

ELECTRICAL POWER

QUICK REFERENCE DATA

A-C Section

Inverter input voltage	24 to 32 volts dc
Inverter output (with internal sync)	115±1.2 volts rms, 400 Hz, single phase
Normal load range	0 to 350 volt-amperes (at power factors 0.65 lagging to 0.80 leading)
Maximum overload at constant voltage output	525 volt-amperes for 10 minutes

D-C Section

Steady-state bus voltage limits	26.5 to 32.5 volts dc
Nominal supply bus voltage	28 volts dc
Transient voltages	50 volts above or below nominal supply voltage

Descent battery

Number of batteries	5
Capacity (each battery)	415 ampere-hours
Nominal voltage	30.0 volts dc
Minimum voltage	28.0 volts dc
Maximum voltage	32.5 volts dc
Weight	135 pounds
Construction	Silver-zinc plates, 20 cells
Electrolyte	Potassium hydroxide

Ascent battery

Number of batteries	2
Capacity	296 ampere-hours
Nominal voltage	30.0 volts dc
Minimum voltage	27.5 volts dc
Maximum voltage	32.5 volts dc
Weight	125 pounds
Construction	Silver-zinc plates, 20 cells
Electrolyte	Potassium hydroxide

The Electrical Power Subsystem (EPS) is the principal source of electrical power necessary for the operation of the LM. The electrical power is supplied by seven silver-zinc batteries: five in the descent stage and two in the ascent stage. The batteries provide dc for the EPS d-c section; two solid-state inverters supply the a-c section. Both sections supply operating power to respective electrical buses, which supply all LM subsystems through circuit breakers. Other batteries supply power to trigger explosive devices, to operate the portable life support system, and to operate scientific equipment.

The descent stage batteries power the LM from T-30 minutes until the docked phases of the mission, at which time the LM receives electrical power from the CSM. After separation from the CSM, during the powered descent phase of the mission, the descent stage batteries are paralleled with the ascent stage batteries. Paralleling the batteries ensures the minimum required voltage for all possible LM operations. Before lift-off from the lunar surface, ascent stage battery power is introduced, descent battery power is terminated, and descent battery feeder lines are deadfaced and severed. Ascent stage battery power is then used

FUNCTIONAL DESCRIPTION

The outputs of the **five descent stage batteries** and two ascent stage batteries are applied to four electrical control assemblies. The two descent stage electrical control assemblies provide an independent control circuit for each descent battery. The two ascent stage electrical control assemblies provide four independent battery control circuits, two control circuits for each ascent battery. The electrical control assembly monitors reverse-current, overcurrent, and overtemperature within each battery. Each battery control circuit can detect a bus or feeder short. If an overcurrent condition occurs in a descent or ascent battery, the control circuit operates a main feed contactor associated with the malfunctioning battery to remove the battery from the distribution system.

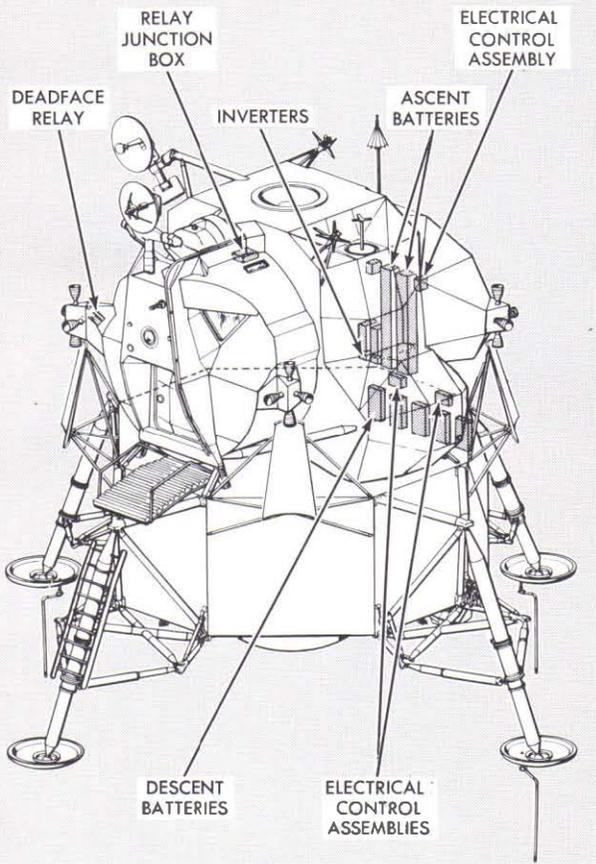
Ascent and descent battery main power feeders are routed through circuit breakers to the d-c buses. From these buses, power is distributed through circuit breakers to all LM subsystems. The two inverters, which make up the a-c section power source, are connected to either of two a-c buses. Either inverter, when selected, can supply the LM a-c requirements.

