

S T U D Y   G U I D E

LM

ELECTRICAL POWER SUBSYSTEM

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DATE: April 1, 1967

Prepared By:

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LM Training

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## Preface

This document is designed to support the  
Electrical Power Subsystem Course, and  
is oriented toward the Design Reference  
Mission configuration.



### List of References

- |                      |  |
|----------------------|--|
| 1. LDW 390-54000     | Schematic - Level III<br>Electrical Power Subsystem  |
| 2. LDW 540-210000-21 | Vehicle - Level 2A<br>Sheet No. XIV Electrical Power |
| 3. LMA 790-3         | Lunar Excursion Module<br>Familiarization Manual     |
| 4. LSC 390-6         | Inverter Assembly                                    |
| 5. LSC 390-21000     | Battery, Primary Power, Ascent                       |
| 6. LSC 390-22000     | Battery, Primary Power, Descent                      |
| 7. LSC 390-23        | Relay, Deadface                                      |
| 8. LSC 390-24        | Relay, Deadface                                      |
| 9. LSC 390-25        | Electrical Control Assembly, Ascent                  |
| 10. LSC 390-26       | Electrical Control, Descent                          |

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### List of Abbreviations

ALT MFC	Alternate Main Feed Contactor
ASC	Ascent
ASC ECA	Ascent Electrical Control Assembly
CES	Control Electronic Section
CMDR	Commander
CSM	Command Service Module
DES	Descent
DES ECA	Descent Electrical Control Assembly
DFR	Deadface Relay
DPTT	Double Pole - Triple Throw
ECA	Electrical Control Assembly
ECS	Environmental Control Subsystem
EPS	Electrical Power Subsystem
GSE	Ground Support Equipment
HV MFC	High Voltage Main Feed Contactor
KPPS	Thousand Pulses Per Second
LM	Lunar Module
LDR	Launch Deadface Relay
LUT	Launch Umbilical Tower
LV MFC	Low Voltage Main Feed Contactor
MSFN	Manned Space Flight Network
NORM MFC	Normal Main Feed Contactor
OC	Overcurrent
OT	Overttemperature
PCM	Pulse Code Modulator
RC	Reverse Current
RJB	Relay Junction Box
SCERA	Signal Conditioning Electronic Relay Assembly
SE	System Engineer
SLA	Spacecraft LM Adapter
SPTT	Single Pole - Triple Throw
VGPS	Vehicle Ground Power Supply



## A. INTRODUCTION TO ELECTRICAL POWER SUBSYSTEM

The Electrical Power Subsystem (EPS) provides all electrical power necessary for the Lunar Module (LM) to complete the Lunar Mission.

Power distribution system operation, Mission Requirements.

1. For ground operations up to T-7 hours, power will be supplied from the Mobile Arming Tower (MAT).
2. T-7 hours to T-30 minutes, power will be supplied from Launch Umbilical Tower (LUT).
3. T-30 minutes to transposition, power will be from four descent batteries. For proper voltage regulation, power will be taken from battery taps which use less than the full number of cells.
4. Transposition to approximately 90 minutes prior to separation of the LM from the SIVB, power will be from the Command Service Module (CSM).
5. Pre-separation and up to 30 minutes prior to lunar launch, power will be from the descent batteries primarily and the ascent batteries for periodic checkout. At this time, the full number of cells will be used for all descent batteries.
6. 30 Minutes prior to lunar launch through docking, power will be from the ascent batteries.

Functionally, the EPS consists of a DC section and an AC section. Primary DC power originates at six silver zinc batteries four in the descent stage and two in the ascent stage.

All four descent batteries are required to provide the electrical power necessary to perform the complete LM Mission exclusive of the ascent phase. A curtailed mission may be executed using three descent batteries. Failure of two descent batteries requires the LM Mission to be aborted. Either ascent battery can supply all ascent electrical power loads during normal mission operations or an abort.

AC electrical power is provided by two solid-state inverters supplying AC electrical power to all IM electronic equipment. In addition to the primary batteries and solid-state inverters, the EPS consists of four Electrical Control Assemblies (ECA), a Relay Junction Box (RJT), a Deadface Relay (DFR), one control and display panel (Panel XIV), two circuit breaker panels (Panels XI and XVI), and two sensor power fuse assemblies.

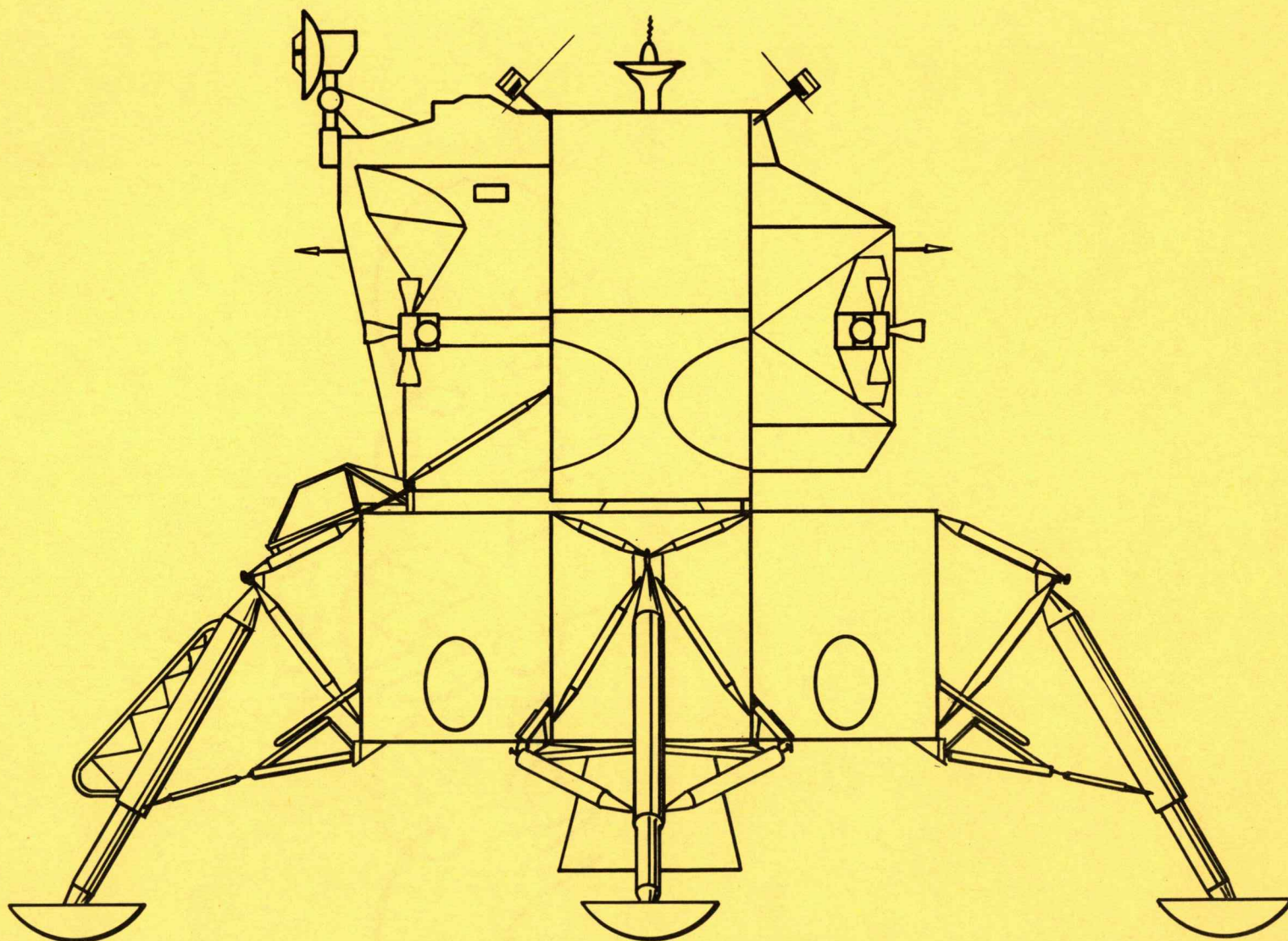


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Figure 1-1



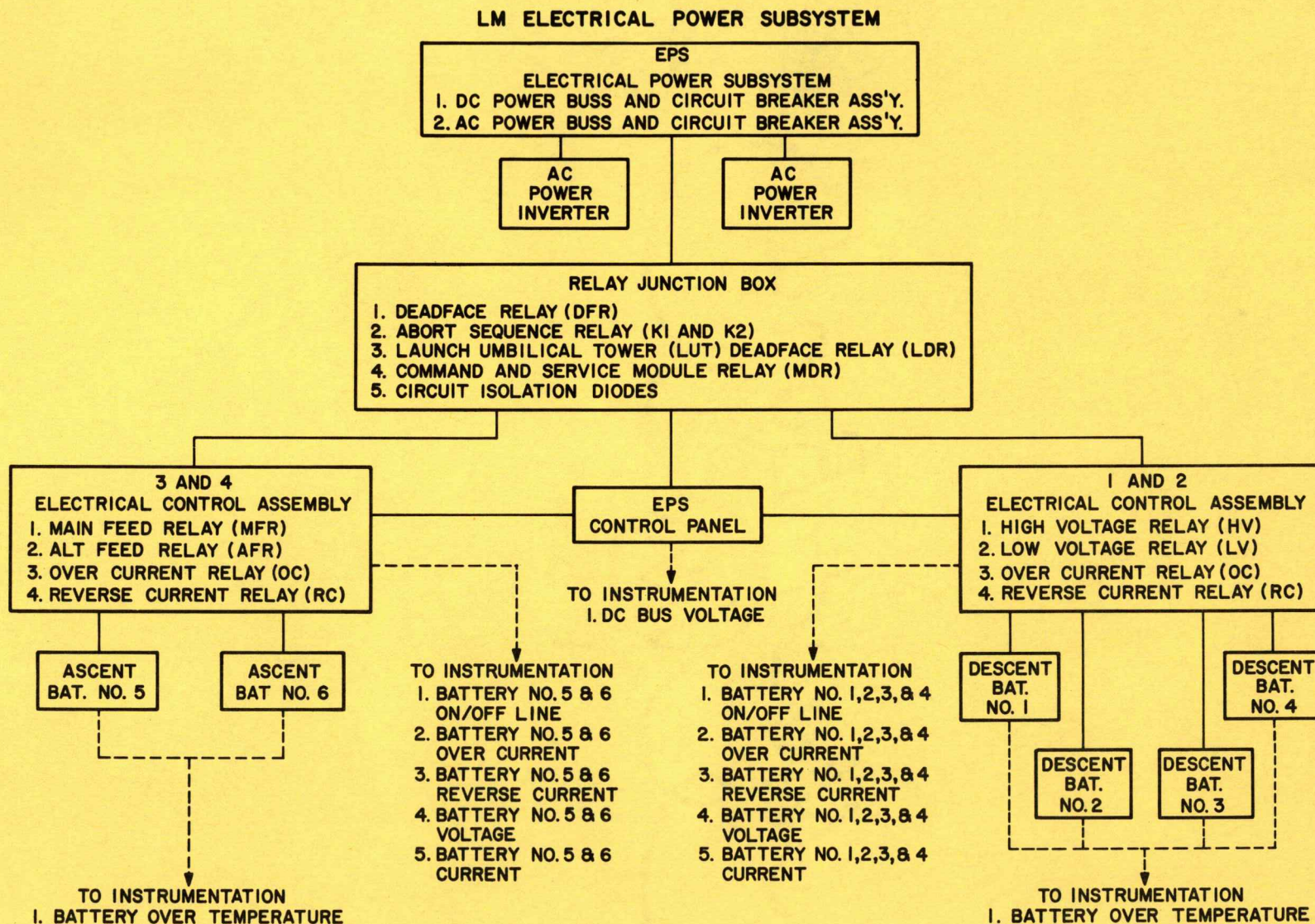
LM CONFIGURATION

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Figure 1-2

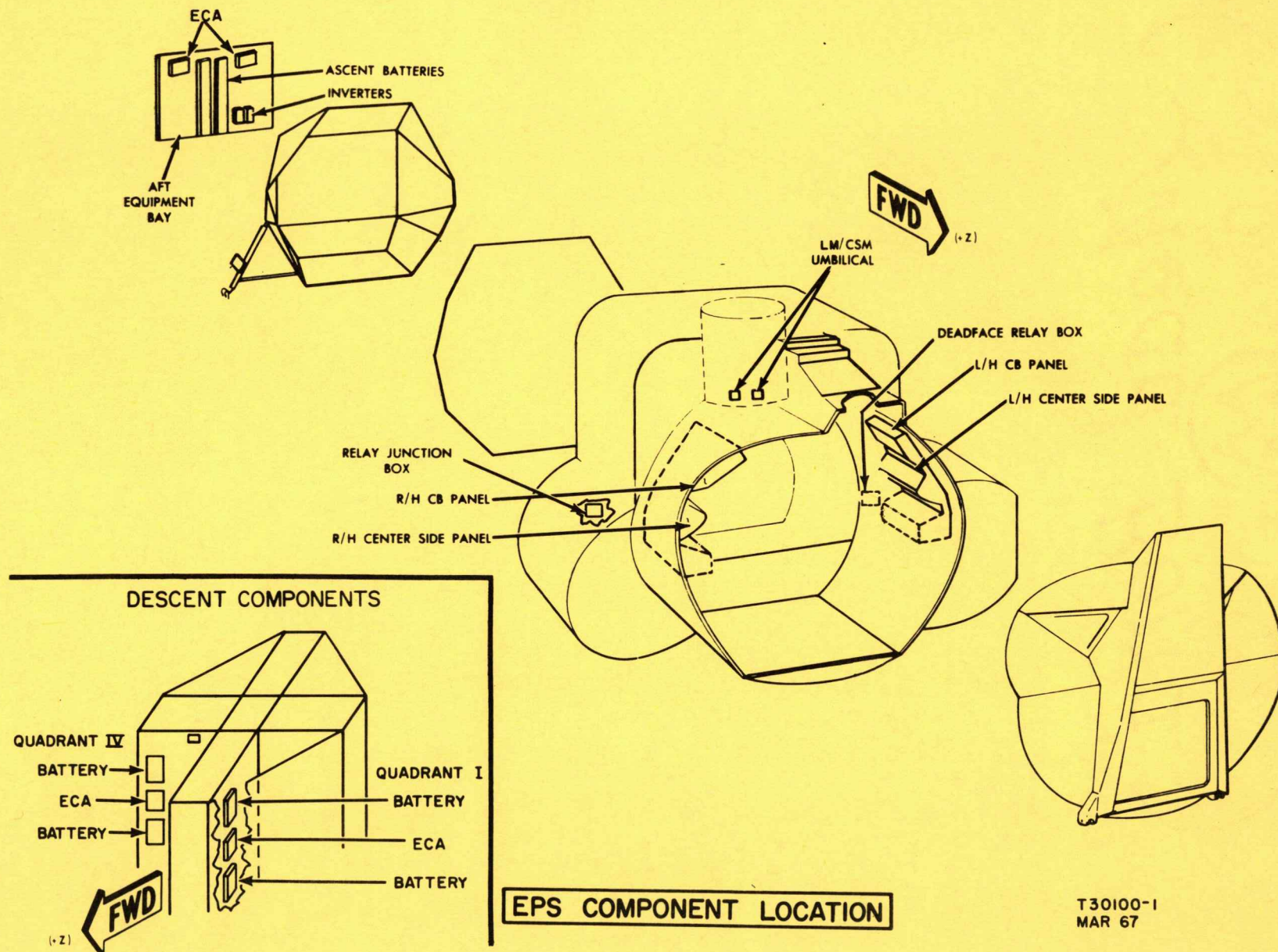
**EPS FUNCTIONAL BLOCK DIAGRAM**



Location of equipment is as follows:

<u>Equipment</u>	<u>Location</u>
1. Descent batteries (4) ]	Descent stage cold rail assemblies. Batteries 1 and 2 quadrant 4, batteries 3 and 4 quadrant 1.
2. Descent ECA's (2) ]	
3. Ascent batteries (2) ]	Aft equipment bay cold rail assembly.
4. Ascent ECA's (2) ]	
5. Inverters (2) ]	
6. Relay junction box	Ascent oxidizer tank bay.
7. Deadface relay box	Ascent fuel tank bay.
8. EPS Control Panel XIV	Center R/H panel.
9. Commander CB Panel XI	Upper L/H panel.
10. System Engineer CB Panel XVI	Upper R/H panel.
11. Sensor power fuse assemblies (2)	Aft equipment bay on - Z27.0 bulkhead.

Figure 1-3





## B. EPS FUNCTIONAL DESCRIPTION

The LM EPS has the capability of supplying all power to the other LM subsystems through all phases of the Apollo Mission starting with launch to completion of the LM mission. Ground Support Equipment (GSE) will supply pre-launching DC and AC power requirements to T-30 minutes. From T-30 minutes completion of the LM mission, the LM and CSM will supply the required power. A brief description of the EPS follows:

The output of each battery is applied to an Electrical Control Assembly (ECA). In the descent stage the ECA's are designed to provide for four independent battery control circuits, one control circuit for each descent battery. The ascent ECA's are designed to provide four independent battery control circuits, two identical control circuits for each ascent battery.

Overtemperature, reverse current and overcurrent condition are monitored by the ECA's. Each ECA battery control circuit will have the capability to detect a battery or feeder malfunction and operate a Main Feed Contactor (MFC) associated with the malfunctioning battery to remove it from the EPS distribution system (overcurrent only).

Descent stage battery power is controlled and monitored by the descent ECA's and is properly switched and applied to the Relay Junction Box (RJB) and the Deadface Relay Box (DFR). Descent batteries No. 1 and 2 power feeders are routed through the RJB deadface relays and applied to the System Engineer's CB Panel XVI. Batteries No. 3 and 4 power feeders are routed through the DFR deadface relays and applied to the Commander's CB Panel XI. This circuit arrangement provides for deadfacing all descent battery power in the event of abort stage situations.

Ascent stage battery power is controlled and monitored by the ascent ECA's and is properly switched and applied through power feeder to terminal junction points at the RJB and DFR. Power is applied through common main power feeders to the System Engineer's and Commander's CB Panel DC Bus System.

In addition to providing for deadfacing the descent batteries No 1 and 2 and terminal junction points for the ascent batteries, the RJB also provides power/control interface between the following Apollo Space Vehicles and GSE.



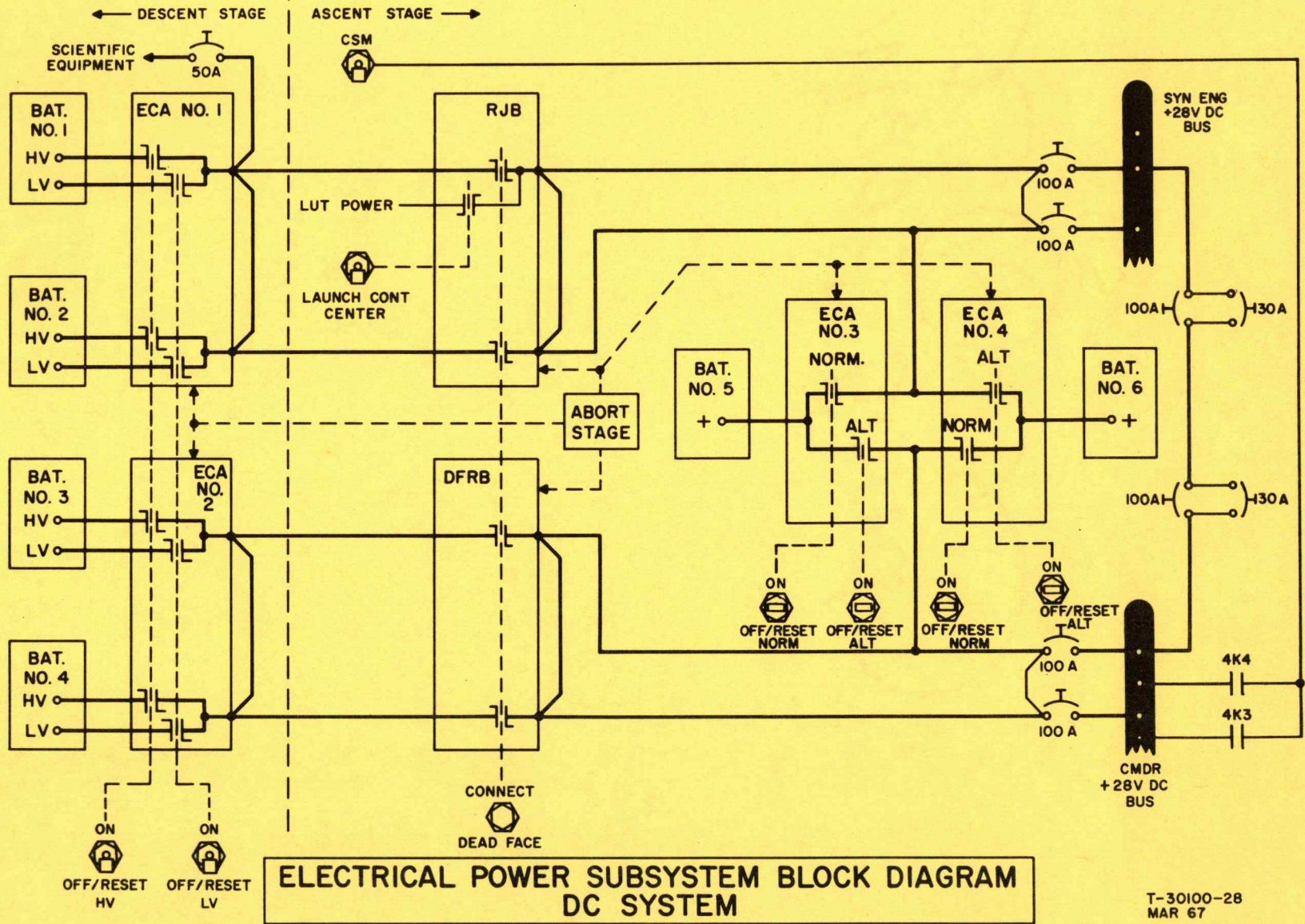
1. Launch Umbilical Tower (LUT) Ground Power.
2. CSM/LM Power.
3. EPS/Guidance and Navigation, "Abort Stage" Command.

Ascent and descent battery power feeders are routed through circuit breakers to the DC Bus assemblies. The circuit breakers provide bus short circuit protection. From the DC Bus assemblies, DC power is distributed through circuit breakers to all LM subsystems.

Two general purpose inverters supply all AC power requirements for the LM vehicle. An inverter selector switch is used to connect either inverter to the split AC Bus system with crossfeed capability. Either inverter has the capability to adequately supply the LM AC load requirements:



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### C. EPS COMPONENT FUNCTIONAL DESCRIPTION

The DC section of the EPS consists of four descent batteries, two descent ECA's, a RJB, a DFR, two ascent batteries, two ascent ECA's a control panel, two circuit breaker panels and two sensor power fuse assemblies.

#### 1. Descent Batteries

Four descent batteries are used to power the LM equipment starting at T-30 minutes through the docking phase ending with CSM transposition and docking. They will again be used for approximately 1 hour during LM checkout, and then again from CSM/LM separation till approximately 30 minutes from launch from the lunar surface.

