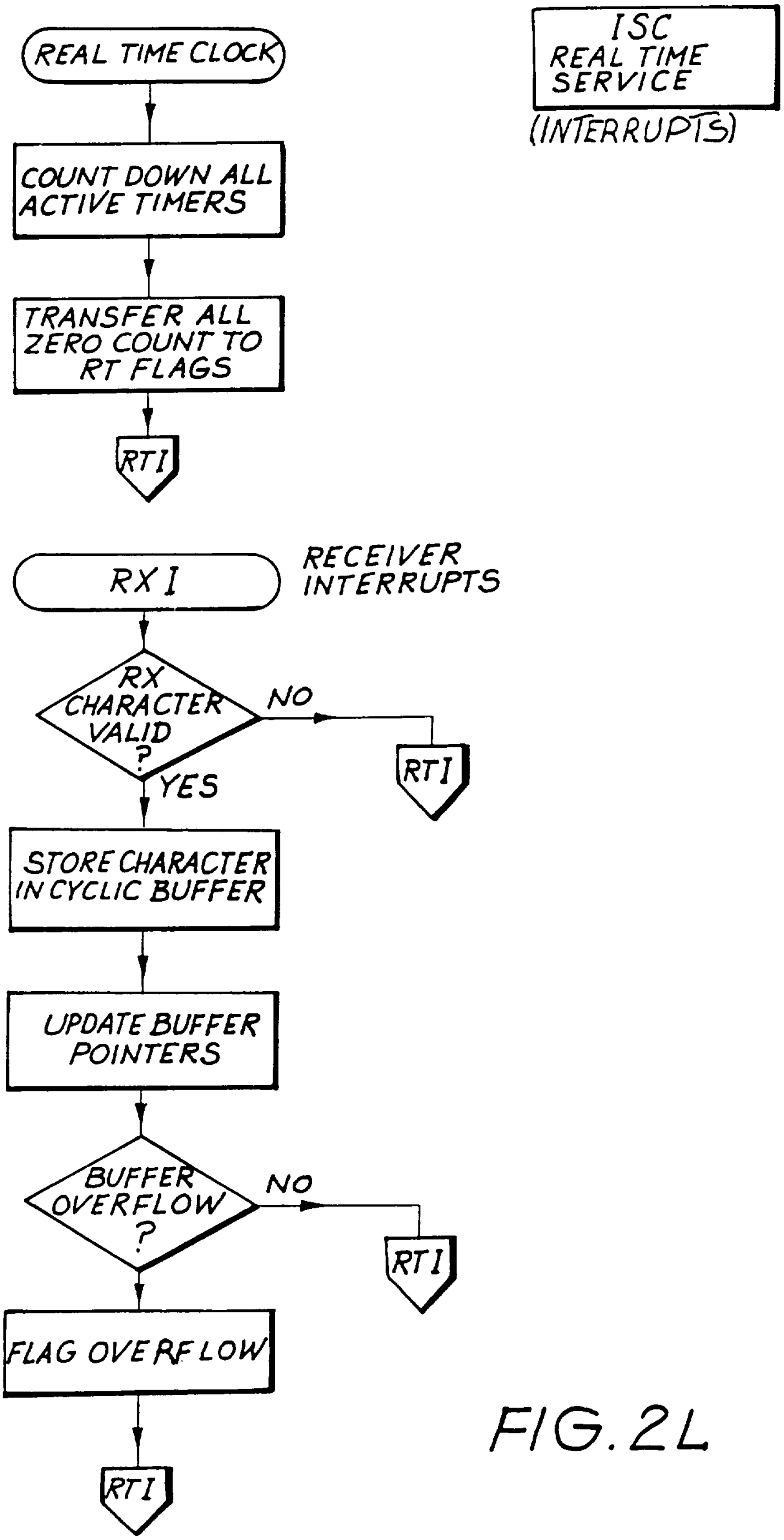
ISC
REAL TIME
SERVICE
(INTERRUPTS)
REAL TIME CLOCK
COUNT DOWN ALL ACTIVE TIMERS
TRANSFER ALL ZERO COUNT TO RT FLAGS
RTI
RX I
RECEIVER INTERRUPTS
RX CHARACTER VALID ?
NO
RTI
YES
STORE CHARACTER IN CYCLIC BUFFER
UPDATE BUFFER POINTERS
BUFFER OVERFLOW ?
NO
RTI
FLAG OVERFLOW
RTI