Throughout the mission, the astronauts monitor the primary a-c and d-c voltage levels, d-c current levels, and the status of all main power feeders. The electrical power control and indicator panel in the cabin has talkbacks that indicate main power feeder status, indicators that display battery and bus voltages and currents, and component caution lights. The component caution lights are used to detect low bus voltages, out-of-limit, a-c bus frequencies, and battery malfunctions. Backup a-c and d-c power permits the astronauts to disconnect, substitute, or reconnect batteries, feeder lines, buses, or inverters to assure a continuous electrical supply.

EQUIPMENT

DESCENT STAGE BATTERIES

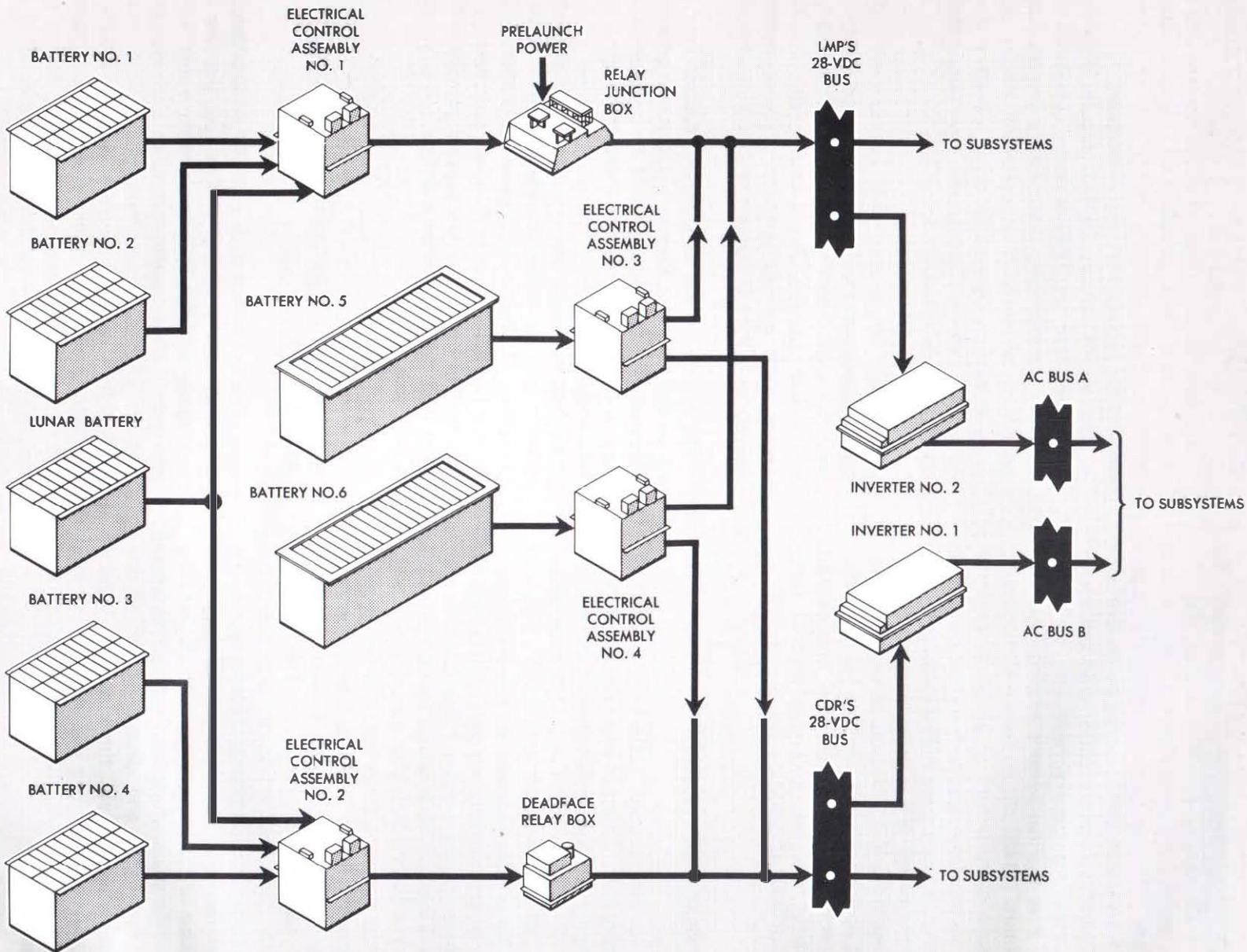
The **five descent stage batteries** are identical. Each battery is composed of silver-zinc plates, with