The descent batteries are rated to supply 400 ampere-hours minimum when discharged in accordance with the load profile within 30 days after activation. The battery shall be capable of a discharge of 25 amperes at 28 volts minimum, for 16 hours at 80°F. Each battery has two voltage taps, HI voltage tap (20th cell) and LO voltage tap (17th cell). They are installed in the LM fully charged and the LO voltage tap is used to power the LM equipment starting at T-30 minutes through the launching phase ending with CSM transposition and docking, and again for approximately 1 hour during LM lunar orbit checkout. The HI voltage tap is used for LM operational modes (LM powered up). Each descent ECA provides ON/OFF control of each HI and LO voltage main power contactors. These contactors enable the connection of either the 17th cell or the 20th cell descent battery tap to the power distribution system.



The terminal voltage of the battery shall be as follows:

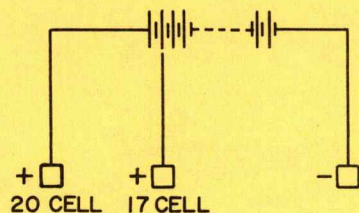
- a. Nominal voltage 30.0 Volts
- b. Minimum voltage during a 40 ampere discharge 28.0 Volts
- c. Maximum voltage during a 5 ampere discharge 32.5 Volts

The batteries are stored in a dry stage and are activated prior to installation in the LM. The batteries are activated by filling the cells with electrolyte solution (potassium hydroxide and water). After the filling of the cells, they are monitored for 72 to 80 hours (cold soaked) to determine cell integrity.

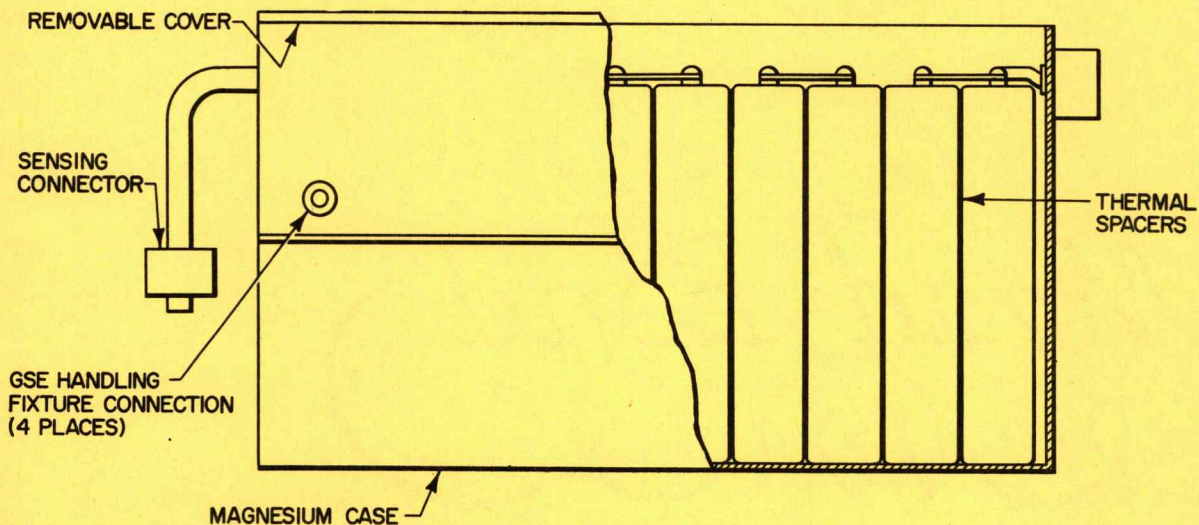
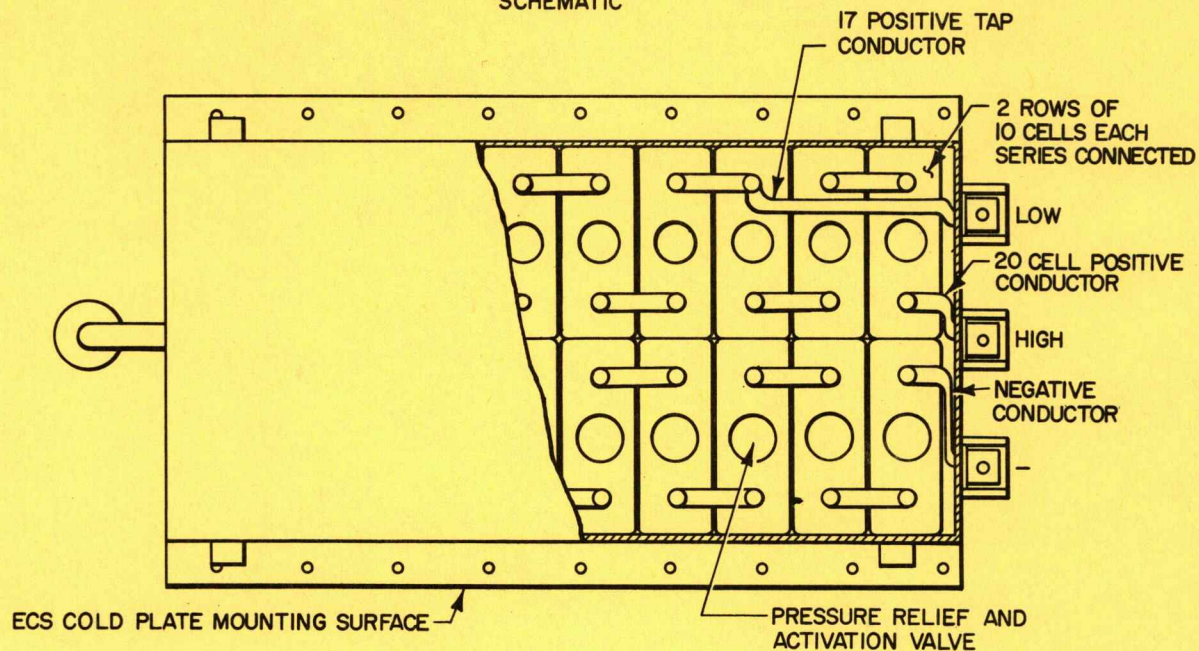
The mechanical and environmental specifications are such that each descent battery can operate in a vacuum while being cooled by a thermal control system (cold rail assembly), to which the battery heat sink surface is conductively mounted. The battery shall be capable of providing the power profile for the LM mission when the temperature of the root of the heat sink flange is between 35° and 120°F.

The nominal operating temperature for the descent battery is 100°F. Battery temperatures in excess of 145 + 5°F will close a thermal switch in the battery illuminating the battery caution light on Panel II (the light will be inhibited if the descent battery is not connected to the system). The astronaut must take corrective action to eliminate the faulty battery.





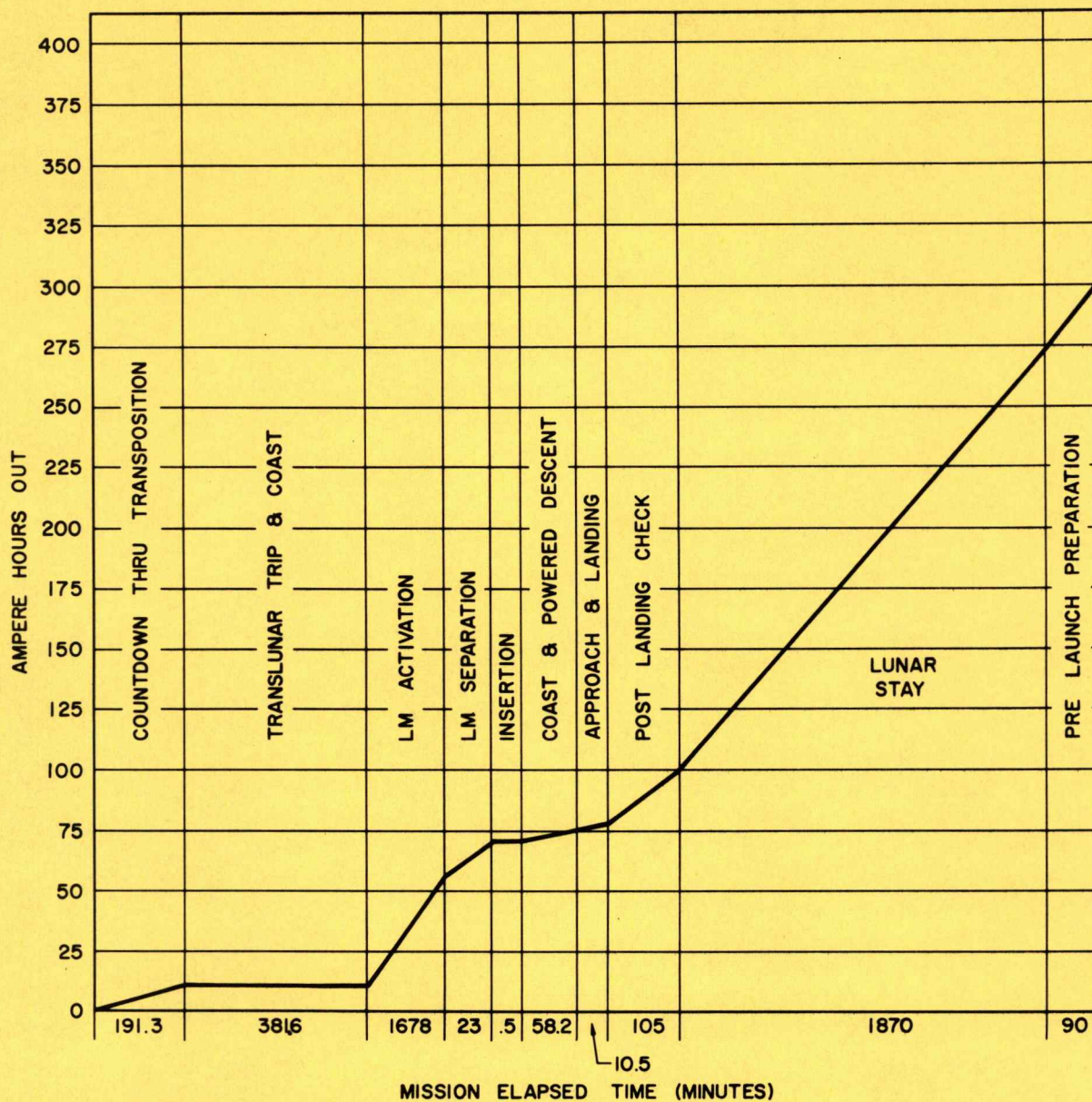
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DESCENT BATTERY

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**DESCENT BATTERY CAPACITY VS  
LM MISSION TIME GROWTH PROFILE**

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## 2. Descent ECA

Two descent ECA's are used to provide protection and control of the four descent batteries. Each descent ECA provides separate control of a pair of descent batteries. The descent ECA contains HI voltage main feeder contactors, LO voltage main feeder contactors, battery current monitors, overcurrent relays and reverse current relays.

Each descent ECA shall provide two separate sets of battery controls and protective devices. The functions which follow are to be provided for each of the two batteries. A failure in one of the battery controls shall not result in a loss of the other set of controls.

- a. Provide capability to connect the associated battery to the power distribution system from either the HV tap or the LV tap.
- b. Provide a lockout circuit to prevent closing the HV main feeder contactor and the LV main feeder contactor of a descent battery at the same time.
- c. Provide a current monitor for the battery load current.
- d. Provide each battery with overcurrent protection.
- e. Provide each battery with reverse current detection.
- f. Provide auxiliary relays to supply system logic contact closures to other control assemblies in the LM power distribution system.
- g. Provide the capability to interrupt a battery overtemperature signal when both contactors in a section are open.

Self-contained transistorized DC-to-AC power supply inverters in each descent ECA provide operating power for ECA sensing and monitoring electronics. Three regulated DC outputs (+18 volts, +12 volts, and -6 volts) are obtained from each inverter to provide operating power for the ECA transistorized current-sensing circuitry.

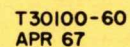
The current-sensing circuitry has the function of giving isolated information outputs to other circuits from the battery current flowing in the contactor circuit of the ECA.



- a. Current flow which is displayed on the Electrical Power Control panel. All meter readings are divided by two for actual reading.
- b. Overcurrent protection, if the current flow is excessive, it will trip the HV/LV contactors. When current from the battery is within the overcurrent trip range, the overcurrent shall disconnect the battery from the power distribution system. The ECA shall provide an alarm signal for each separate overcurrent circuit to the LM Caution and Warning. The overcurrent signal, once initiated by the overcurrent condition, shall be maintained until manually reset. The tripping time due to overcurrent, varies inverse relationship to the amount of overcurrent; the greater the overcurrent, the sooner the trip.
- c. Reverse current detection, it gives indication (no tripping) when the battery current is negative by more than 10 amps and exists for at least 4 to 6 seconds. The alarm shall not appear if the reverse current exists for less than 4 seconds. The alarm signal shall return to normal when the battery current is negative by 5 amps or less or if the battery current is positive for a period of 4 seconds.



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Figure 1-7



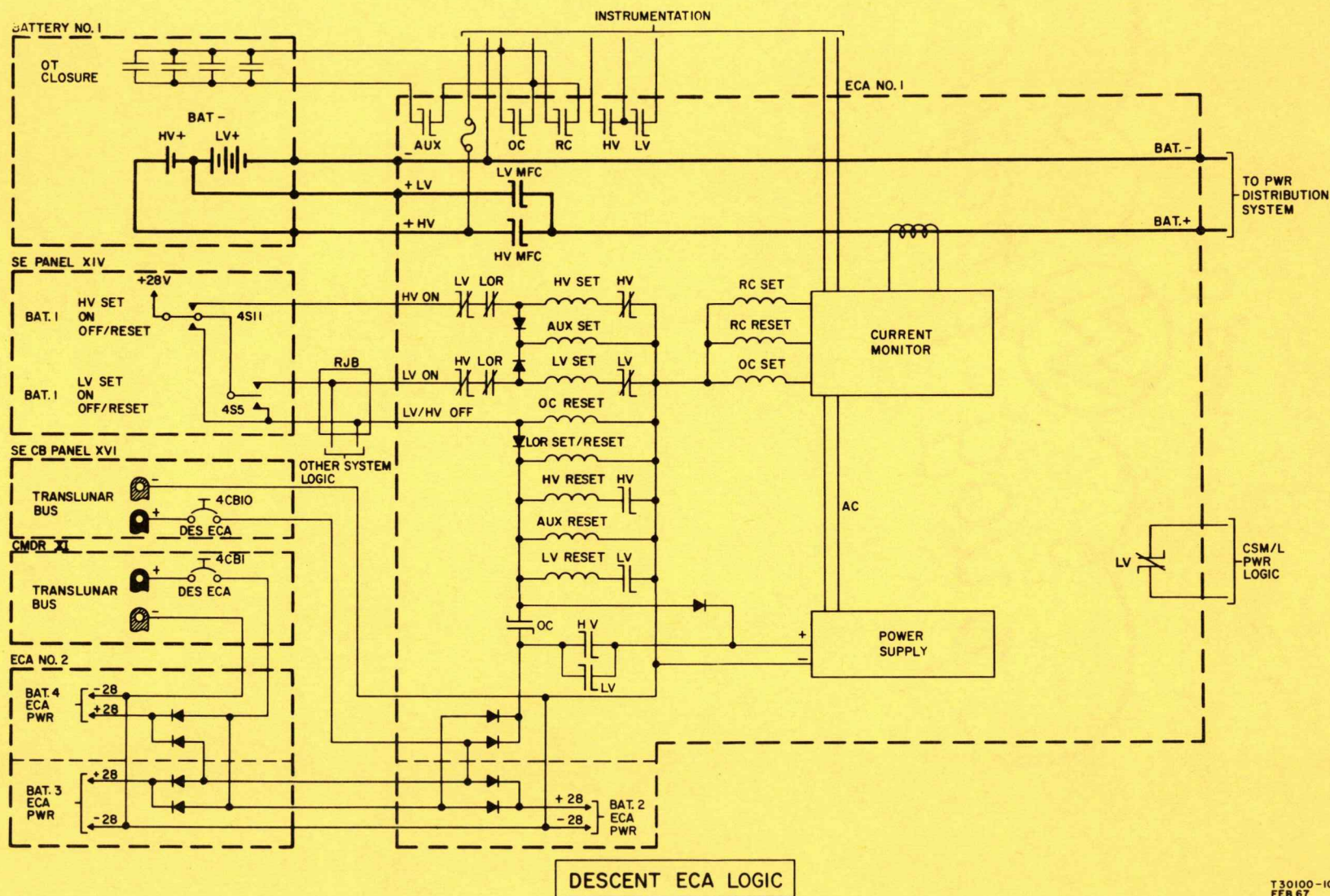


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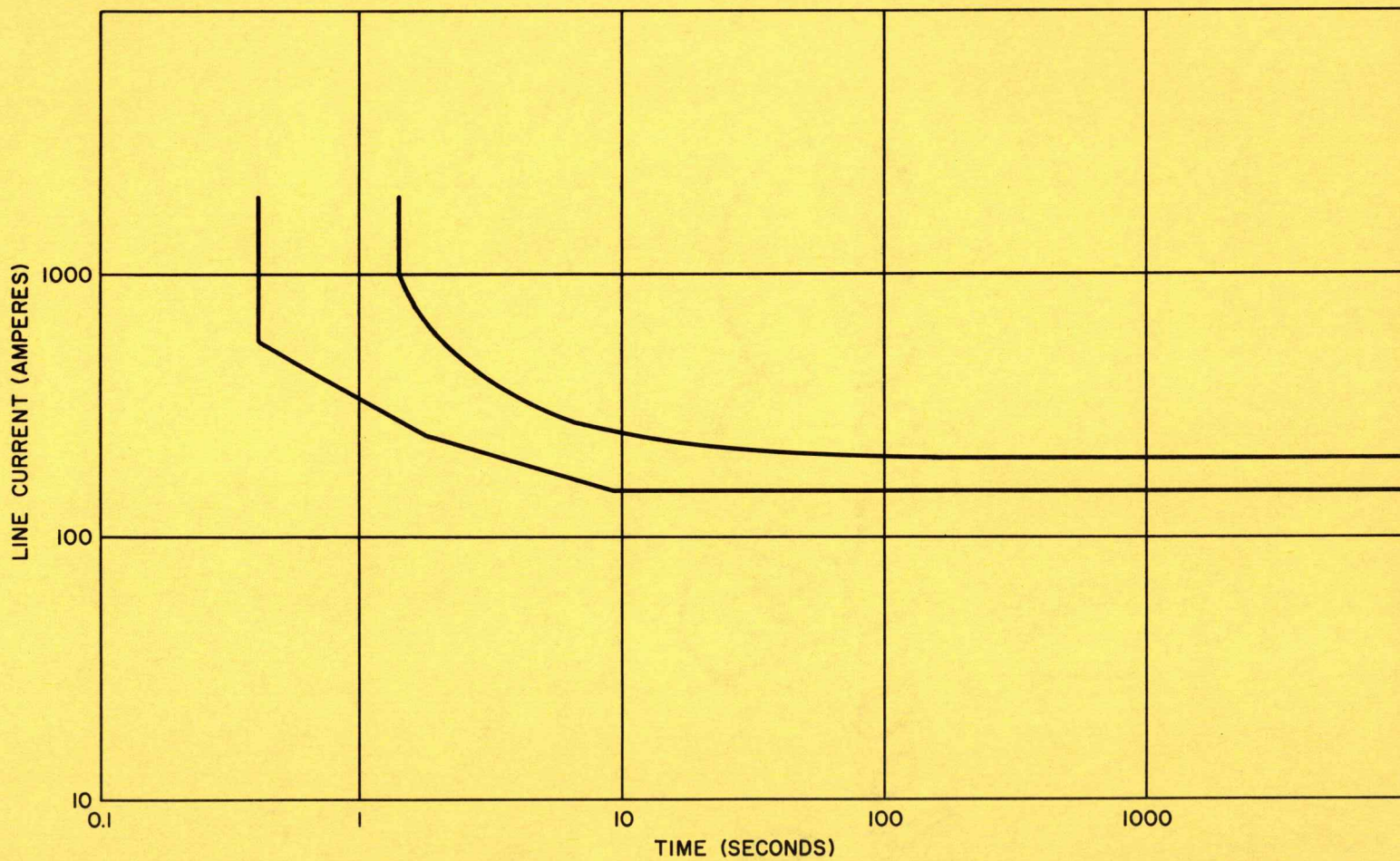
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Figure 1-8



# DESCENT ECA OVERCURRENT TRIP LIMITS



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Figure 1-9

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### 3. Ascent Batteries

Two ascent batteries are used to supply the DC power requirements from lunar ascent to docking of the LM ascent stage with the orbiting CSM, or during an abort that requires separation of the LM ascent and descent stages. The batteries are checked periodically before separation and during lunar stay. Both batteries undergo a partial discharge procedure before installation in the LM. This is necessary to alleviate their inherent high plateau voltage characteristic.

The ascent battery can deliver 296 ampere-hours of power when discharged in accordance with the nominal load profile within 30 days after activation. The battery shall be capable of a discharge of 25 amperes to a cutoff of 28 volts minimum for 11.8 hours at 80°F. The capacity of the second and third cycles, when discharged within 60 days after activation, shall be 85% of the first cycle (252 ampere-hours minimum, at a discharge of 25 amperes to a cutoff of 28 volts minimum, for 10.1 hours at 80°F).

The terminal voltage of the battery shall be as follows:

a. Nominal voltage	30.0 Volts
b. Minimum voltage	28.0 Volts
c. Maximum voltage	32.5 Volts

The batteries shall be capable of meeting the above requirements while supplying the power requirements for the load profiles under the following conditions.

- a. Nominal load profile - 2 batteries operating.
- b. Abort load profile - 1 battery operating.



The mechanical and environmental specifications are such that the ascent battery is capable of operating in a vacuum, while being cooled by a thermal control system in which the battery heat sink surface is conductively mounted on a coolant cooled plate. The temperatures of the root of the heat sink flange for the nominal load profile shall be between 35° and 115°F. The temperature of the root of the heat sink flange for the abort load profile shall be between 35° and 140°F. The nominal operating temperature of the ascent battery is approximately 100°F. Battery temperatures in excess of 145+5°F will close a thermal switch illuminating the Battery caution light on Panel II (the light will be inhibited if the ascent battery normal main feed contactor is open). The astronaut must then take corrective action to eliminate the faulty battery.