FIG. 2L

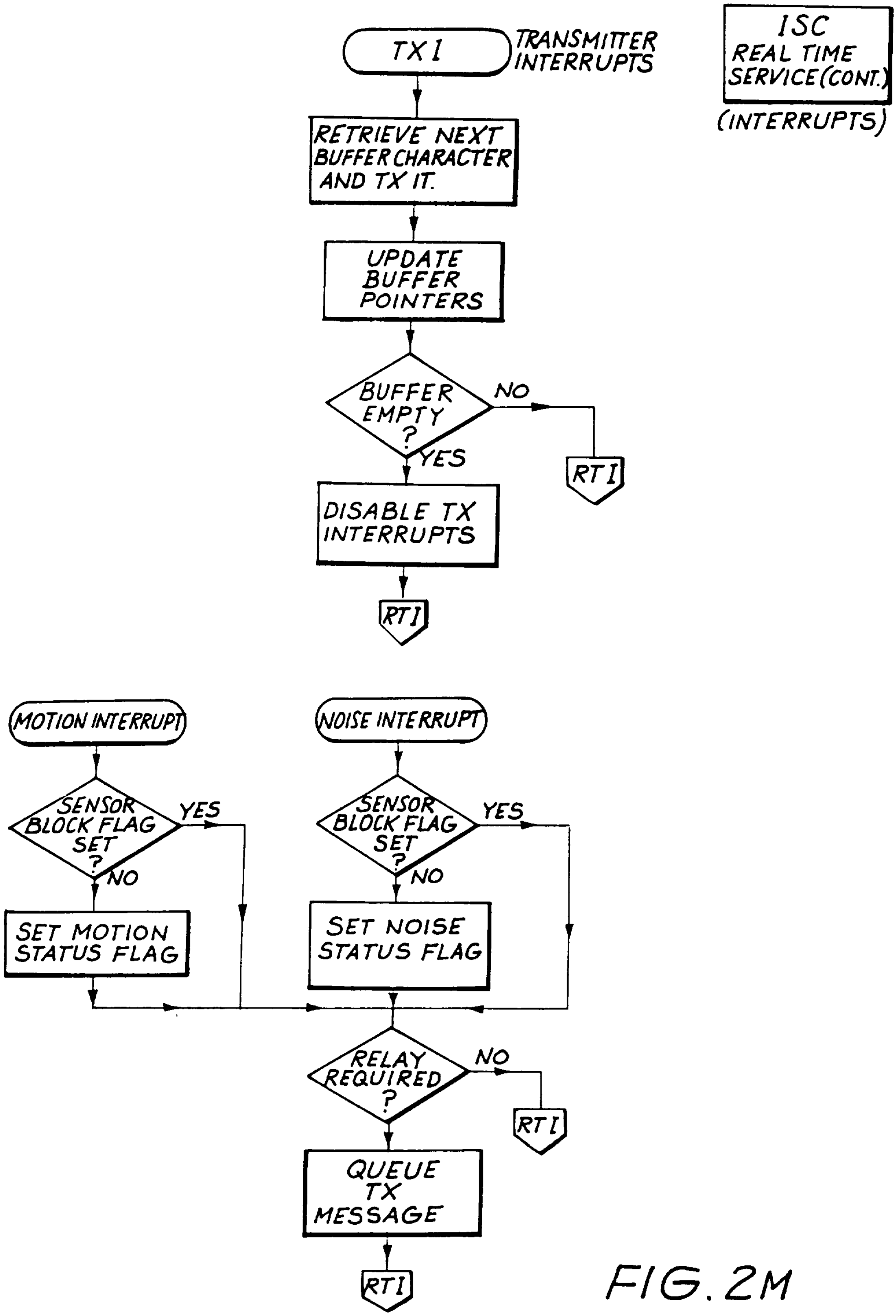
ISC
REAL TIME
SERVICE (CONT.)
(INTERRUPTS)
TX1
TRANSMITTER INTERRUPTS
RETRIEVE NEXT BUFFER CHARACTER AND TX IT.
UPDATE BUFFER POINTERS
BUFFER EMPTY ?
NO
YES
RTI
DISABLE TX INTERRUPTS
RTI
MOTION INTERRUPT
SENSOR BLOCK FLAG SET ?
YES
NO
SET MOTION STATUS FLAG
NOISE INTERRUPT
SENSOR BLOCK FLAG SET ?
YES
NO
SET NOISE STATUS FLAG
RELAY REQUIRED ?
NO
RTI
QUEUE TX MESSAGE
RTI

FIG. 2M

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00881

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^6: F21S 9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC^6 : F21S 9/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : 22.51 40/0, 6

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT : SOLAR

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4841416 A (DOSS) 20 June 1989	1, 2
X,P	POPULAR MECHANICS, a TIMES MIRROR magazine, issued August 1995 (PARK AV. NEW YORK) Advertisement, p.109, "With convenient wireless installation, two lighting systems offer the brightest solar light ever available!"	1, 2
X	DE 3938251 A (DIEHL GmbH & Co) 25 May 1991	1
A	DE 4242333 A (ZURELL) 23 June 1992	

☐ Further documents are listed in the continuation of Box C   ☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 March 1996	2ND APRIL 1996.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 95/00881

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
DE	393825	CA	2030045

END OF ANNEX