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Major Electrical Power Equipment Location

until after final docking and astronaut transfer to the CM. The batteries are controlled and protected by electrical control assemblies, a relay junction box, and a deadface relay box, in conjunction with the control and display panel.

In addition to being the primary source of electrical power for the LM during the mission, the EPS is the distribution point for externally generated power during prelaunch and docked operations. Prelaunch d-c and a-c power is initially supplied from external ground power supplies until approximately T-7 hours. At this time, the vehicle ground power supply unit is removed and d-c power from the launch umbilical tower is connected. From launch until LM-CSM transition and docking, the EPS distributes internally generated d-c power. After docking, LM power is shut down and the CSM supplies d-c power to the LM. Before LM-CSM separation, all LM internally supplied electrical power is restored.



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Diagram of Electrical Power Subsystem

a potassium hydroxide electrolyte. Each battery has 20 cells, weighs 135 pounds, and has a 415-ampere-hour capacity (approximately 25 amperes at 28 volts dc for 16 hours, at +80° F). Normally, the descent stage batteries are paralleled so that they discharge equally. The batteries can operate in a vacuum while cooled by an Environmental Control Subsystem (ECS) cold rail assembly to which the battery heat sink surface is mounted. Five thermal sensors monitor cell temperature limits (+145° ±5° F) within each battery; they cause a caution light to go on to alert the astronaut to a battery over-temperature condition. The batteries initially have high-voltage characteristics; a low-voltage tap is provided (at the 17th cell) for use from T-30 minutes through transposition and docking. The high-voltage tap is used for all other normal LM operations. If one descent stage battery fails, the remaining descent stage batteries can provide sufficient power.

ASCENT STAGE BATTERIES

The two ascent stage batteries are identical. Each battery is composed of silver-zinc plates, with a potassium hydroxide electrolyte. Each battery weighs 125 pounds, and has a 296-ampere-hour capacity (50 amperes at 28 volts for 5.9 hours, at +80° F). To provide independent battery systems, the batteries are normally not paralleled during the ascent phase of the mission. The batteries can operate in a vacuum while cooled by ECS cold rails to which the battery heat sink surface is mounted. The nominal operating temperature of the batteries is approximately +80° F. Battery temperature in excess of +145° ±5° F closes a thermal sensor, causing a caution light to go on. The astronaut then takes corrective action to disconnect the faulty battery. The batteries ordinarily supply the d-c power requirements, from normal staging to final docking of the ascent stage with the orbiting CSM or during any malfunction that requires separation of the ascent and descent stages. If one ascent stage battery fails, the remaining battery provides sufficient power to accomplish safe rendezvous and docking with the CSM during any part of the mission.

DESCENT STAGE ELECTRICAL CONTROL ASSEMBLIES

The two descent stage electrical control assemblies control and protect the descent stage batteries. Each assembly has a set of control circuits for each battery accommodated. A failure in one set of battery control circuits does not affect the other set. The protective circuits of the assembly automatically disconnect a descent stage battery if an overcurrent condition occurs and cause a caution light to go on if a battery overcurrent, reverse-current, or overtemperature condition is detected.