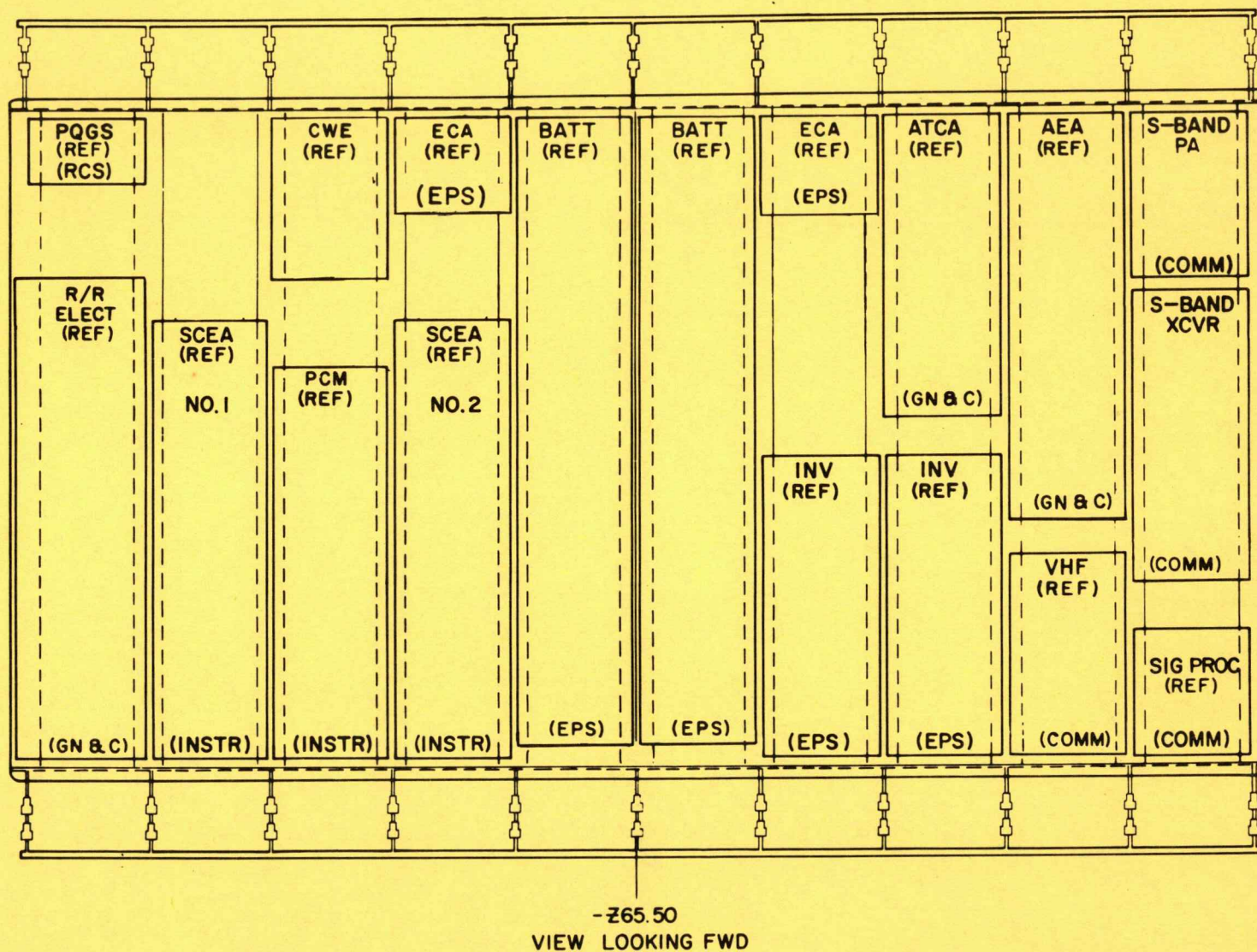


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Figure 1-10



## AFT EQUIPMENT BAY-ERA ARRANGEMENT

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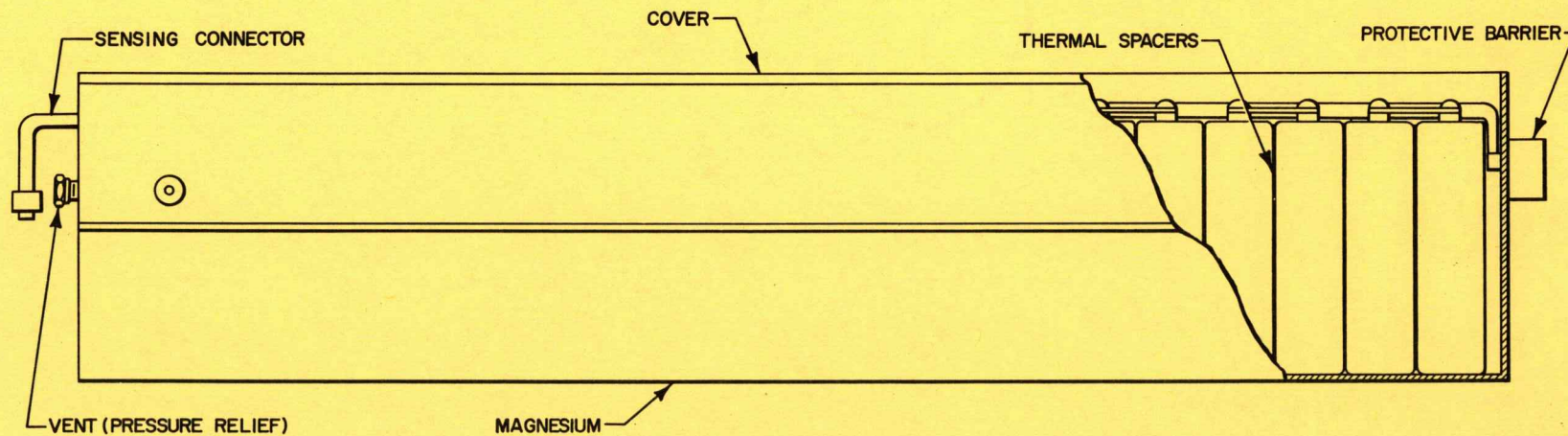
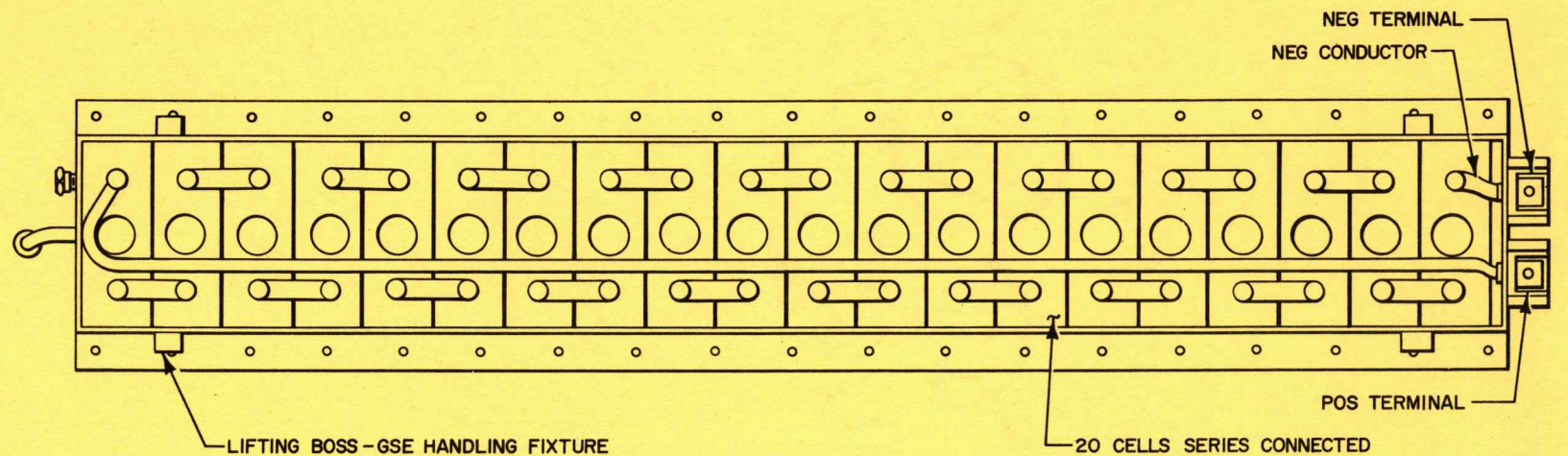


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EPS



ASCENT BATTERY

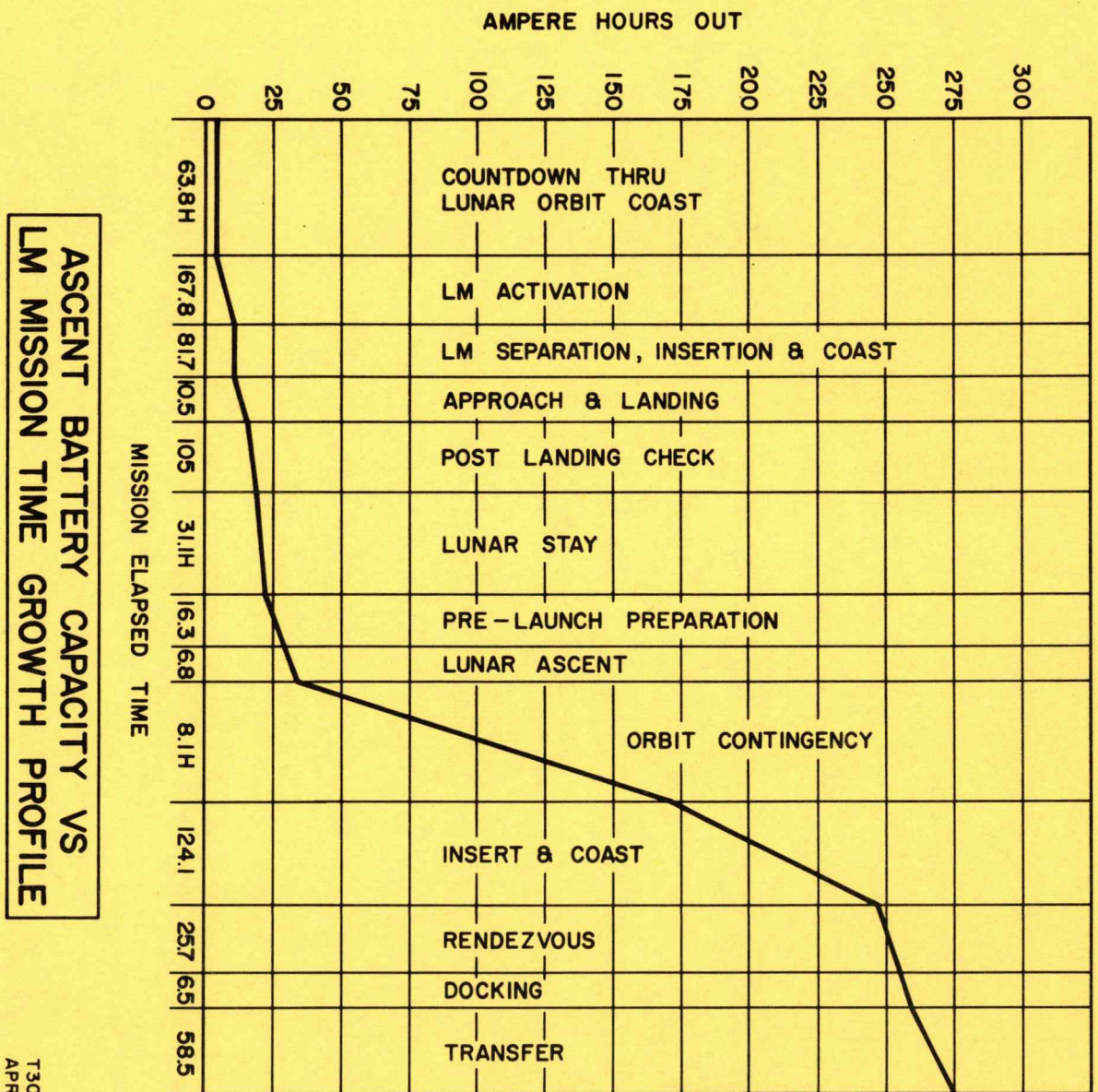
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Figure 1-11



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Figure 1-12





#### 4. Ascent ECA

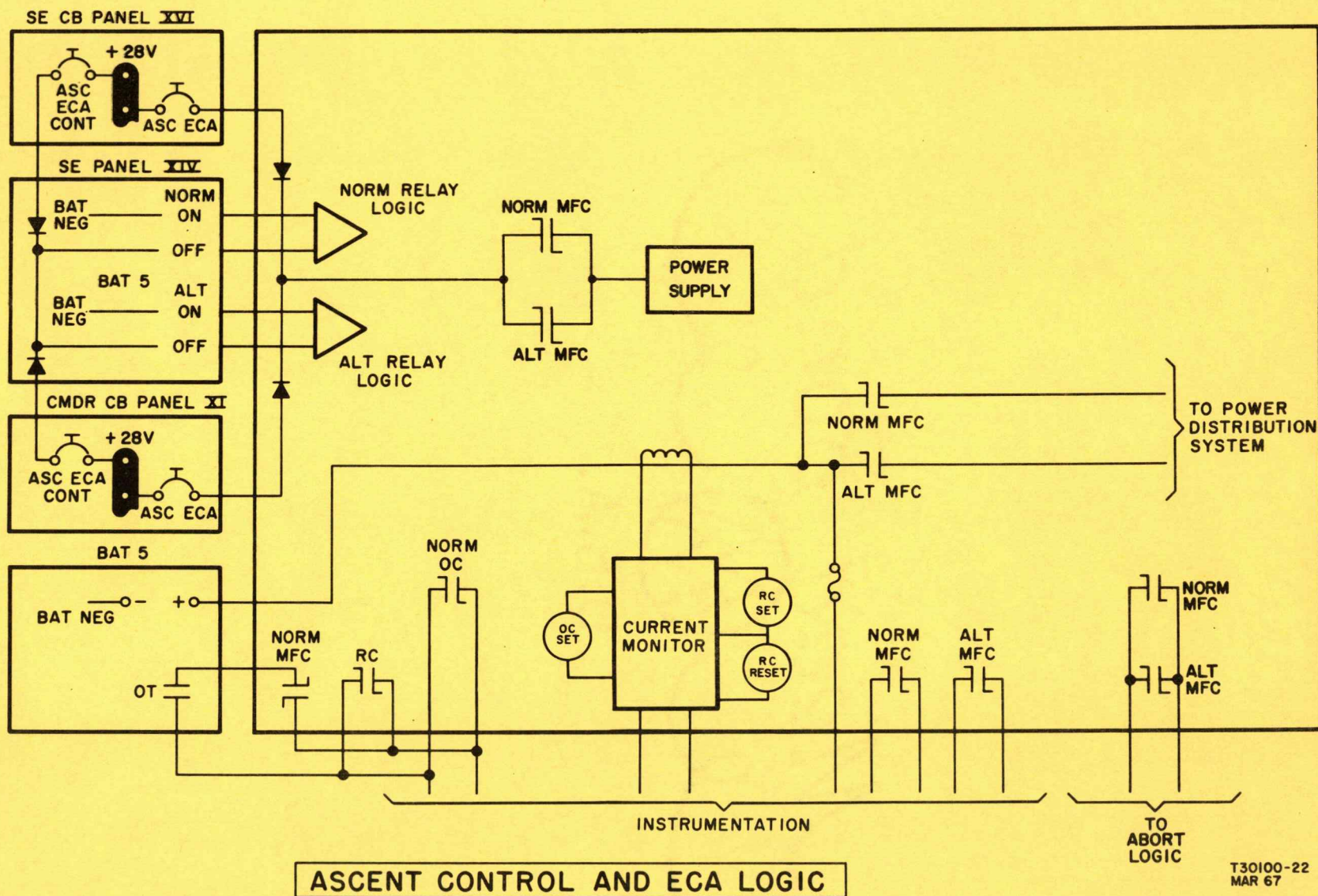
Two ascent ECA's are used in the system, one for each ascent battery. The primary function of the ascent ECA is to connect its battery to either or both DC bus systems as desired. Each ascent ECA contains normal and alternate (backup) main feeder contactors, an overcurrent relay, a reverse current relay and a battery current monitor.

The ECA shall provide the following functions.

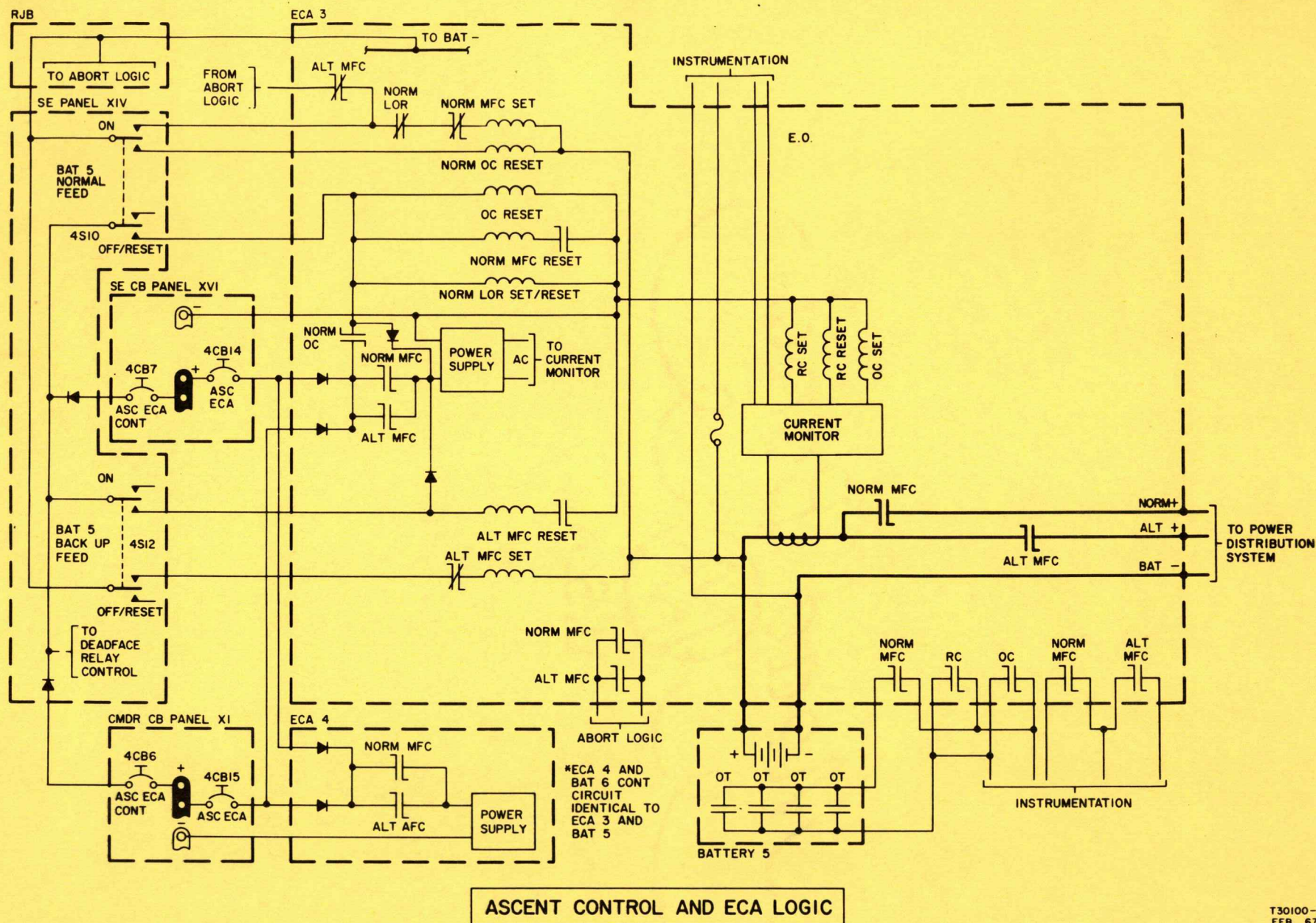
- a. Provide capability to connect the associated battery to either one or both DC buses.
- b. Provide contact closure for indicators.
- c. Provide a current monitor for the battery load current.
- d. Provide overcurrent protection when control power is supplied to the ECA, and the normal MFC is closed.
- e. Enable the battery overtemperature circuit when the normal MFC is closed.
- f. Provide auxiliary relays to supply system logic contact closures to other assemblies in the LM power distribution system.

The power supply, current monitor, overcurrent relay and reverse current relay are identical to those in the descent ECA, except that the overcurrent relay in the ascent ECA will only trip the normal MFC.

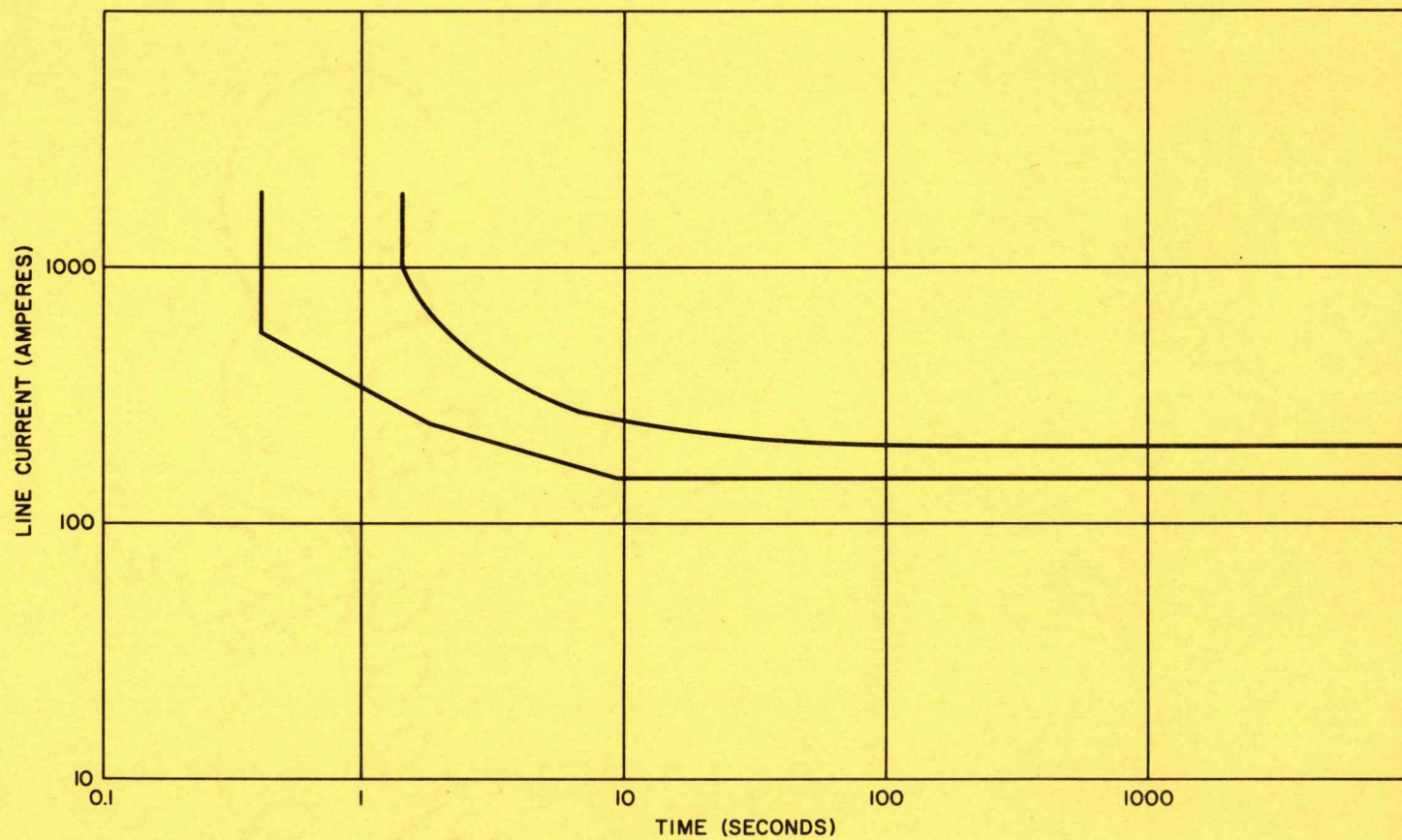












ASCENT ECA OVERCURRENT TRIP CURVE

## 5. Relay Junction Box & Deadface Relay

The relay junction box (RJB) provides logic and junction points for connecting external power to the LM from the launch umbilical tower (LUT). In addition, the RJB provides control and power junction points for the ascent and descent ECA's and deadfacing of batteries 1 and 2 main power feeders between the ascent and descent stage, the other feeder system (batteries 3 and 4) is controlled by the deadface relay (DFR).

The RJB provides the following switching logic for descent battery feeders 1 and 2:

- a. Deadface.
- b. Ground power.
- c. Internal power.
- d. Abort stage.

The deadface switching logic provides the deadfacing of descent batteries 1 and 2 from the ascent stages. The primary control of the deadface switching logic is by the deadface battery selector switch. (Connect-Maintain-Deadface). It also receives deadface commands from the Abort Stage logic.

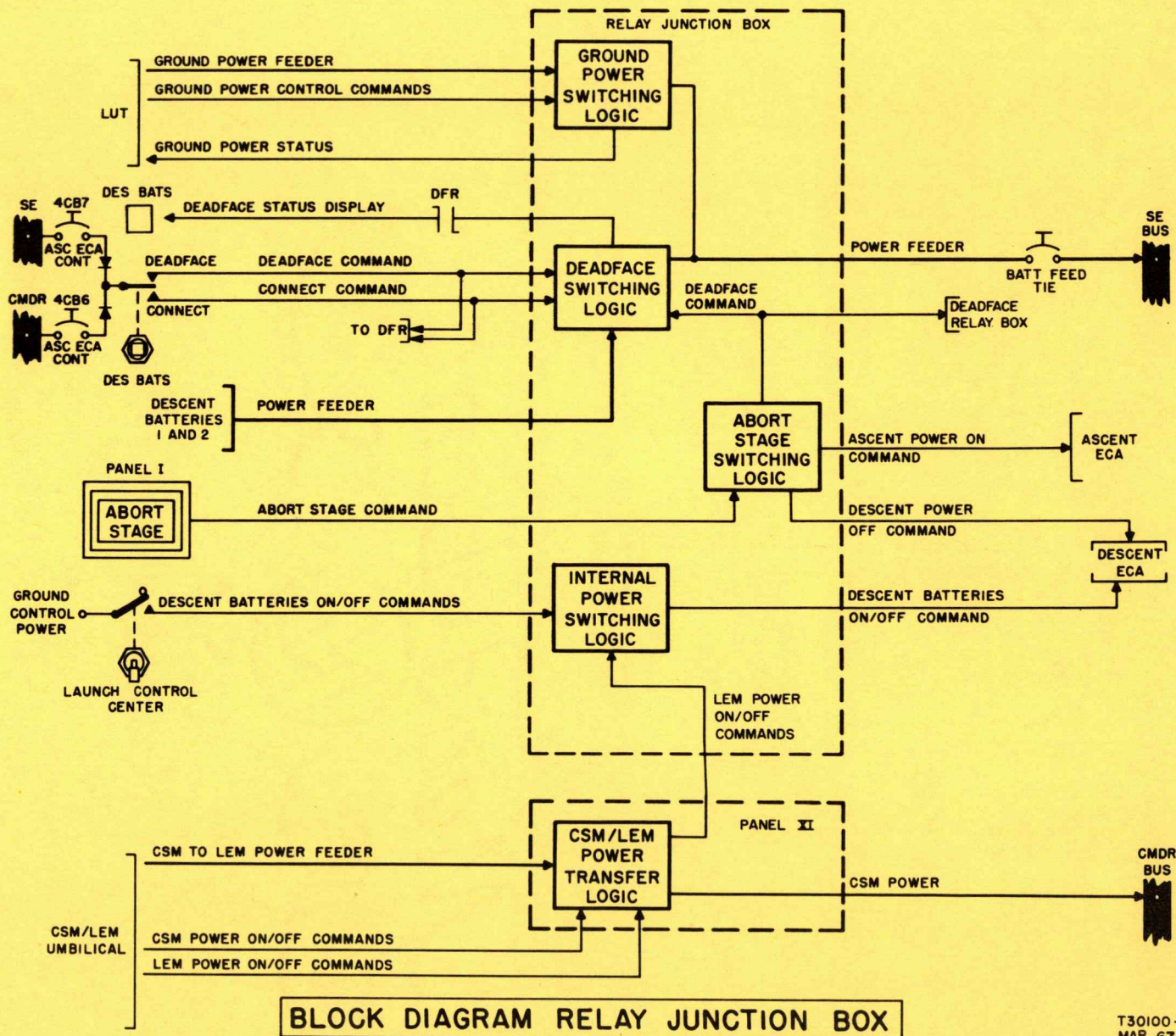
The ground power switching logic provides control of connecting ground power to the LM when the LM batteries are not in use. The switching logic receives its connect and disconnect commands from the launch control center. When ground power is being supplied to the LM power distribution system, power ON status is displayed at the launch control center.

The internal power switching logic, provides control of the descent batteries from LUT and CSM. It provides control of the OFF circuitry of the descent batteries HV/LV contactors. It also provides control of the ON circuitry of the LV contactors.

The abort stage switching logic upon receiving an abort stage signal will transfer power from the descent batteries to the ascent batteries without a power interruption and then deadface the descent stage from the ascent stage.



Figure 1-16





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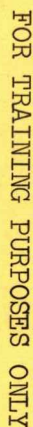


Figure 1-17

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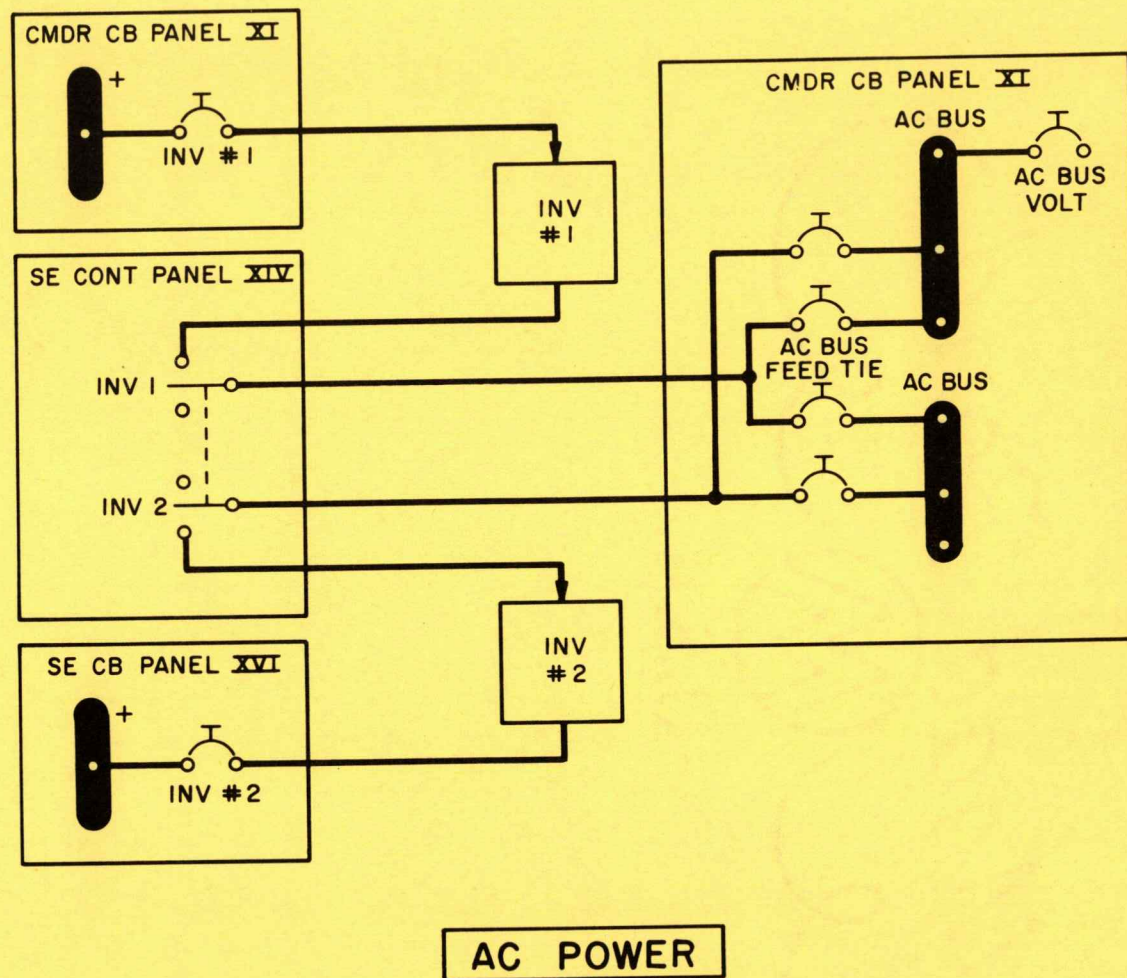


## 6. AC Power

AC power is redundantly provided by two identical inverters. The inverters are initiated by engaging INV 1 and INV 2 circuit breakers one each located on the Commander's and System Engineer's circuit breaker panels. Selection of an individual inverter output is accomplished by the AC PWR inverter switch. Either inverter can be selected and placed on the AC split bus system through isolating AC BUS FEED TIE circuit breakers. An AC bus voltage and frequency readout signal is supplied to instrumentation for telemetry, caution light and advisory display. An out-of-tolerance frequency or low voltage will initiate caution warning only. The astronaut will make a determination of the indication and perform corrective action. A Power/Temp Monitor switch will select the AC bus for a metered voltage display.



Figure 1-18





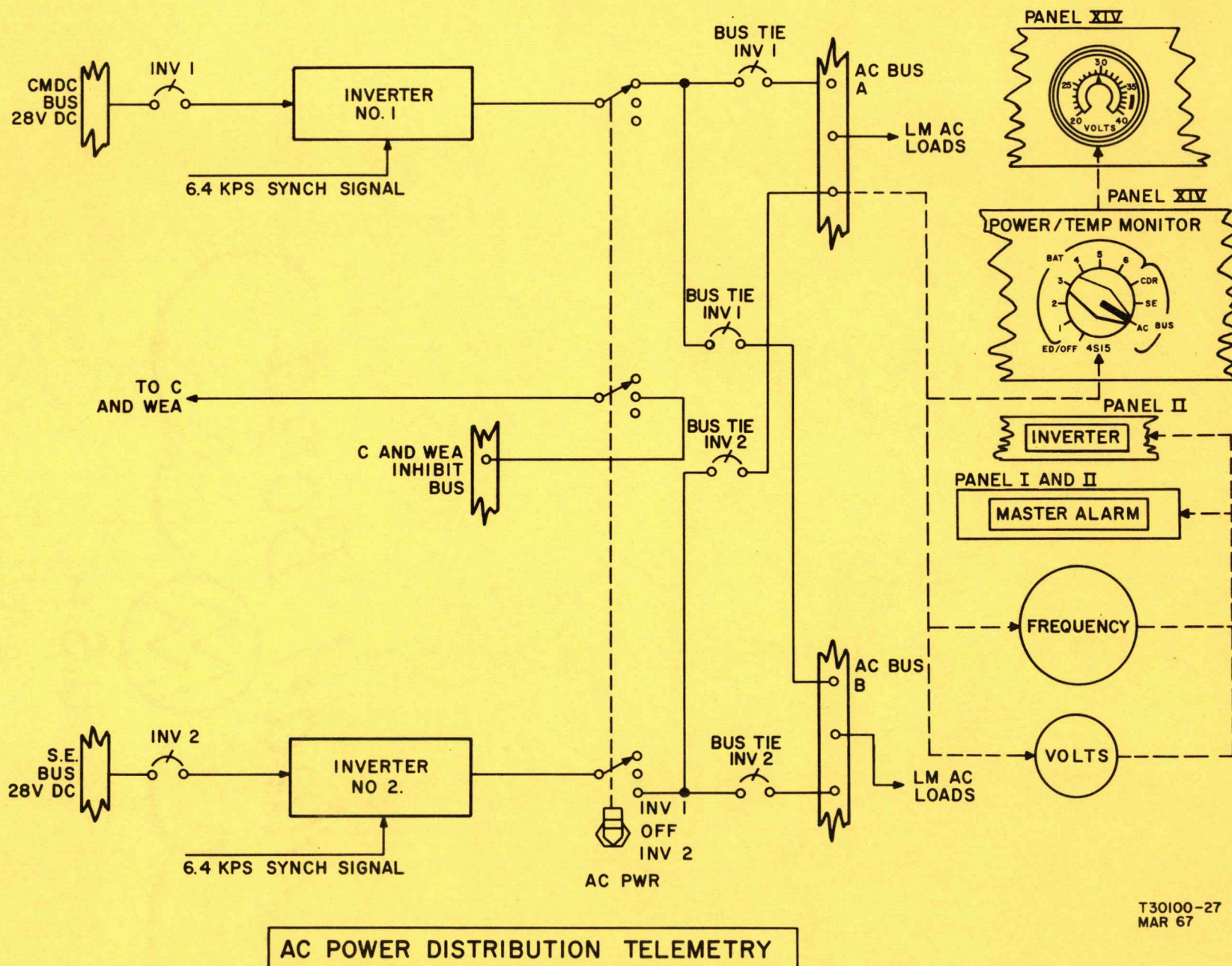
## 7. AC Inverters

Two solid-state inverters supply all 400 cps AC power requirements in the LM. Each inverter supplies  $115 \pm 2$  volts, single phase 400 cps, operating on an input of  $28 \pm 4$  volts DC, and can deliver an output of 350 volt-amperes.

Each unit is synchronized, using a 6.4 kilopulse-per-sec (kpps) master timing pulse delivered by the LM Pulse Code Modulator and Timing Equipment (PCM & TE). Under these conditions, the inverter output frequency is  $400 \pm 0.4$  cps. In the absence of the PCM & TE timing pulses the inverter is free-running and the output frequency is  $400 \pm 10$  cps. The output waveform contains less than 5% total harmonic distortion and the maximum allowable peak output transient voltage is 225 volts.

The inverters are individually connected to the Commander's and System Engineer's 28 volt DC buses by operating the respective circuit breakers located on the EPS circuit breaker panels. The output of each inverter is connected to the split AC distribution buses by the INVERTER selector switch, arranged according to a double, three input AND-INHIBIT gate logic system. During checkout procedures performed before CSM/LM separation, inverter no. 2 is energized by closing the INV 2 circuit breaker. The inverter output is connected to the split AC distribution buses by setting the AC power switch on the Electrical Control Panel to INV 2. If inverter no. 2 fails, the other inverter can be energized by closing the INV 1 circuit breaker. Its output is connected to the split AC distribution buses by setting the AC power switch to INV 1.







## 8. Control Panel

Control of the distribution system is provided on the Systems Engineer's Power Distribution, Panel XIV. The panel consists of the following controls and displays:

- a. Eight SPTT - momentary (ON) - maintain-momentary (OFF/RESET) switches to control the contactors for each descent battery, (two for each battery).
- b. Four three position flags indicate the status of the descent battery contactors, (one flag for each battery).
- c. Four DPTT - momentary (ON) - maintain-momentary (OFF/RESET) switches control the contactors in each ascent ECA (two for each battery).
- d. Four flags indicate the position of the ascent ECA contactors, (one for each contactor).
- e. One SPTT - momentary (CONNECT) - maintain-momentary (DEADFACE) switch controls the "deadfacing" of the main power feeds between the descent and ascent stages.
- f. One flag indicates the position of the Deadface Relays.
- g. One ammeter indicates battery current.
- h. One voltmeter indicates battery, bus and AC voltages.
- i. One rotary selector switch for the analog meters (ammeter, voltmeter).
- j. A battery fault light to isolate a battery overcurrent, reverse current or overtemperature.
- k. A bus fault light to locate a bus or feeder short.



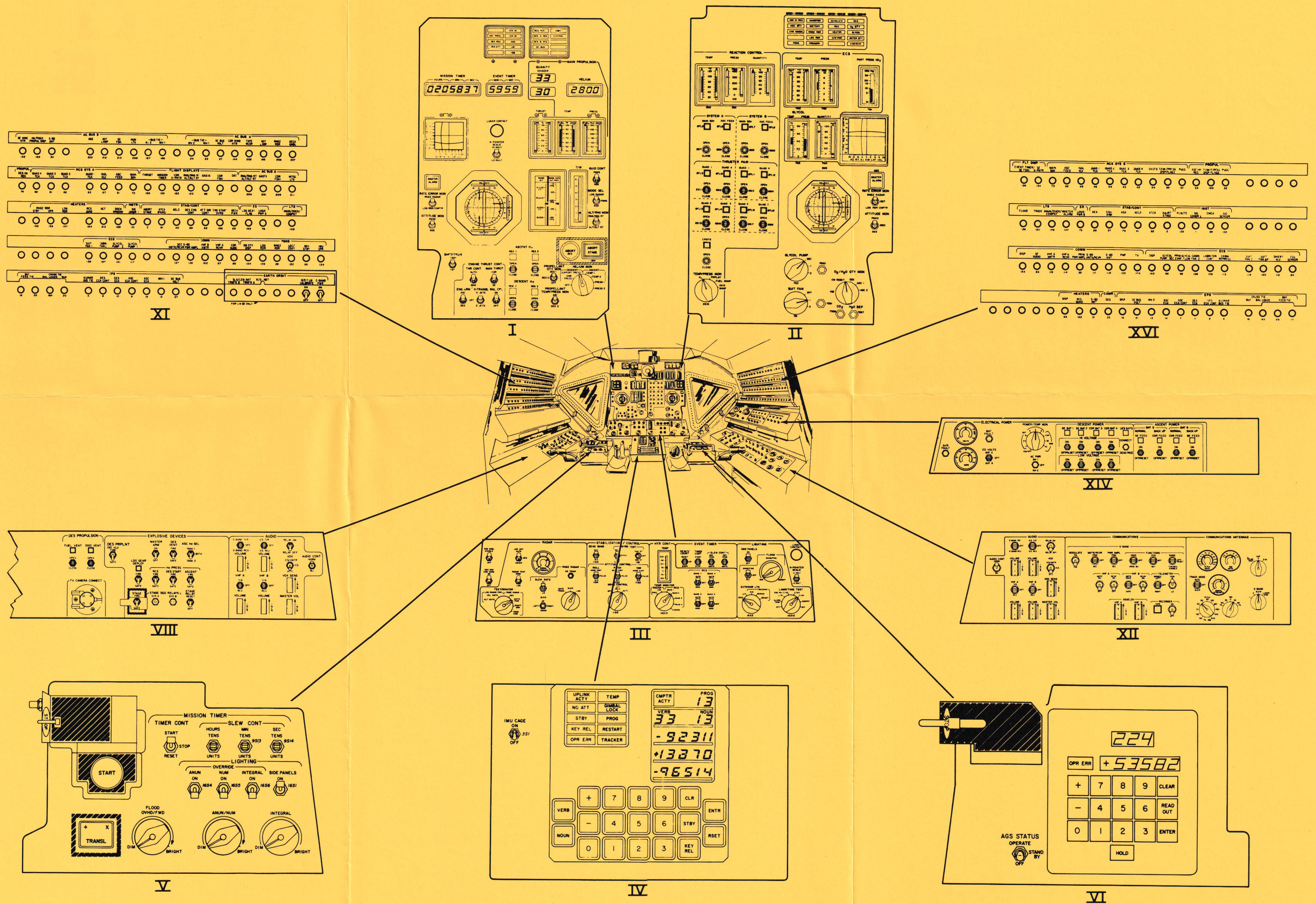
9. Circuit Breaker Panels

Two DC busses (Commander's and System Engineer's) are connected electrically by the main power feeder system. Where redundant or functionally redundant equipment exists, this equipment is placed on different busses so that each bus can perform an abbreviated abort mission.

10. Sensor Power Fuse Assemblies

Two Sensor Power Fuse Assemblies provide a secondary DC bus system supplying excitation to ECS RCS and Propulsion transducers which in turn develop instrumentation display and telemetry information. Each assembly consists of forty (40) fuses.