The major elements of each assembly are high- and low-voltage main feed contactors, current monitors, overcurrent relays, reverse-current relays, and power supplies. An auxiliary relay supplies system logic contact closures to other control assemblies in the LM power distribution system.

The reverse-current relay causes a caution light to go on when current flow in the direction opposite to normal current flow exceeds 10 amperes for at least 4 seconds. Unlike the overcurrent relay, the reverse-current relay does not open the related main feed contactor and is self-resetting when the current monitor ceases to detect a reverse-current condition. During reverse-current conditions, the related contactor must be manually switched open. The control assembly power supplies provide ac for current-monitor excitation and regulated dc for the other circuits.

ASCENT STAGE ELECTRICAL CONTROL ASSEMBLIES

The two ascent stage electrical control assemblies individually control and protect the two ascent stage batteries in nearly the same manner as the descent stage control assemblies. Each assembly contains electrical power feed contactors, an overcurrent relay, a reverse-current relay, and a current monitor. Each ascent stage battery can be connected to its normal or backup main feeder line via the normal or the backup main feed contactor in its

respective assembly. Both batteries are thereby connected to the primary d-c power buses. The normal feeder line has overcurrent protection; the backup feeder line does not.

RELAY JUNCTION BOX

The relay junction box provides the following:

Control logic and junction points for connecting external prelaunch power (via the launch umbilical tower) to the LM Pilot's d-c bus

Control and power junction points for connecting descent stage and ascent stage electrical control assemblies to the LM Pilot's d-c bus

Deadfacing (electrical isolation) of half of the power feeders between the descent and ascent stages.

The relay junction box controls the low-voltage contactors of batteries 1 and 4 (on and off) from the launch umbilical tower and CSM, and all low- and high-voltage descent power contactors (off) on receipt of an abort stage command. The junction box includes abort logic relays, which, when energized by an abort stage command, close the ascent stage battery main feed contactors and open the deadface main feed contactors and deadface relays. The deadface relay is manually opened and closed or automatically opened when the abort logic relays close. The deadface relay in the junction box deadfaces half of the main power feeders between the descent and ascent stages; the other half of the power feeders is deadfaced by the deadface relay in the deadface relay box. The ascent stage then provides primary d-c power to the LM.

DEADFACE RELAY BOX

The deadface relay box deadfaces those power feeders that are not controlled by the relay junction box, in the same manner as the relay junction box. Two individual deadfacing facilities (28 volts for each circuit breaker panel) are provided.

INVERTERS

Two identical redundant, 400-Hz inverters individually supply the primary a-c power required

in the LM. Inverter output is derived from a 28-volt d-c input. The output of the inverter stage is controlled by 400-Hz pulse drives developed from a 6.4-kilopulse-per-second (kpps) oscillator, which is, in turn, synchronized by timing pulses from the Instrumentation Subsystem. An electronic tap changer sequentially selects the output of the tapped transformer in the inverter stage, converting the 400-Hz square wave to an approximate sine wave of the same frequency. A voltage regulator maintains the inverter output at 115 volts ac during normal load conditions by controlling the amplitude of a dc-to-dc converter output. The voltage regulator also compensates for variations in the d-c input and a-c output load. When the voltage at a bus is less than 112 volts ac, or the frequency is less than 398 Hz or more than 402 Hz, a caution light goes on. The light goes off when the malfunction is remedied.

CIRCUIT BREAKER AND EPS CONTROL PANELS

All primary a-c and d-c power feed circuits are protected by circuit breakers on the Commander's and LM Pilot's buses. The two d-c buses are electrically connected by the main power feeder network. Functionally redundant LM equipment is placed on both d-c buses (one on each bus), so that each bus can individually perform a mission abort.

SENSOR POWER FUSE ASSEMBLIES

Two sensor power fuse assemblies, in the aft equipment bay, provide a secondary d-c bus system that supplies excitation to transducers in other subsystems that develop display and telemetry data. During prelaunch procedures, primary power is supplied to the assemblies from the Commander's 28-volt d-c bus. Before launch, power from the launch umbilical tower is disconnected, and power is subsequently available to the sensor power fuse assemblies from the LM Pilot's 28-volt d-c bus. Each assembly comprises a positive d-c bus, negative return bus, and 40 fuses. All sensor return lines are routed to a common ground bus.