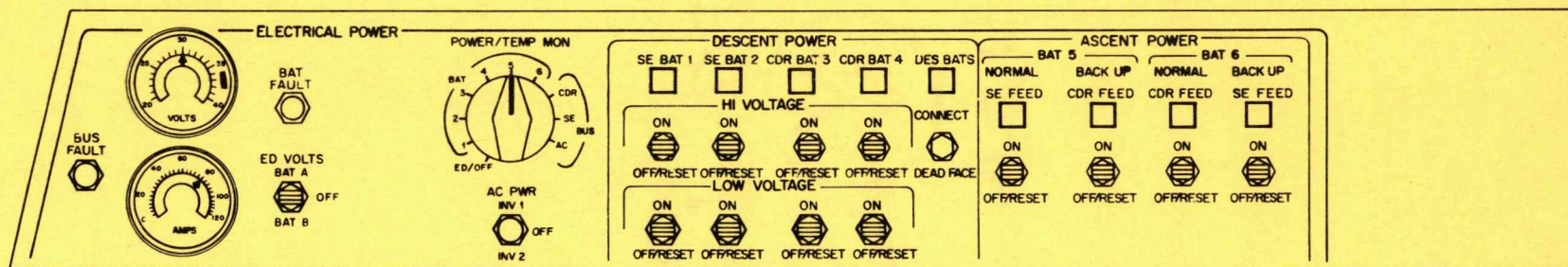




# LM DISPLAYS AND CONTROLS

T30005-28  
DEC 66





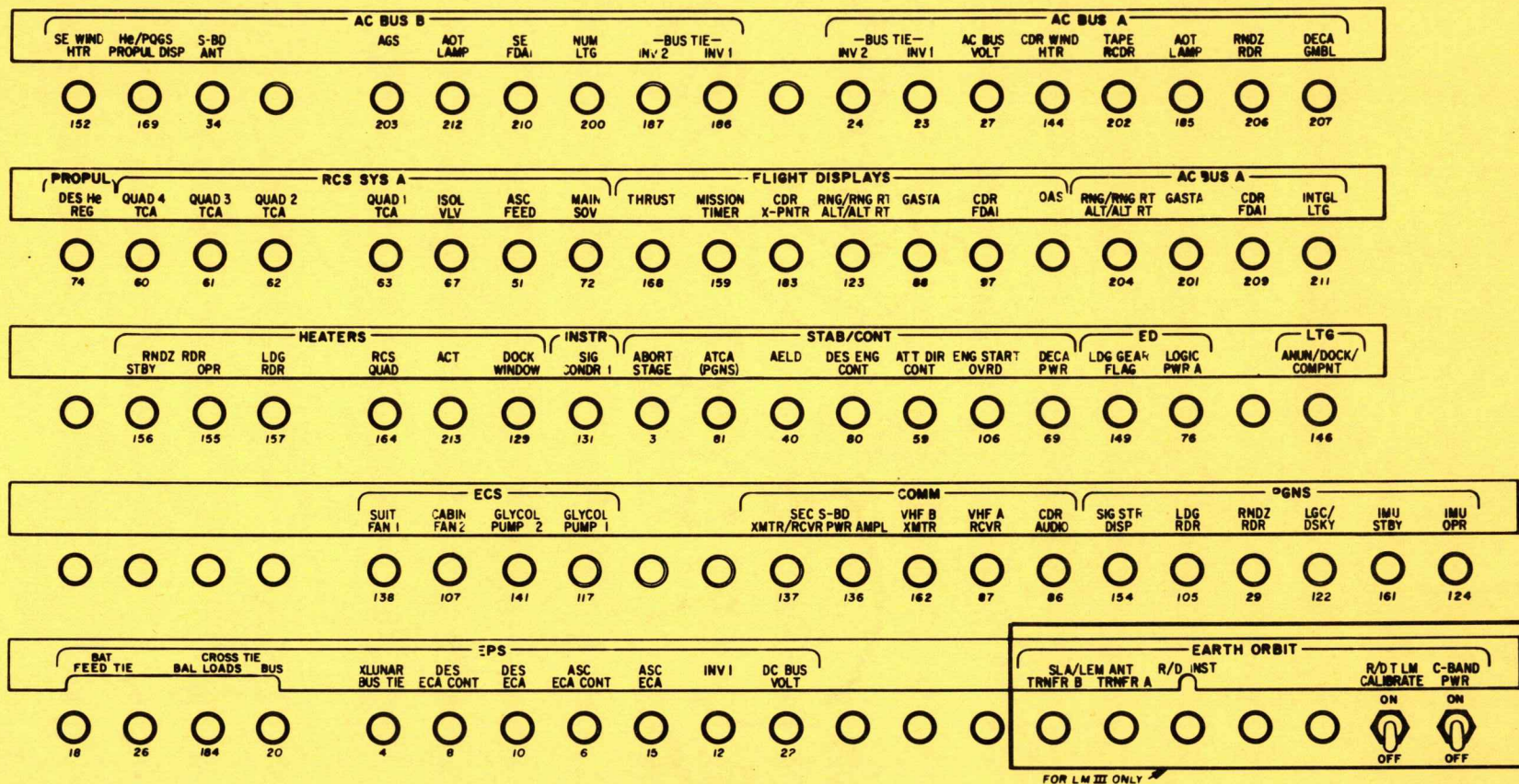
PANEL XIV



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Figure 1-22



FOR LM III ONLY

PANEL XI

T 30900-20  
NOV 66

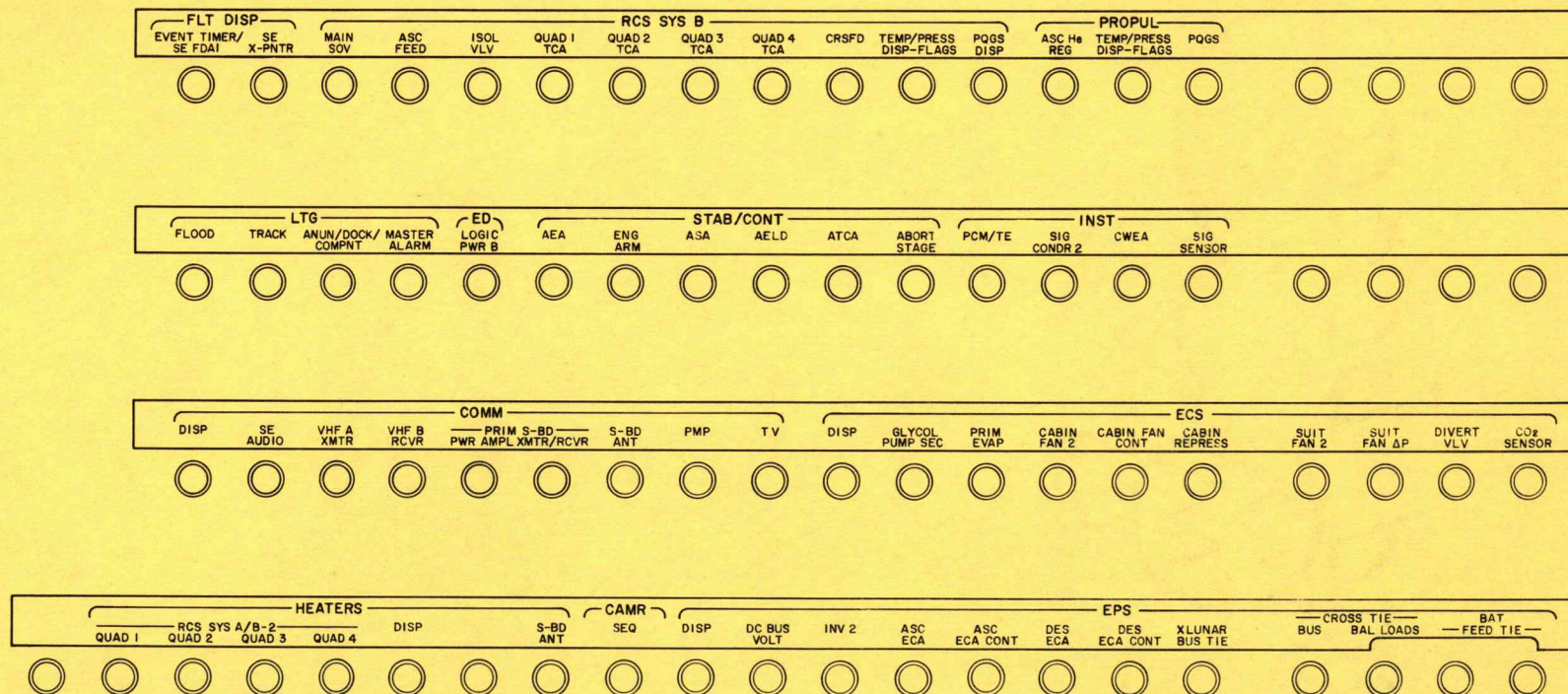


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Figure 1-23



PANEL 16  
LM3

T30900-21  
MAY 67

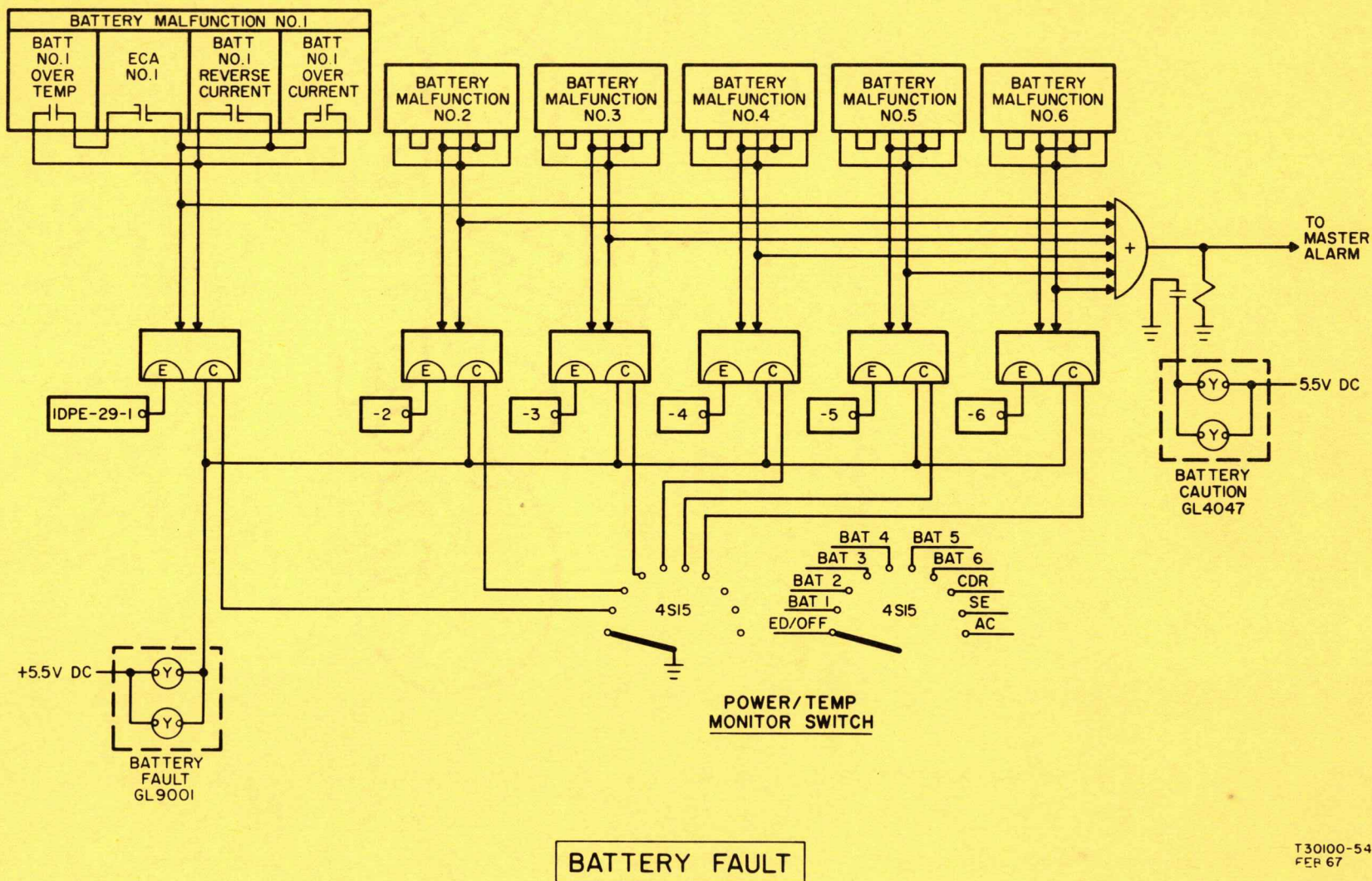


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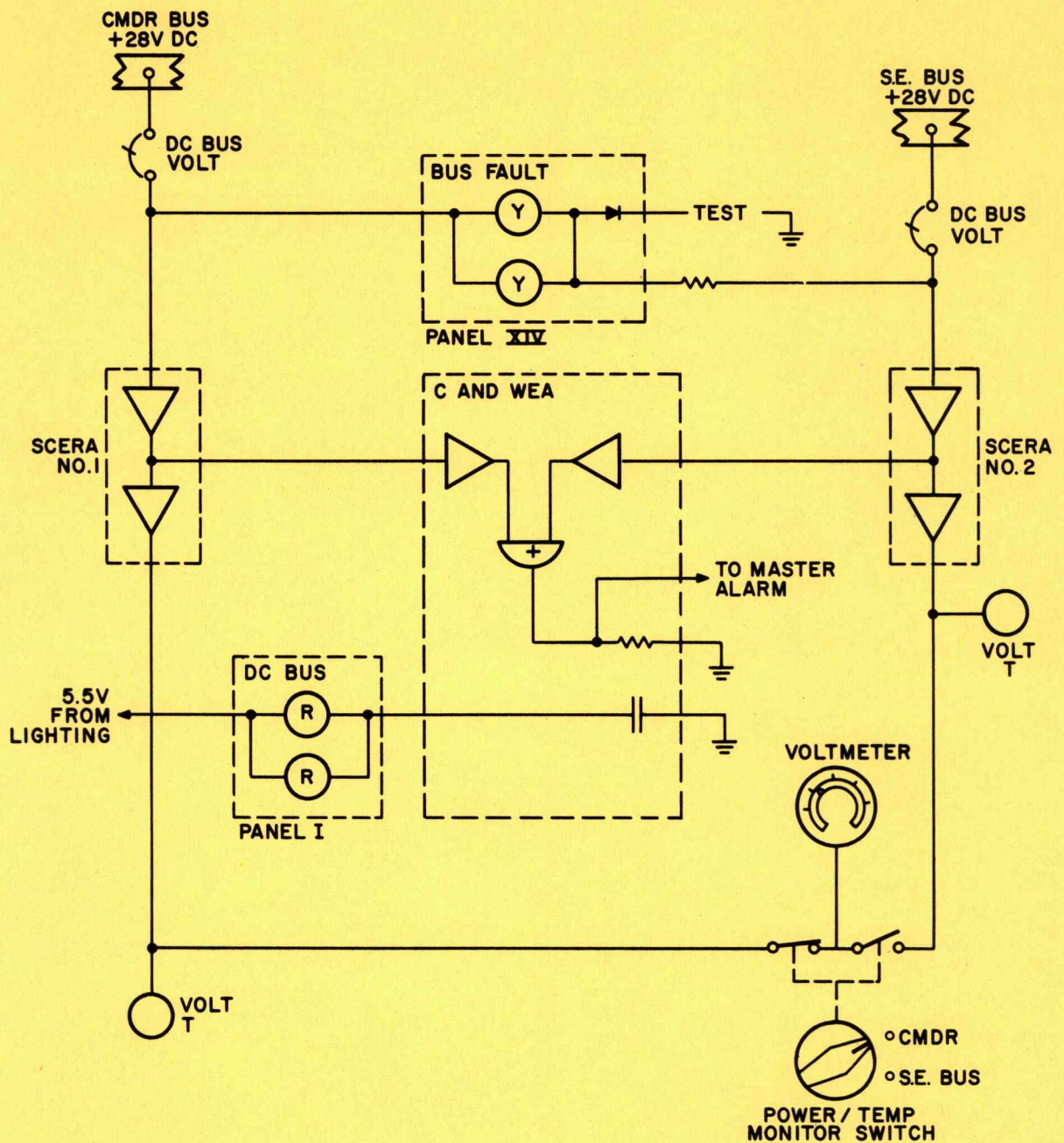
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Figure 1-24



T30100-54  
FEB 67





# DC BUS MONITORING AND WARNING

T-30100-55  
FEB 67

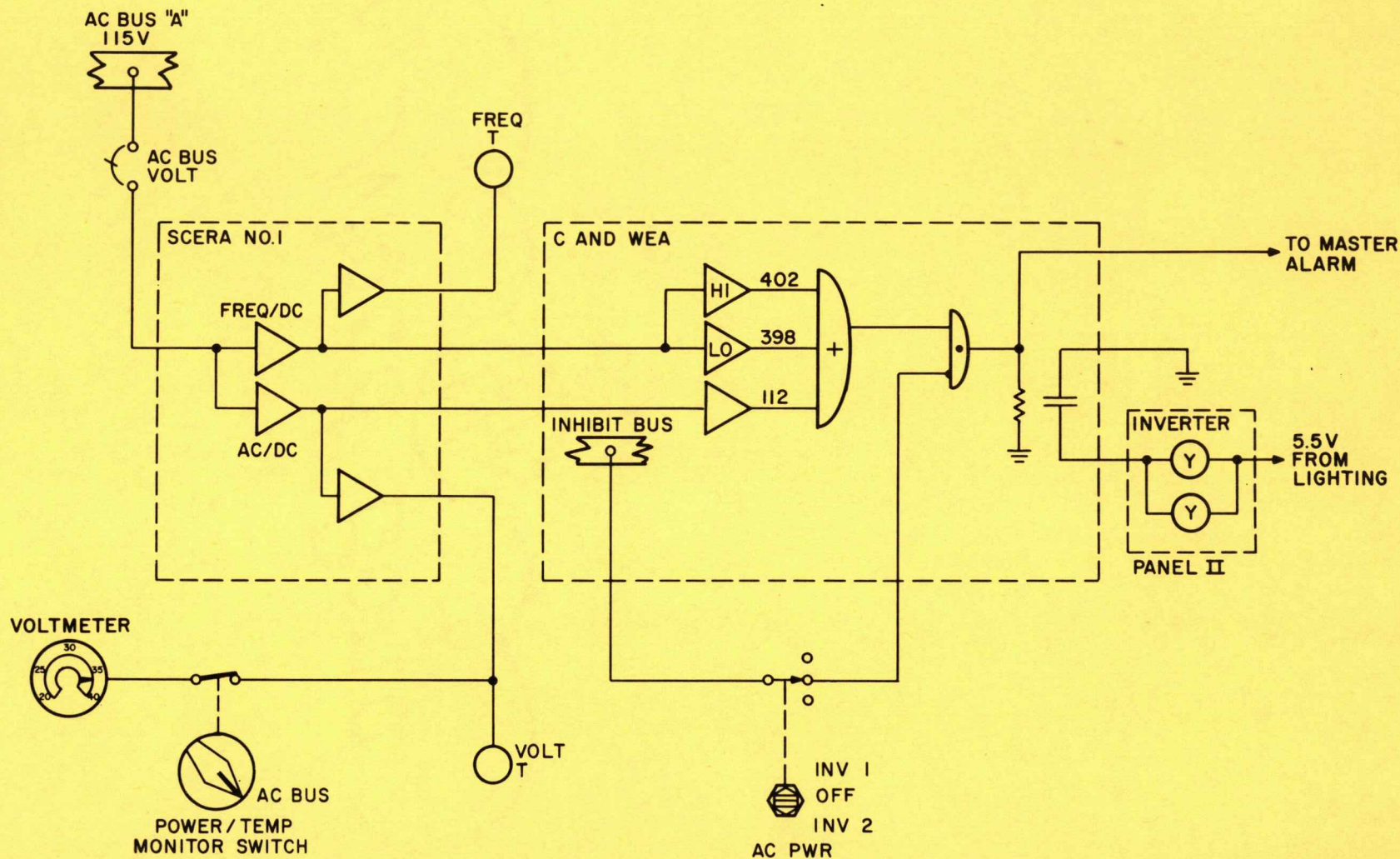


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Figure 1-26



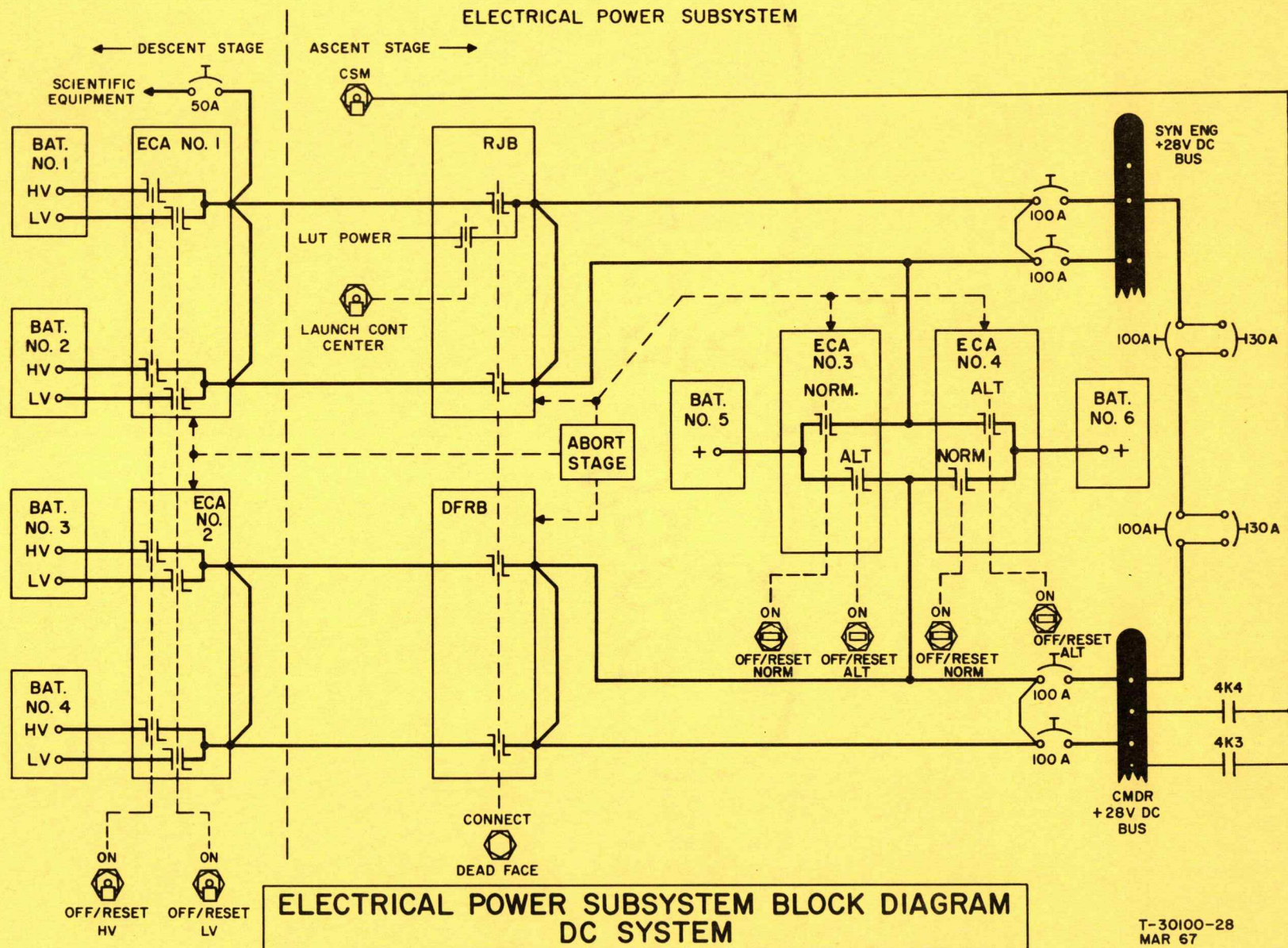
AC POWER MONITORING AND CAUTION

T30100-59  
MAR 67



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Figure 1-27

T-30100-28  
MAR 67



#### D. MODES OF OPERATION

The EPS operates in six modes of operation as follows:

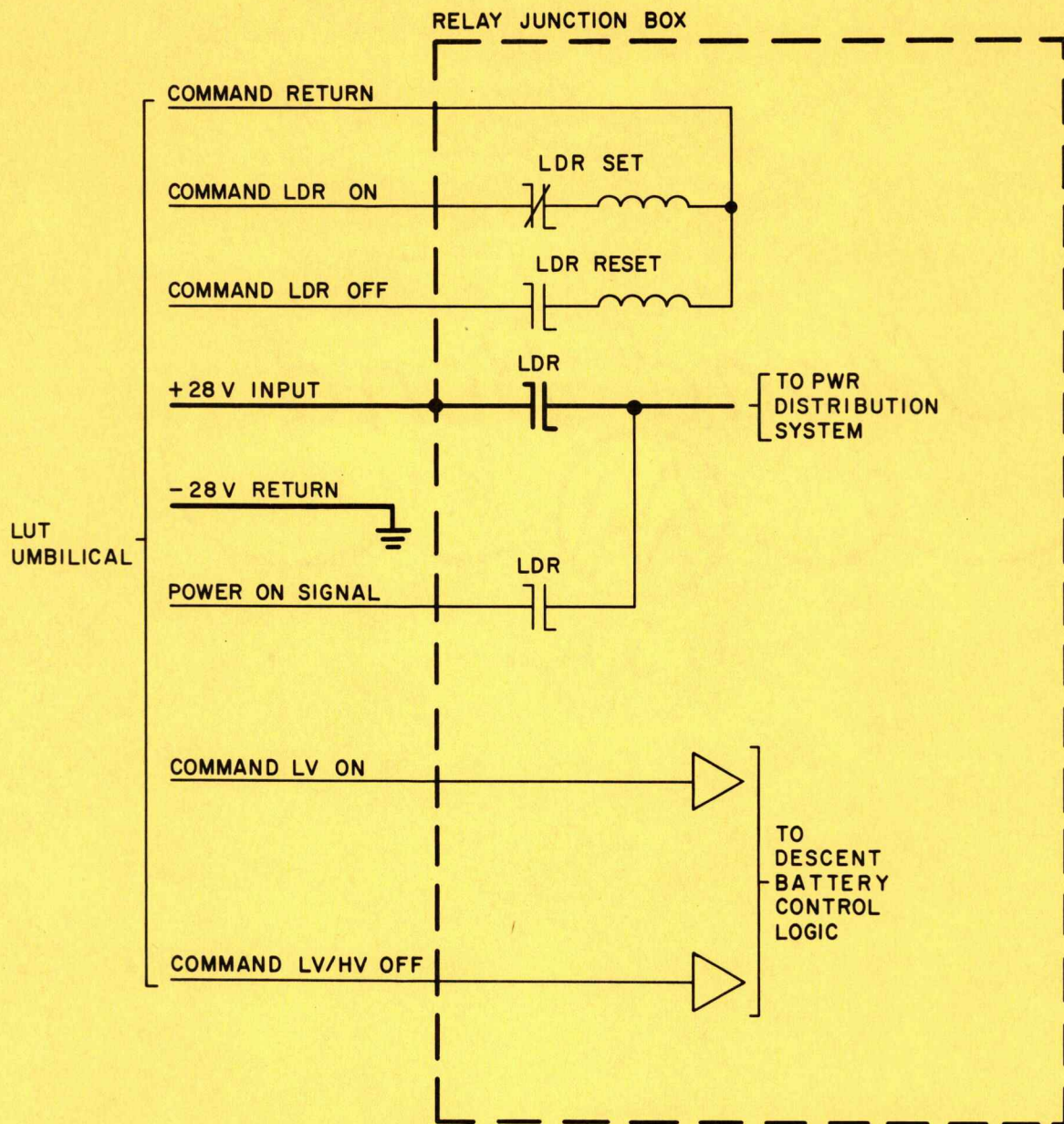
1. GSE
  - a. Vehicle Ground Power Supply (VGPS) - To T-7 hours.
  - b. LUT to T-30 minutes.
2. T-30 minutes through CSM Transposition - descent batteries LV taps.
3. Translunar - CSM/LM power.
4. Descent power - descent batteries HV taps.
5. Ascent power - Normal MFC.
6. EPS "ABORT STAGE" configuration.

The EPS is comprised of a DC power distribution system and an AC power distribution system.

##### 1. GSE Mode of Operation

Pre-launch LM DC and AC power will be supplied by the VGPS. An umbilical cable or a portable power supply will be carried on board the LM and manually connected to two GSE connectors located under the lower circuit breaker tier at the Commander's and System Engineer's panels. At approximately T-7 hours this GSE power will be replaced by the LUT power. The SLA/LM assembly will now be connected to the LUT by an umbilical cable. An internal cable will interface the SIVB Instrumentation Unit to external connectors on the LM. LUT power is supplied to the System Engineer's bus through the RJB. LUT remote control includes launch deadface relay (LDR) "SET" and "RESET", LM HV/LV "OFF" and LV "ON" signal. The LDR supplies power through the System Engineer's main power feeders to the System Engineer's DC bus. Power is supplied to the Commander's DC bus through two DC bus cross tie circuit breakers.





# LUT CONTROL LOGIC

T30100-5  
MAR 66



Prerequisite of the EPS controls are as follows:

- a. Deadface relays - "CONNECT".
- b. DC BUS BALANCE CROSS TIE circuit breakers (2) must be "CLOSED".
- c. DES ECA circuit breakers (2) must be "CLOSED".

2. T-30 Minutes Through CSM Transposition

At T-30 minutes LUT will "RESET" the LDR and initiate EPS descent batteries "LV ON". The EPS batteries will supply limited power to certain critical equipment from T-30 minutes through launch to completion of CSM transposition and docking.

3. Translunar - CSM to LM Power

On completion of CSM transposition and docking, an astronaut will connect power and control umbilical cables to the LM. The CSM will deactivate LM power and then supply power to the LM critical equipment utilizing the LM's translunar negative bus. CSM/LM control logic prohibits CSM power to the LM bus distribution system while LM descent batteries are "ON". CSM/LM control logic is as follows:

- a. CSM initiates CSM power to the LM.
  - (1) CSM selects control switch to "CSM POWER ON" position.
  - (2) A control signal to the LM EPS commanding descent batteries HV/LV "OFF".
  - (3) Descent ECA's LV "OFF" logic returns control signal to initiate relay logic supplying CSM power to LM Commander's DC bus.
- b. CSM deactivates CSM power to the LM.
  - (1) CSM selects control switch to the mid position.

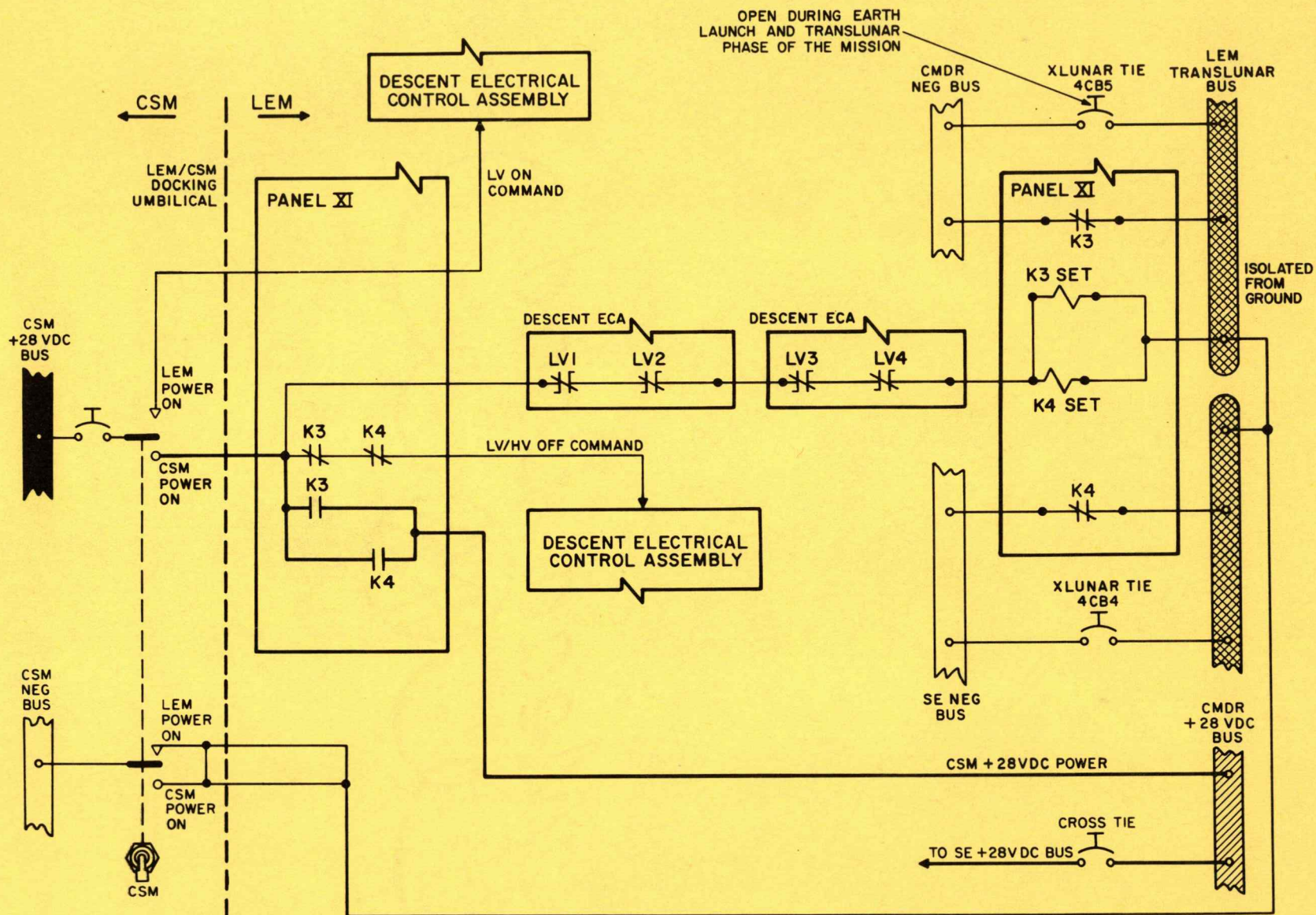


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Figure 1-29



# COMMAND SERVICE MODULE - LM POWER TRANSFER LOGIC

T-30100-39  
MAR 67



c. CSM initiates LM power ON.

- (1) CSM selects control switch to the "RESET" position.
- (2) A control signal deactivates the LM's CSM relay logic and in addition initiates descent ECA's LV "ON" logic.

Prerequisites of the EPS controls are as follows:

- a. Requirements for launch configuration.
- b. TRANSLUNAR BUS TIE CIRCUIT BREAKERS (2) must be "OPEN".

#### 4. Descent Power

EPS descent power Controls and Displays are located on the EPS Control Panel XIV. Each of four descent batteries are provided with HV and LV "ON and OFF" selector switches and flag indicator. The flag indicators are three position marked as follows:

- a. Barber pole (black and white strips) - OFF.
- b. Gray flag - HV tap selection.
- c. LO on a gray background - LV tap selection.

A power/Temp Monitor switch selects individual batteries for metered voltage and current displays. Battery LV control is effected through the RJB to an appropriate ECA while the battery HV control is direct to the ECA. Additional LV control is effected within the RJB through internal logic receiving control signals from the following:

- a. CSM/LM power "ON and OFF".
- b. LUT control logic power "ON and OFF".
- c. LM abort logic.



Descent battery selector control and descent ECA power are redundantly provided by two DES ECA CONT and two DES ECA circuit breakers, one each located on the Commander's and the System Engineer's circuit breaker panels. Negative return from the descent ECA's is connected to the translunar negative bus.

The functional operation of a descent ECA is as follows:

- a. Selection of either HV SET or LV SET will initiate either HV or LV main feed contacts and place the battery on the line to the power distribution system. It is impossible to select both HV and LV "ON" at the same time. Further, OFF/RESET must be initiated prior to changing selection from LV to HV or vice-versa.
- b. Selection of either HV or LV will initiate auxiliary HV or LV contacts providing instrumentation signals for telemetry and "FLAG" indication stating battery is "ON".
- c. Current monitor assembly supplies
  - (1) current readout
  - (2) reverse current relay control
  - (3) overcurrent relay control

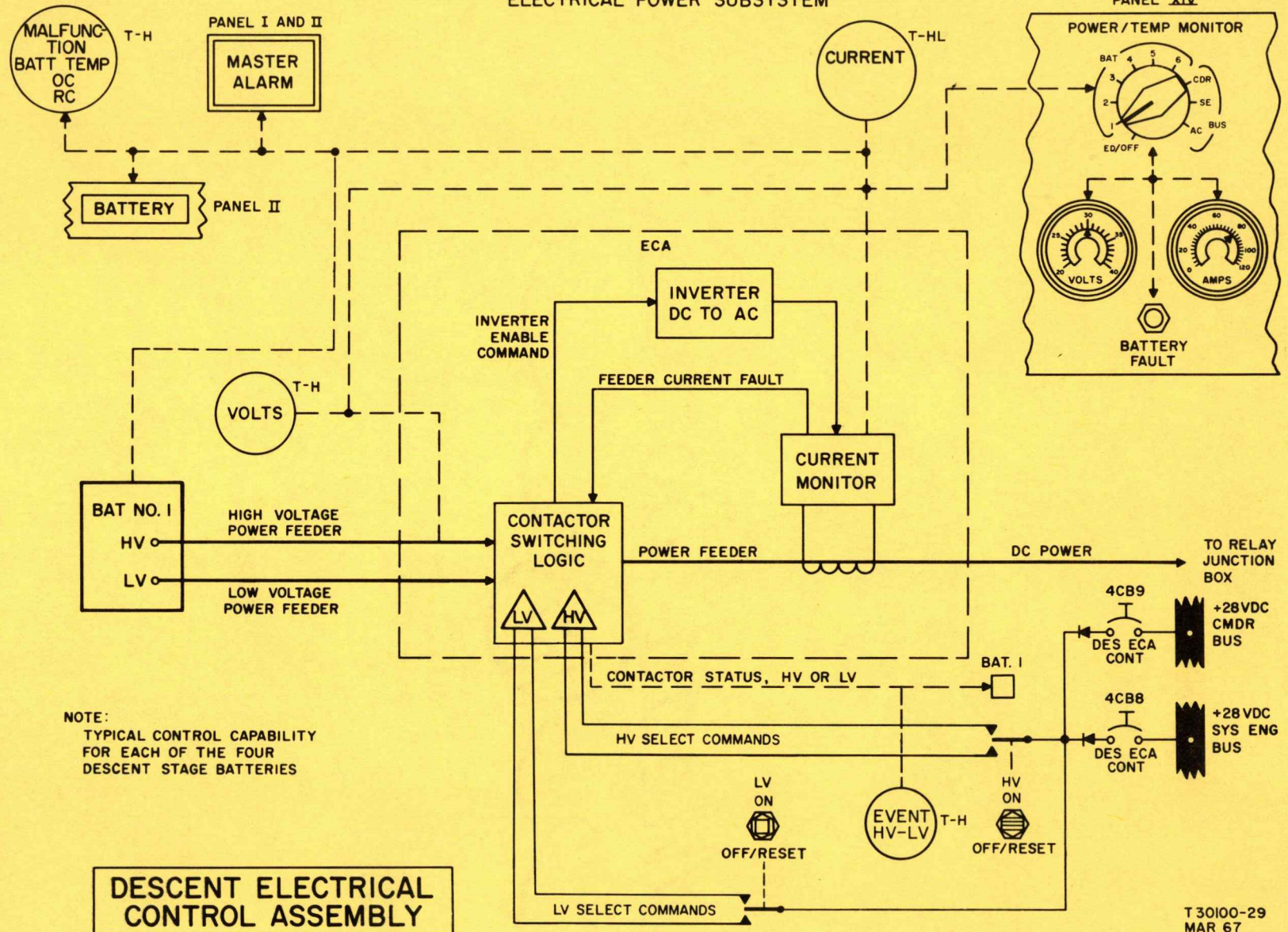
The above readout signals are applied to instrumentation for telemetry, caution warning and advisory display.

An overcurrent condition will initiate caution warning and automatically remove the affected battery from the power distribution system. OFF/RESET must be initiated prior to returning the affected battery to the line. If an overcurrent condition still exists, the current monitor will again automatically shut down the battery.

- d. Battery overtemperature contact closure 'signals' are routed through an auxiliary ECA contactor supplying information to instrumentation for telemetry and caution warning. No analog panel display is available. The astronaut will make a determination of the indication and perform corrective action.



# ELECTRICAL POWER SUBSYSTEM



T 30100-29  
MAR 67

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Figure 1-30



- e. Battery voltage is read directly from battery HV terminal and is supplied to instrumentation for telemetry and advisory display.
- f. Additional AUX LV contacts supply CSM/LM power logic when the descent battery has been removed from the power distribution system.

Prerequisites of the EPS controls are as follows:

- a. Deadface relays - "CONNECT".
- b. TRANSLUNAR BUS TIE circuit breakers (2) "OPEN" at earth launch to lunar orbit; "CLOSED" when the LM is manned and the LM is powered UP in lunar orbit.
- c. DC BUS CROSS TIE circuit breakers (2) must be "OPEN".
- d. DES ECA CONT (2) and DES ECA (2) circuit breakers must be "CLOSED".

#### 5. Ascent Power

EPS ascent power Controls and Displays are located on the EPS Control Panel XIV. Each of the two ascent batteries are provided with dual selector switches, NORMAL FEED and BACKUP FEED (ALTERNATE) and flag indicators. The flags are two position indicators (BARBER POLE - battery OFF and GRAY FLAG - battery ON). A Power/Temp monitor switch select each battery for metered voltage and current displays. Ascent battery selector control and ascent ECA power are redundantly provided by two ASC ECA circuit breakers, one each located, on the Commander's and System Engineer's circuit breaker panels. However, ascent battery control logic precludes the possibility of complete BUS power failure. Both NORMAL FEED and BACKUP FEED are connected directly to the ascent battery permitting initiating of ascent power without the bus being energized.



Battery 5 NORM supplies power to the System Engineer's DC bus and battery 6 NORM supplies power to the Commander's DC bus. Selection of BACK UP MODE of either battery will place it to the opposite DC bus.

The functional operation of an ascent ECA is divided into two parts; NORM FEED control and BACK UP FEED (ALT) control. Both are identical, each section supplies identical readouts to instrumentation for telemetry and displays. ECA operation is as follows:

- a. Selection of either NORM or ALT will initiate main feed contactors and place the battery on the line to the power distribution system. Both NORM and ALT may be selected for either or both ascent batteries.
- b. Selecting either NORM or ALT will initiate auxiliary contactors providing instrumentation signals for telemetry and flag indications displaying battery status.
- c. There is one current monitor assembly in each ECA.
  - (1) One common unit supplying reverse current relay control, current readout and overcurrent protection for the normal feeder only.

The above readout signals are applied to instrumentation for telemetry, caution light and advisory display.

An overcurrent condition will initiate the caution warning system and will automatically trip the normal main feed contactor, the alternate main feed contactor is not affected by overcurrent. OFF/RESET must be initiated prior to operating the normal main feed contactor. If an overcurrent condition still exists, the overcurrent monitor will again trip the normal main feed contactor.

A reverse current condition will initiate caution warning only. The astronaut will have to make a determination of the indication and perform corrective action.

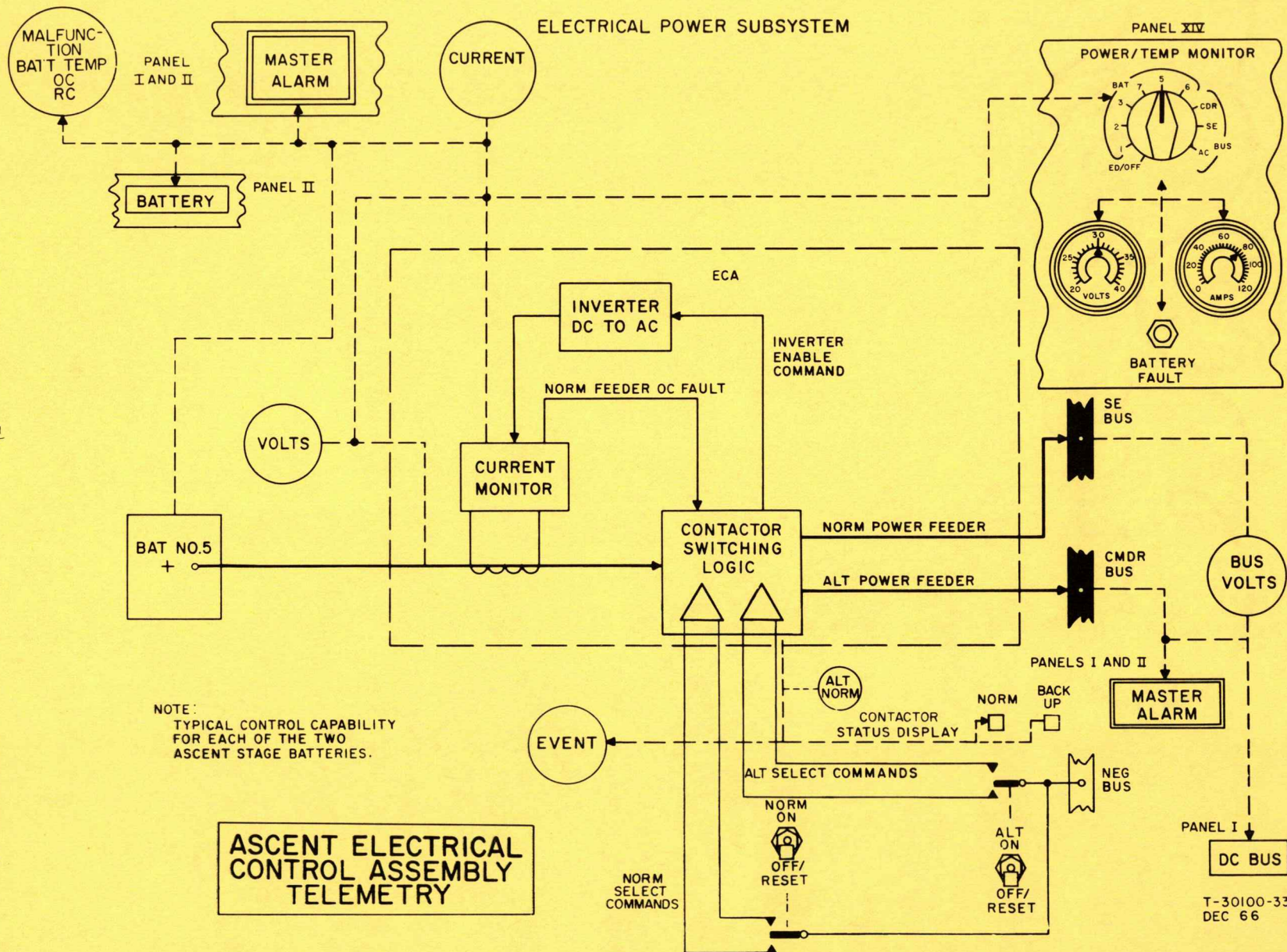


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Figure 1-31





- d. Battery overtemperature contact closure 'signals' pass through an auxiliary NORM ECA contactor supplying information to instrumentation for telemetry and caution lights. No analog panel display is available. The astronaut will make a determination of the indication and perform corrective action. This information is not available when the battery is utilized in the BACK UP mode of operation.
- e. Battery voltage is read directly from battery input to the ECA and is supplied to instrumentation for telemetry and advisory display.
- f. Additional NORM and ALT contacts supply ABORT logic permitting "SHUT DOWN" of descent batteries only after an ascent battery is on the line. This assures continuity of power to the DC bus system.
- g. An additional ALT auxiliary contact completes the path for an ABORT command to the NORM FEED selector provided the battery has not already been in the BACK UP mode.

Prerequisites of the EPS controls are as follows:

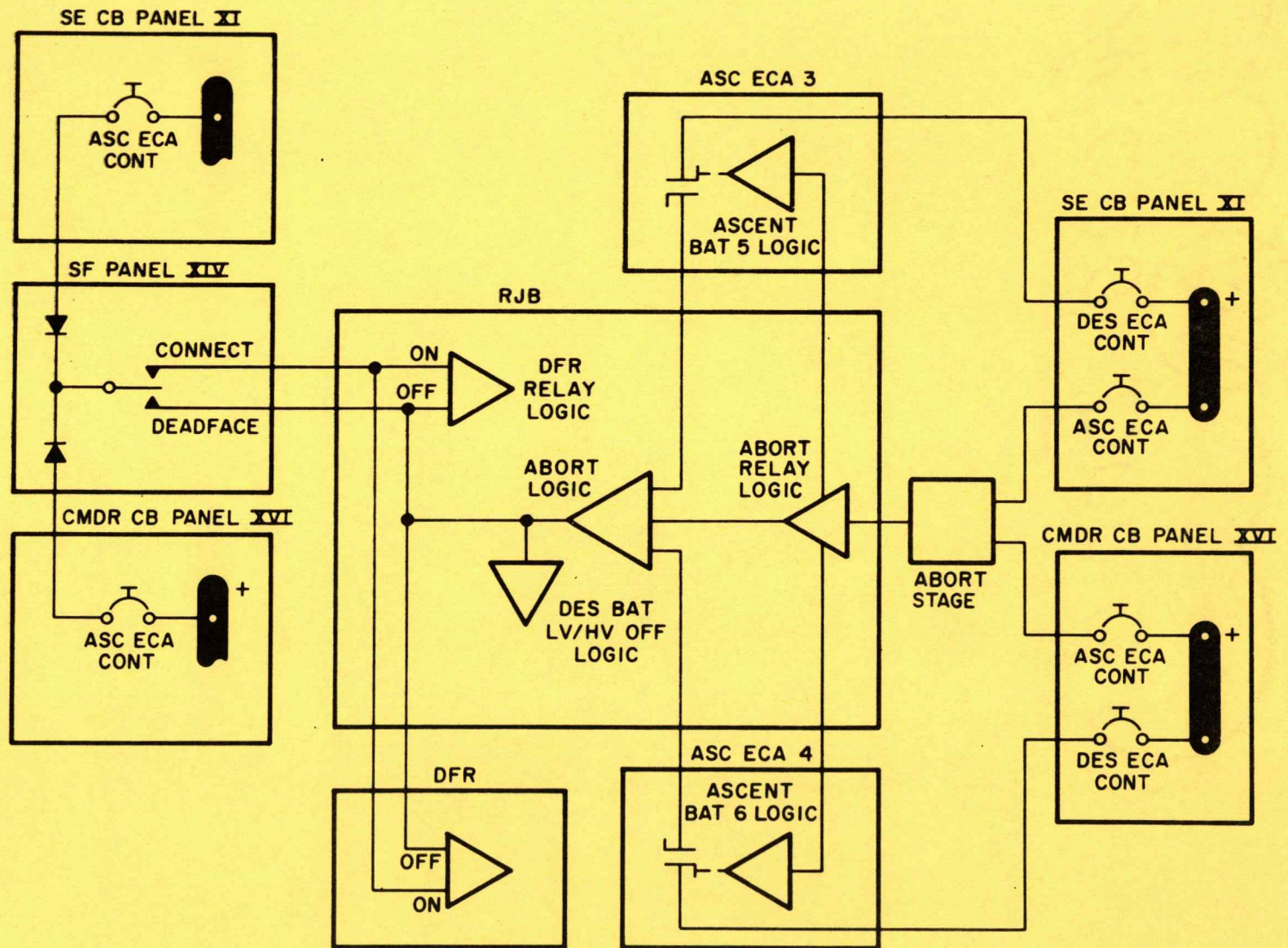
- a. ASC ECA CONT (2) and ASC ECA (2) circuit breakers must be "CLOSED".
- b. DC BUS CROSS TIE circuit breakers (2) must be "OPEN".
- c. TRANSLUNAR BUS TIE circuit breakers (2) must be "CLOSED".
- d. DISPLAY circuit breaker must be "CLOSED".

#### 6. EPS Abort Configuration

The EPS ABORT mode of operation consists of automatically transferring the LM DC BUS loads from descent batteries to ascent batteries maintaining continuous uninterrupted DC power to the bus distribution system. This condition is initiated by operating the ABORT STAGE resulting in a +28 VDC signal being applied to the EPS abort relays (2).

A normal transfer of batteries can be initiated by the following manual controls:

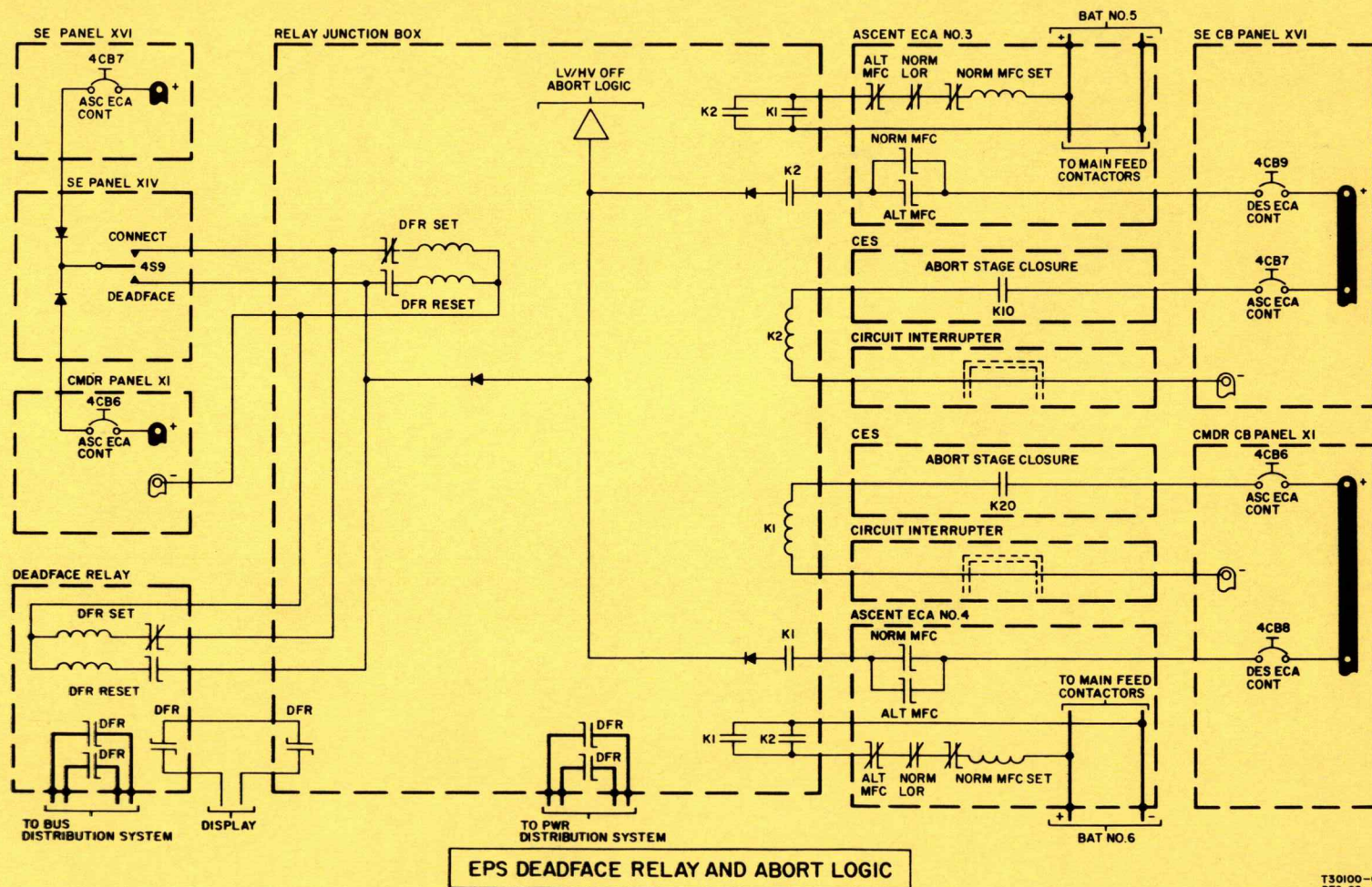




DEADFACE RELAY AND ABORT LOGIC



Figure 1-33





- a. Manually select ascent batteries to "ON" status.
- b. Manually select descent batteries to "OFF" status.
- c. Select DES BATS switch to "DEADFACE" position.

Auxiliary DFR contacts in the RJB and DFR provide direct control to a DES BATS flag display.

In the automatic mode the same sequence of events occur. The "Abort Stage" switch initiates two ABORT relays which in turn initiates the NORM main feed contactors of each ascent ECA provided the ECA's have not been previously selected in the ALT mode of operation. Additional ABORT relay contacts supply an OFF/RESET signal through the RJB to all four descent batteries and to the deadface relay only after the ascent battery main feed contactors have placed them on the line.

## 7. DC Bus Distribution

A system of 'bus feeder cables' interfaces the descent batteries and ECA's through the RJB and DFR to a BUS distribution system located at the Commander's and System Engineer's circuit breaker panels. The ascent batteries and ECA's are connected to the feeder cable system at the RJB and DFR.

GSE ground power is manually connected directly to the DC and AC bus system. GSE LUT DC power is interfaced through the SIV B Instrumentation unit to the RJB. In addition the LUT control center can initiate the descent batteries LV "ON" or "OFF".

CSM/LM power is interfaced with the LM through a docking umbilical cable located in the LM docking tunnel. CSM/LM equipments separate from the regular EPS NEG BUS and provides a ground return loop to the CSM power system through the trans-lunar negative bus.

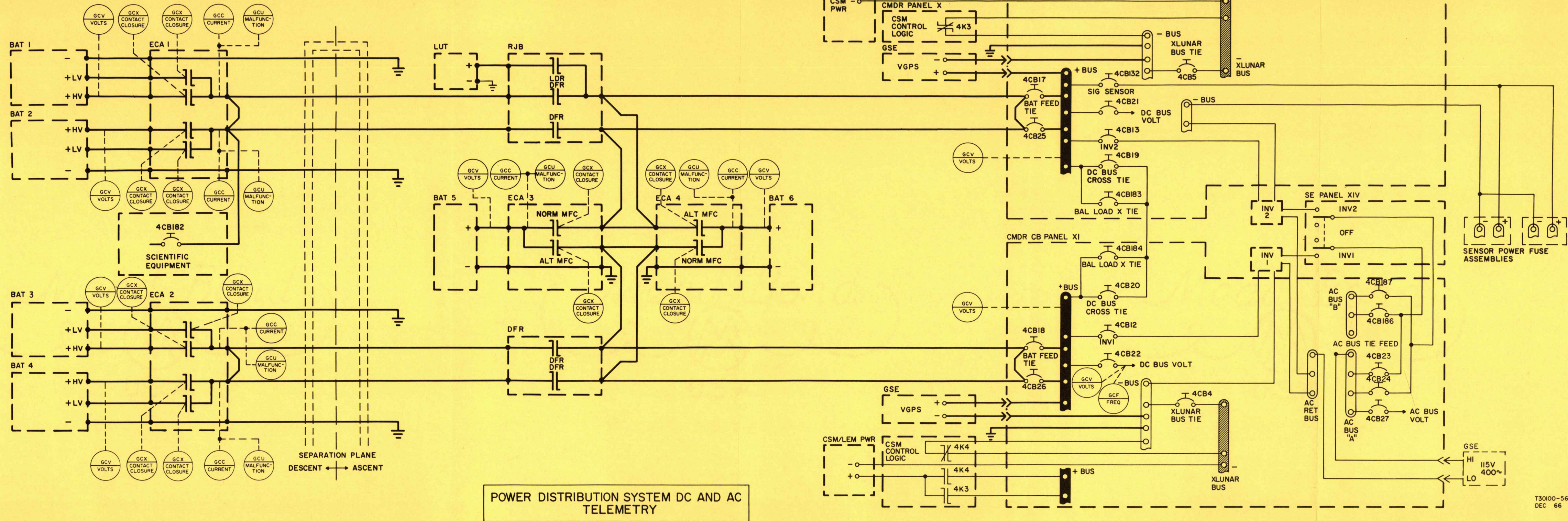
The functional operation of the DC Bus Distribution System is as follows:

- a. Descent batteries 1 and 2 are individually connected to ECA 1. The battery outputs of the ECA are paralleled and connected by a dual feeder system to the RJB DFR relay assembly. The parallel feeder system continues to the System Engineer's DC Bus through two BAT FEED TIE circuit breakers.



- b. Descent batteries 3 and 4 are individually connected to ECA 2. Battery outputs again are paralleled and connected by a dual feeder system to the DFR relay assembly. The Parallel feeder system continues to the Commander's DC Bus through two BAT FEED TIE circuit breakers.
- c. The LUT umbilical tie to the distribution system is made through the RJB LUT Deadface relay. LUT power is interfaced with Battery 1 and 2 feeder systems to System Engineer's DC BUS. Two DC BUS CROSS TIE circuit breakers connect to the System Engineer's DC BUS to Commander's DC BUS.
- d. Ascent battery 5 is connected to ECA 3 and ascent battery 6 is connected to ECA 4. ECA 3 NORM supplies power to System Engineer's DC BUS and ECA 4 NORM supplies power to Commander's DC BUS. The ALT mode of each ascent ECA reverses battery connection to DC busses.
- e. GSE power feeders are manually connected to the System Engineer's DC bus system and to the Commander's DC and AC bus system.
- f. CSM/LM control logic and power input are interfaced at the Commander's Panel XI. DC power is supplied to the Commander's DC BUS and then to System Engineer's DC BUS through two DC BAL LOAD CROSS TIE circuit breakers. CSM DC return is interfaced to both System Engineer's and Commander's translunar bus. The translunar busses are connected to the NEG busses through two TRANSLUNAR BUS TIE circuit breakers.
- g. A SIG SENSOR circuit breaker supplies power to two Sensor Fuse Power Assemblies.
- h. Bus voltage readouts are available from two DC BUS VOLT circuit breakers supplying signals to instrumentation for telemetry, WARNING light and advisory display. The Power/Temp Monitor switch selects either the System Engineer's or Commander's busses for metered voltage displays. A bus fault warning on Panel XIV will come ON with a short on the Commander or System Engineer Bus.







## LIGHTING

The LM lighting consists of exterior and interior illumination. The choice of illumination is based upon vehicle performance, crew visual tasks, operator fatigue, interior contrast relationships and interior-exterior environmental relationships. The lighting system must give optimum performance and maximum reliability and yet be compatible with electrical power and vehicle weight restrictions.

### Interior Lighting

The LM interior illumination shall consist of integral lighted components and flood lighting devices.

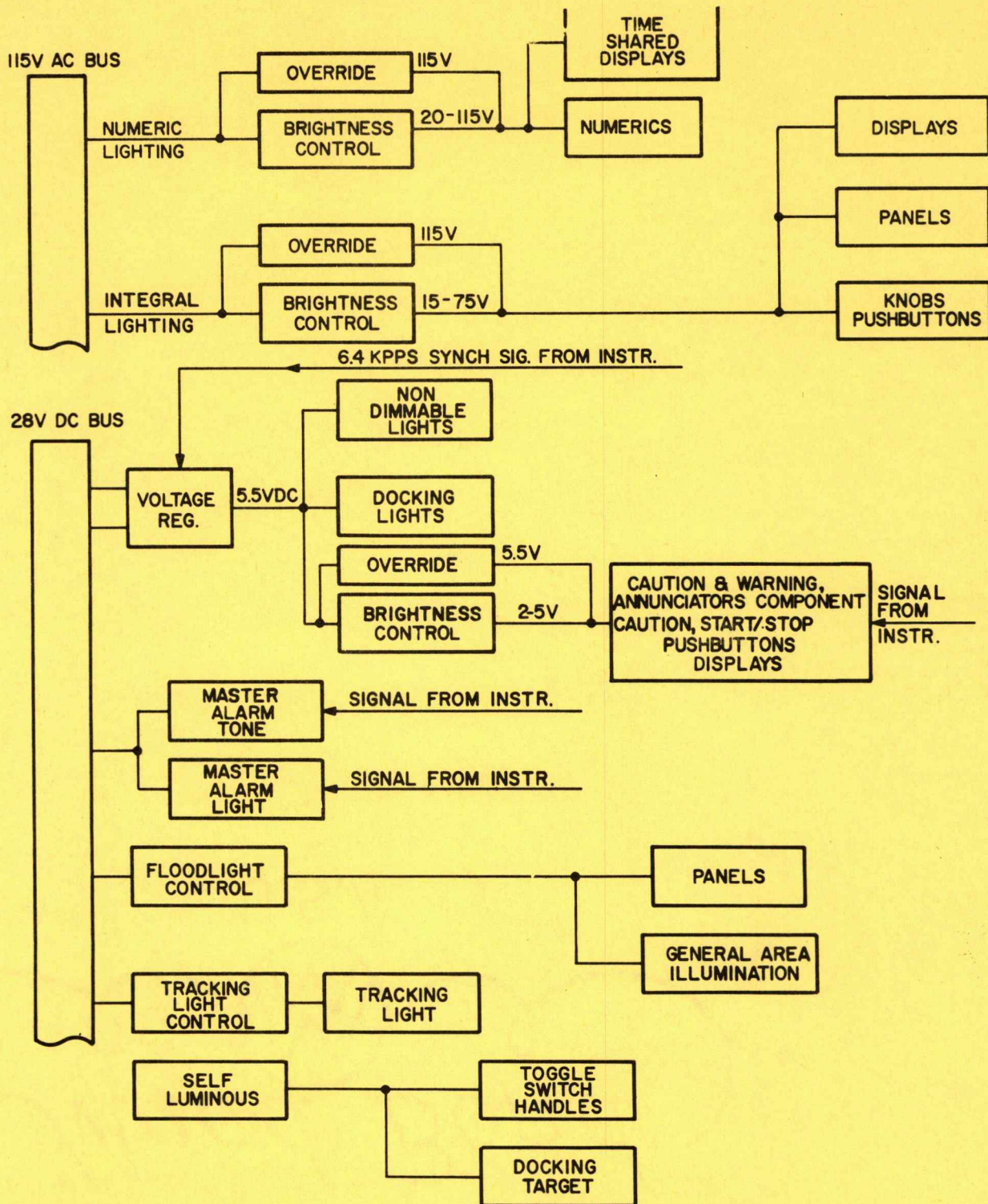
### Integral Lighted Components

There are three types of integral lighted components: Panel areas, Displays, and Caution and Warning (C&W) annunciators. These integral lighted components utilize either electroluminescent (EL) or incandescent devices. Provision is made for manually controlling the brightness of an integral lighting components in a continuous fashion. All nomenclature on the display and control panels is integrally lighted by white electroluminescent lamps in conjunction with suitable overlays. The displays have electroluminescent light sources contained within the display enclosure. The information contained in the display consists of white illuminated markings on a non-illuminated background. The non-illuminated pointer travels over an illuminated background. Numeric EL Displays have illuminated green or white digital markings on a non-illuminated background. Provisions are made for manually controlling the brightness continuously from the maximum. Caution and Warning (C&W) and component caution annunciators and numeric displays are dimmable on the same control.

### Flood Lighting

Floodlighting is provided as a secondary means of illuminating all display and control panel areas. In addition, illumination is provided as necessary within the crew compartment, for the performance of crew duties or tasks. Panel flood lighting fixtures are provided for each of the forward display panels and provides even illumination of the panel areas. Provision is made so that partial flood lights are turned on automatically when the docking hatch is opened.

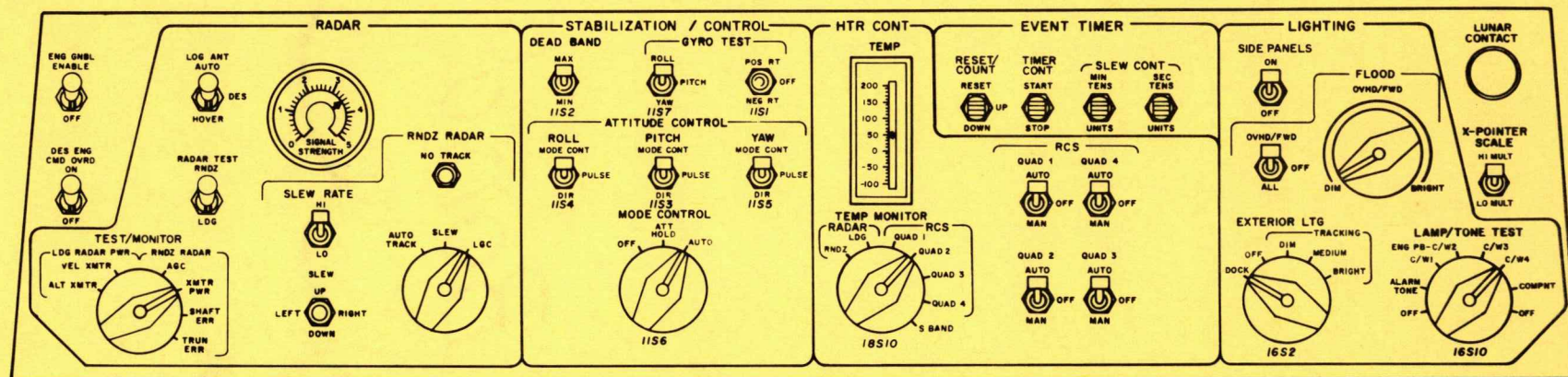




**LIGHTING BLOCK DIAGRAM**

T30900-38  
DEC 65





PANEL III

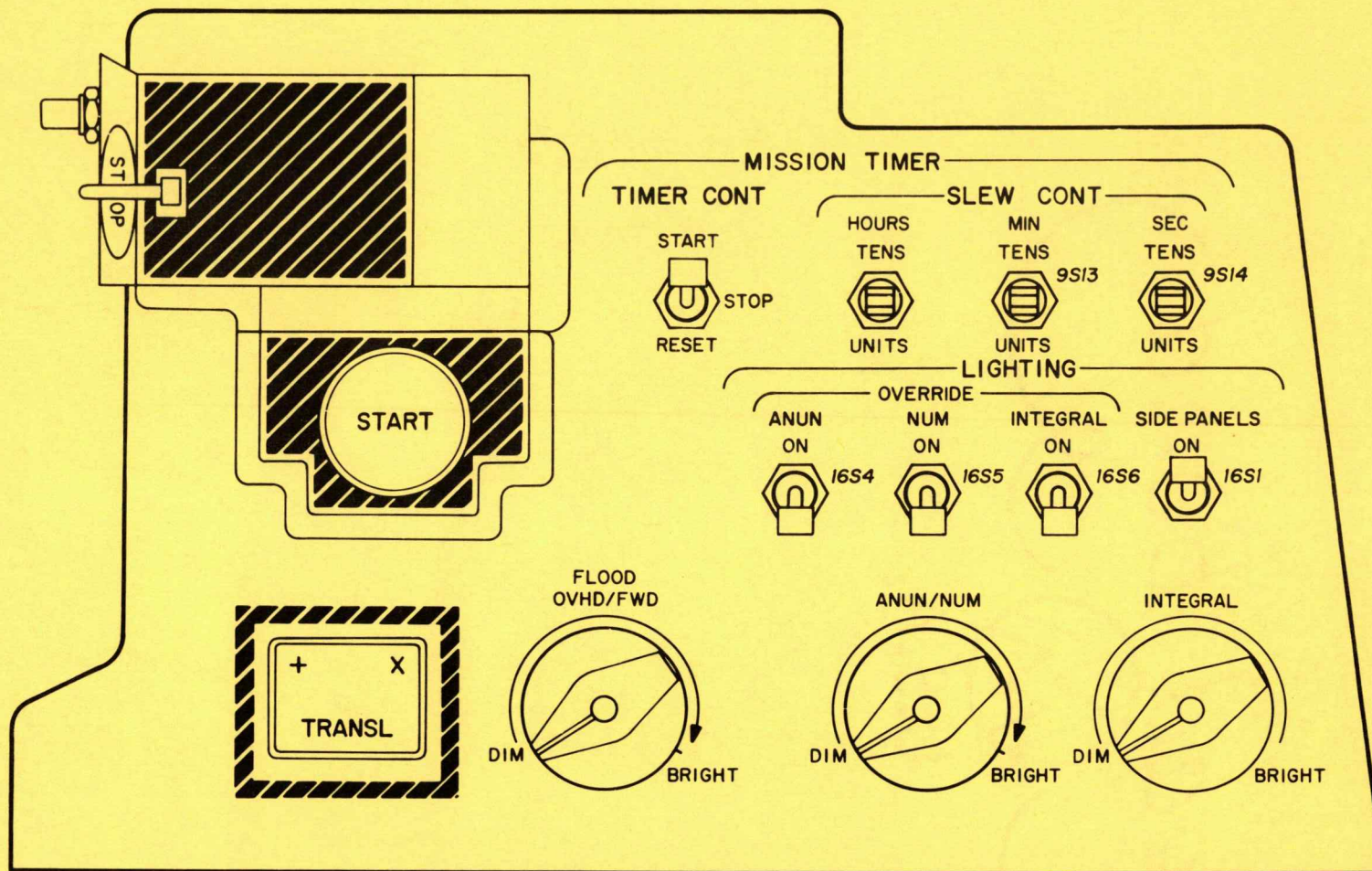


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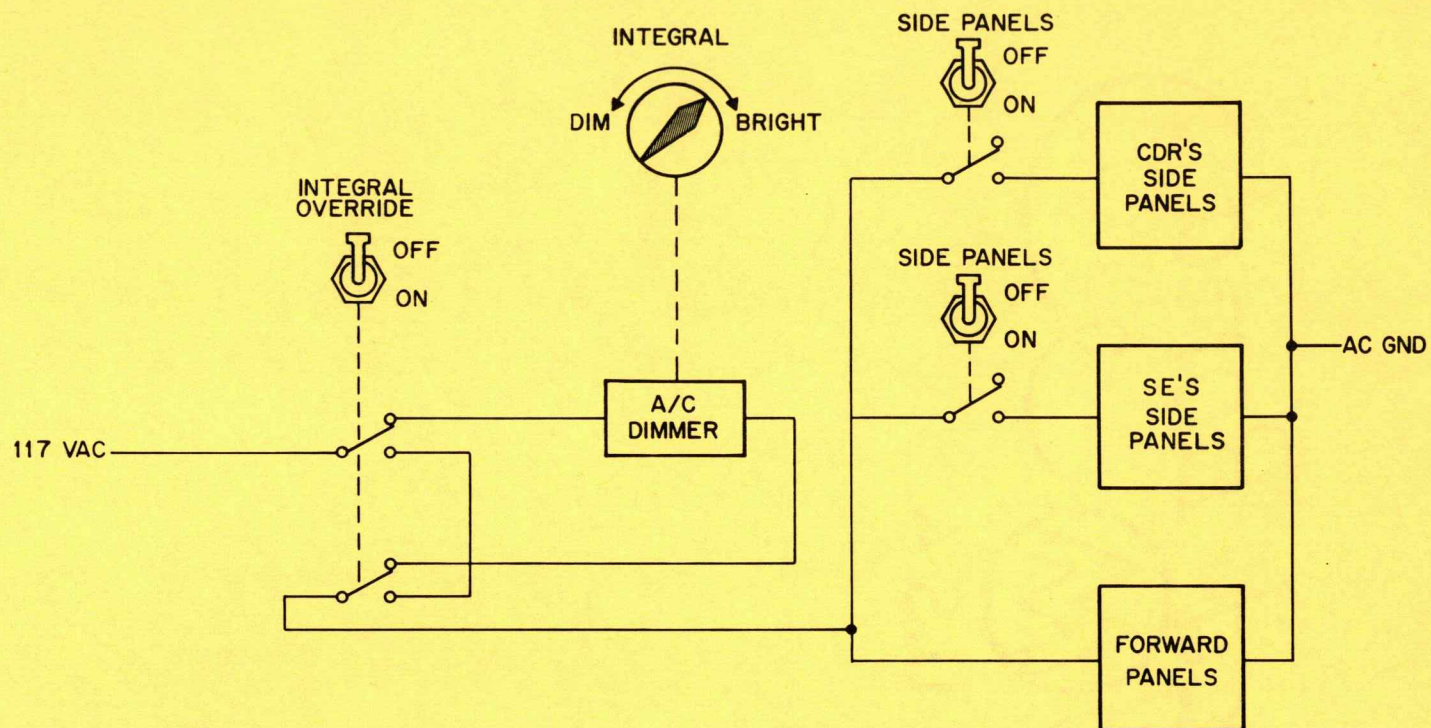
Figure 2-3



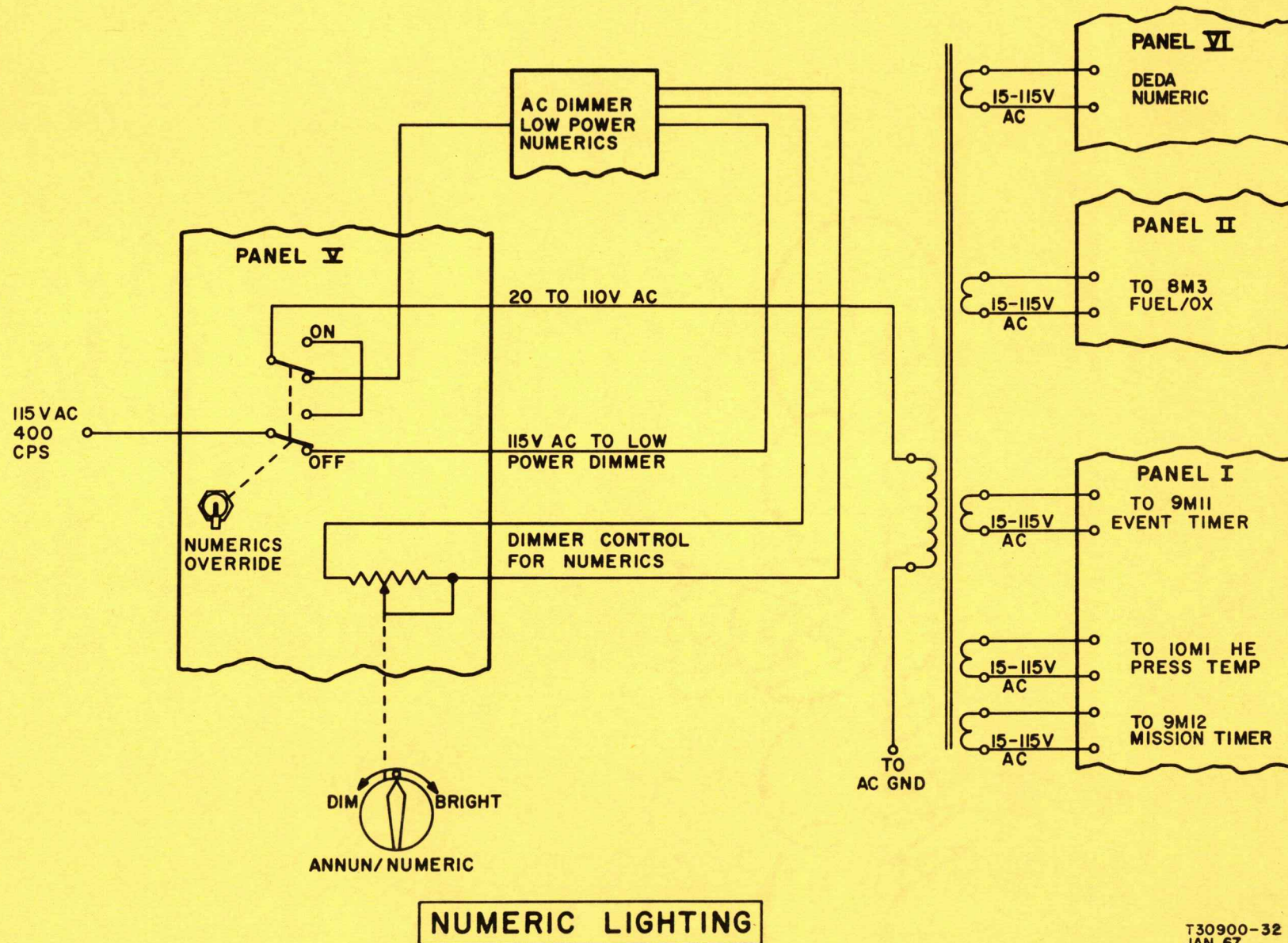
PANEL V

T30900-4  
DEC 66



**INTEGRAL LIGHTING**T30100-50  
JULY 66







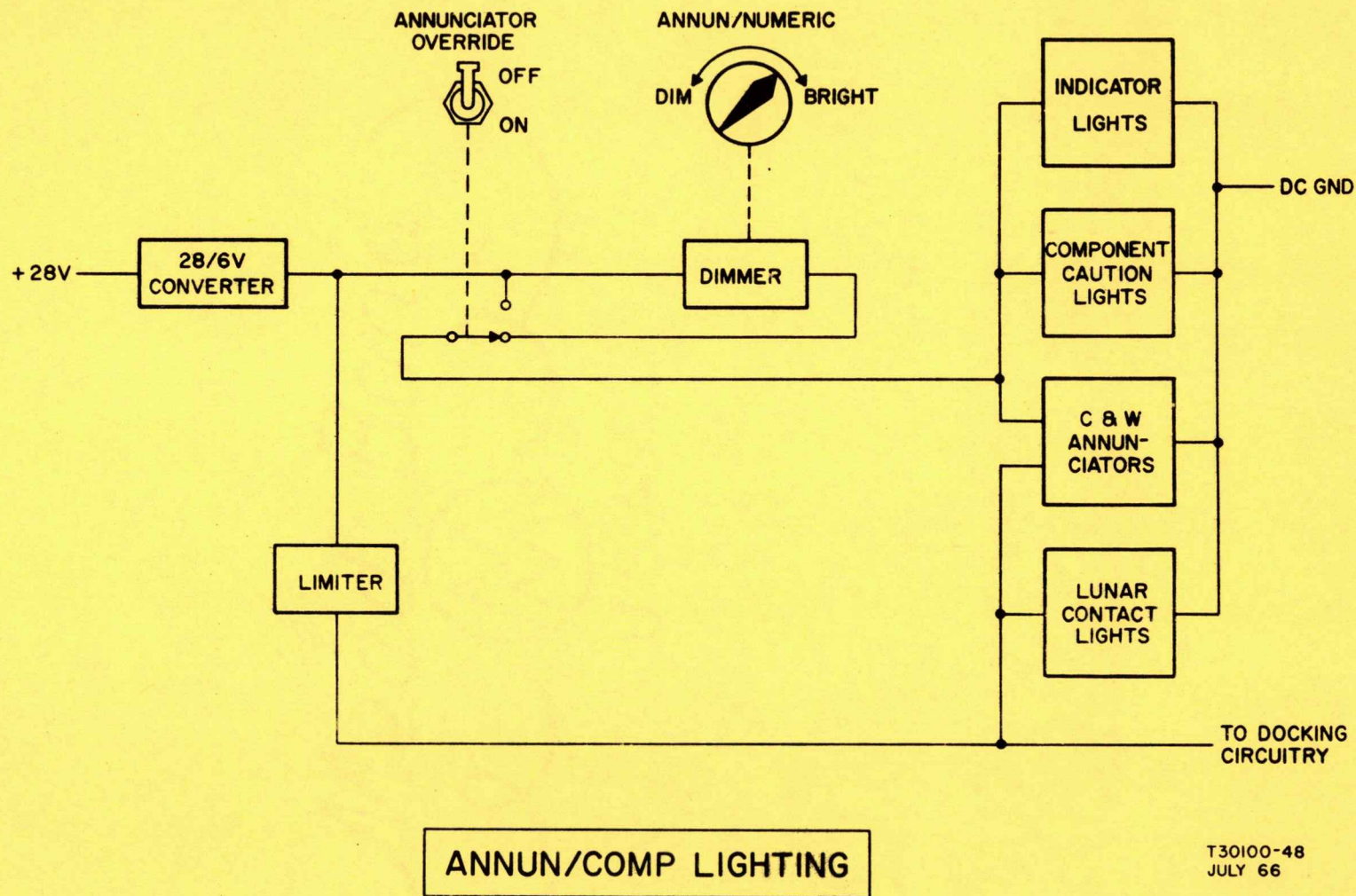
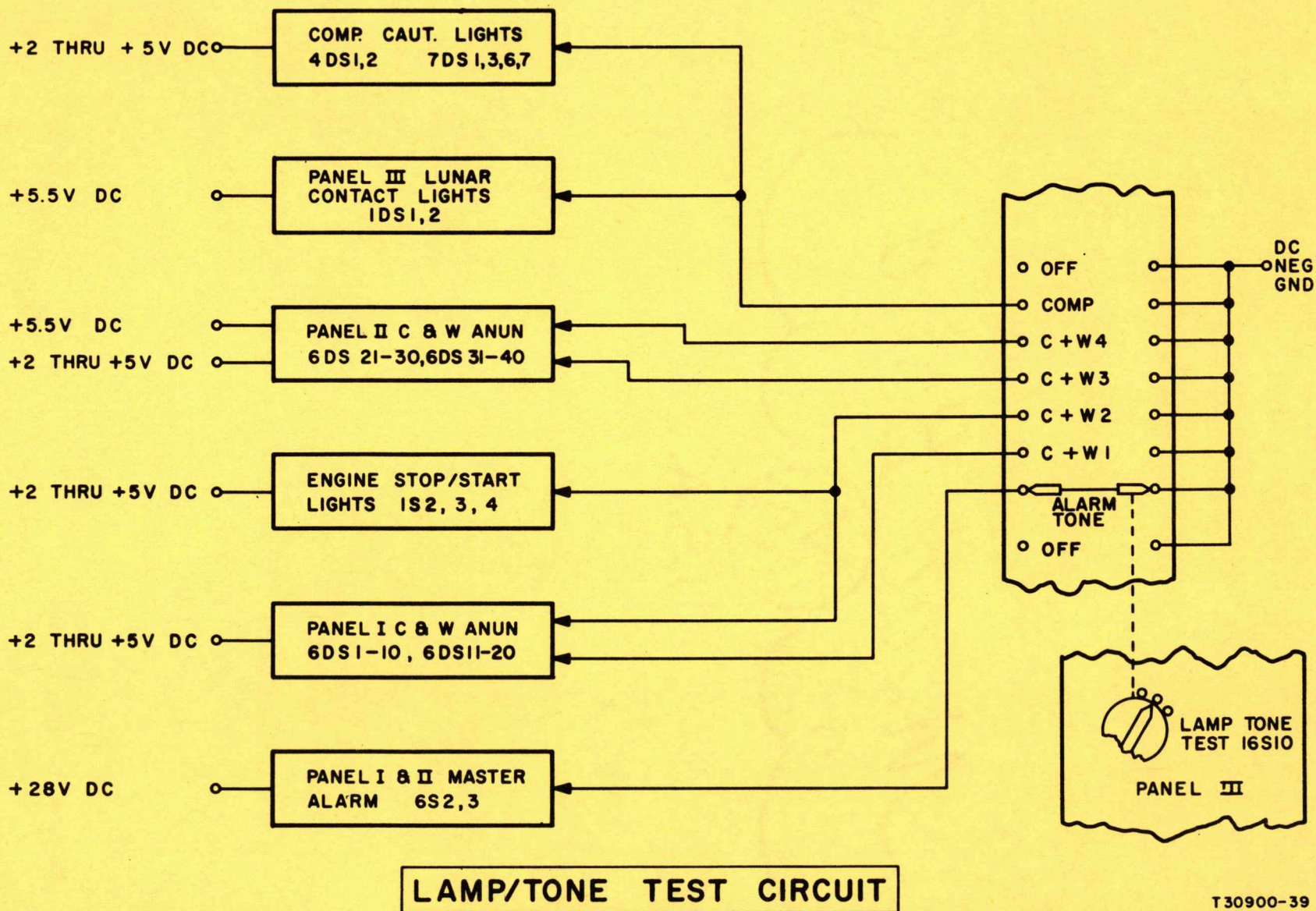
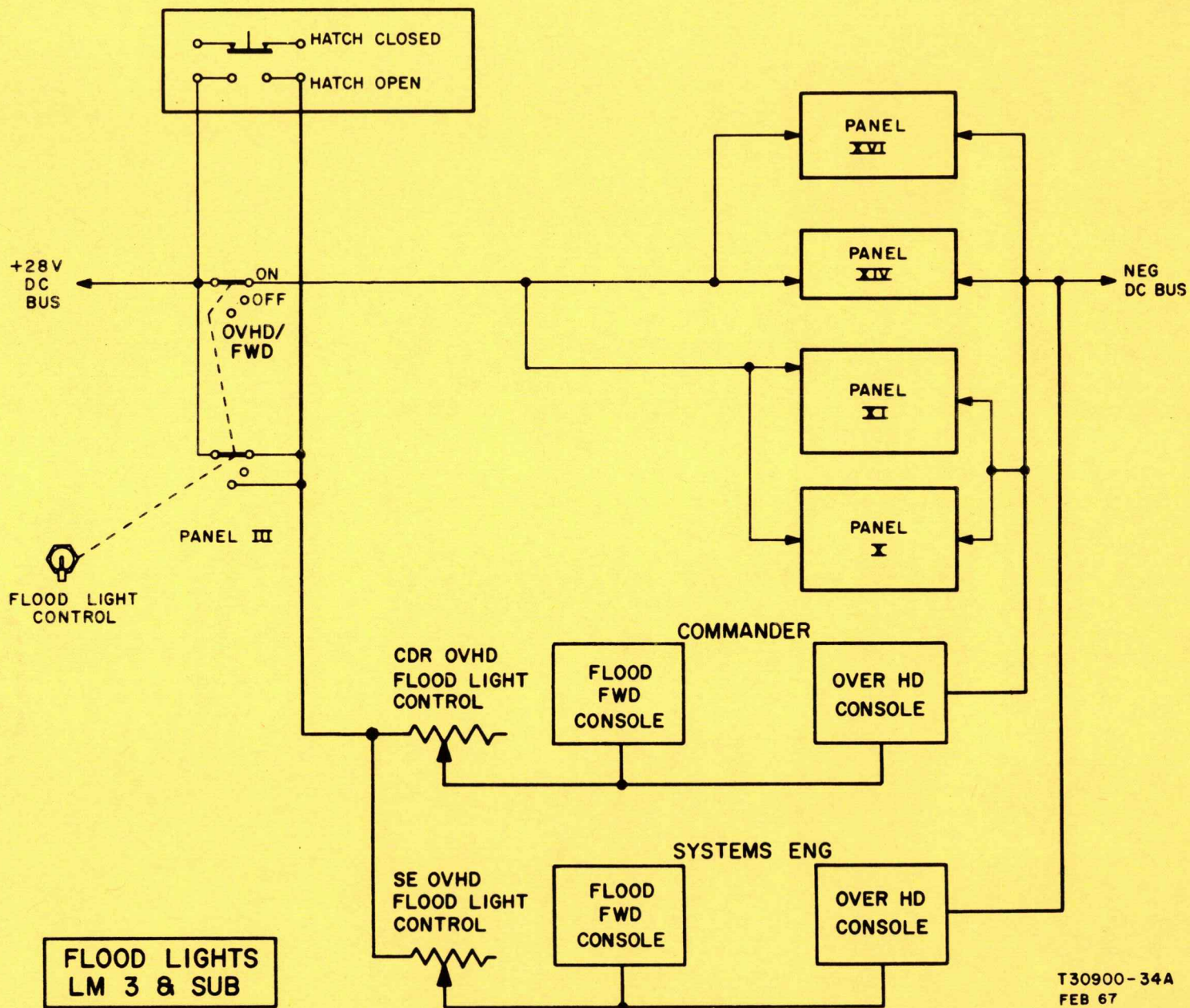
T30100-48  
JULY 66

Figure 2-6







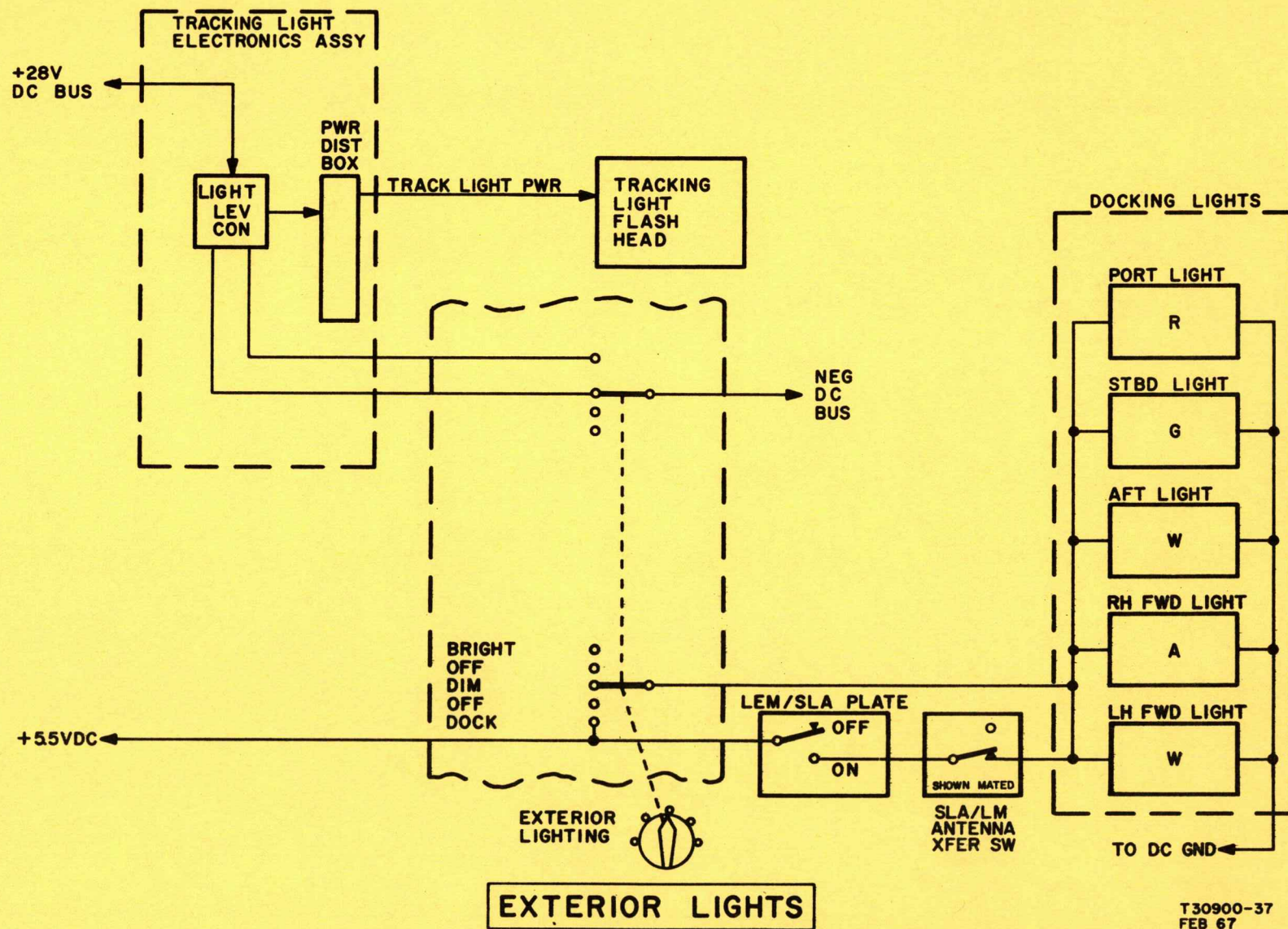




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T30900-37  
FEB 67

Figure 2-9



### Exterior Lighting

Exterior illumination consists of docking and tracking lights on the LM to provide orientation cues to the crew of the CSM.

### Docking Lights

Docking lights are provided for visual orientation cues and gross attitude determination during rendezvous and docking. These lights shall be on/off controlled by the onboard crew during the lunar docking phase. Provision is made to illuminate these lights automatically prior to the translunar docking maneuver.

### Tracking Light

A tracking light is provided to allow visual tracking of the LM by the CSM. This light is on/off controlled and dimmed by the LM.