NATIONAL RADIO ASTRONOMY OBSERVATORY
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BATTERY PACK FOR HEWLETT-PACKARD 5065A RUBIDIUM FREQUENCY STANDARD

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Introduction

The battery pack described in this report enables the HP 5065A to be run for about 9 hours without connection to an external power source. The battery pack may be recharged from 115/230 V, 50/60 cps in about 20 hours. A trickle charge maintains the batteries in a fully charged condition.

Metering of the individual batteries with an expanded scale meter allows the user to estimate the state of charge. The weight of the combined frequency standard and battery pack is 116 pounds.

Description

The battery pack is build in two sections which fit into an HP combining case (Figure 1). The larger section contains 20 NiCd batteries, charger, regulator, and two meters. The other section contains a simple 35 V, 4a DC power supply which is used to charge the batteries and to drive a 29 V regulator to provide a DC supply for the clock from 115 or 230 V. If the AC supply fails or drops below 105 or 210 volts, the clock automatically runs from the batteries; when the power returns, the clock then runs from the regulator and the charger commences to operate again.

Batteries

The Nickel-Cadmium rechargeable batteries are manufactured by General Electric, Model number 41B004FD16G1. Their important parameters are:

Voltage		6.0 volts	See Figure 2 for more data.
Capacity	1 hour	4.0 AH	
	10 hours	4.4 AH	
Charge rate	16-20 hours	0.350 A	
Trickle charge continuous		0.035 A	

Twenty batteries are connected to make five separate 24 V batteries. The five batteries are charged independently and their outputs are summed with germanium diodes. Consequently, a charger or battery failure would only reduce the battery pack capacity by one fifth.

The nominal capacity of such a battery is about 22 AH; however, this assumes an end point when the individual cell voltage is 1 V. In our application we have defined the end point as 24 volts for the battery pack which occurs when the cell voltage is 1.2 volts. Reference to Figure 2 shows that this results in an apparent loss of ≈ 20% of the AH capacity.

The clock should run at least 9 hours off the fully charged batteries. A typical voltage/time discharge curve of the battery voltage is shown in Figure 3. Note that the output voltage will be 0.35 volts lower than the voltage shown in this graph.

Circuit Description

The charger/regulator is driven by a 25 V, 4A supply (Figure 4). A switch in this supply connects the two transformers in series or parallel, depending on the primary power available. A cable connection joins the power supply unit to the battery unit. The regulator and charger inputs are separately fused so that a catastrophic failure of one circuit does not affect the other.

A simple, constant current regulator is used to charge the batteries; the rate is adjustable — 0.35 A high and 0.035 A low. The voltage regulator is set to give about 29 volts when the primary supply is connected. A battery light indicates when the primary supply has been interrupted.

The battery voltages and currents may be measured individually. The output voltage should be 29 V when running off the internal regulator and about 0.3 V less than the batteries when the primary power is off.

Operation

Sixteen to twenty hours of fast charging is necessary to fully charge the batteries from a discharged state. The batteries can be maintained fully charged with the charge switch in the low charge position. When fully charged, the battery voltage will be approximately as follows:

$\simeq$ 27.0 V — Standby, no charging (1 hour rest open circuit)		Battery
$\simeq$ 27.3 V — Low charge, 0.035 A		at 25 °C.
$\simeq$ 28.2 V — High charge, 0.35 A.		

When charging at the high rate, there is a tendency for the batteries to overheat when the end of charge is approached. When this occurs, a thermostat will reduce the charging current to the lower value. If time permits, charge at high rate for about 10 hours and then trickle charge for at least 4 days. This should enable the batteries to take the maximum charge. The capacity of the batteries is dependent on charging temperature, i.e., if charged at 40 °C, only 60 percent of capacity will be available on discharge. See Figure 2 showing GE data sheet.

The current meter reads charge current to the right, and discharge current to the left of the zero. The clock takes about 1.5 A; consequently, each battery supplies about 300 mA.

When the clock is running off the battery pack, there is a tendency for the clock internal battery light to start flashing. When this occurs it indicates that the clock internal battery is also in use as well as the external battery. Consequently, when the clock has been run off the battery pack for a long time, the internal battery will be in a low charge condition and should be fast charged at the earliest opportunity. This battery can only be charged when the 115 V supply is reconnected to the clock. It is permissible to run the clock off the 115 V directly and the battery pack regulator simultaneously for maximum reliability.

When operating clock from 230 V, make sure clock power and battery pack switches are in the correct positions.


5065A RUBIDIUM VAPOR FREQUENCY STANDARD
HEWLETT • PACKARD
100 kHz
INTEGRATOR LIMIT
1 MHz
5 MHz
CONTINUOUS OPERATION
NRAO Cal Date 8-25-71
NRAO-NSF OBSERVATORY
NO. 5087
U.S. GOVERNMENT PROPERTY
BATTERY
1 PPS
230 VOLTS
115 VOLTS
ON
AC
OFF
POWER ON
VOLTS D.C.
Simpson
INTERNAL BATTERY
AMPERES D.C.
FAST CHARGE
SLOW CHARGE
VOLTAGE
CURRENT
B1
B2
B3
B4
B5
OUTPUT
BATTERY OUTPUT
REGULATOR OUTPUT

Figure 1

Electrical characteristics

CAPACITY — Capacity, or the energy available from a battery, is usually defined in terms of ampere-hours. The rated capacity of General Electric nickel-cadmium batteries is based on a discharge period of one hour — the one-hour or "C" rate — to an end voltage of 1.0 volt per cell. *For example, a 4 amp hr. battery will deliver 4 amps for one hour.* If current is withdrawn at a lower rate than the standard one-hour rate, there is more available capacity. Conversely, there is a small loss of capacity at higher discharge rates. The extremely low impedance of GE sealed cells provides extra capacity at very high current values.

VOLTAGE — During discharge at the one-hour or "C" rate, the average voltage of a nickel-cadmium cell is approximately 1.2 volts. The plateau voltage level will vary with discharge rate as shown in Figure 2, but is nearly flat at all discharge rates until the cell approaches complete discharge.

Voltage levels also vary depending on the particular mode of operation — charge, discharge, or open circuit. Typical voltage levels are shown in Figure 3.

TEMPERATURE — General Electric nickel-cadmium batteries are designed for discharge service in temperatures ranging from −20°C to +40°C. A reduction in capacity occurs at both low and high temperatures as shown in Figure 4.

Charging at both very high and low temperatures is detrimental to sealed nickel-cadmium battery life. The batteries should not be charged at temperatures above +40°C or below +5°C.

For maximum battery life the following temperature ranges should be observed:

Charge	+5°C to +40°C
Discharge	−20°C to +40°C
Storage	−40°C to +50°C

CHARGE RETENTION — Charge retention is defined as the ability of a battery to hold its energy once it has been charged. Loss in energy due to self-discharge is accelerated at high temperatures as shown in Figure 5. Self-discharge does not adversely affect battery life.

Storage — General Electric batteries may be stored indefinitely at temperatures from −40°C to +50°C without damage. Even though the battery may eventually lose its charge, it can be returned to service with a normal recharge without damage to the battery.

CYCLE LIFE — The life expectancy of General Electric nickel-cadmium batteries exceeds 1000 charge-discharge cycles under normal operating conditions.

CHARGING — The normal method of charging GE sealed cell batteries is with a constant-current power source at the ten-hour, or C/10 rate for 14 to 16 hours. They may be charged at the current rate indefinitely without damage.

Cells and batteries for specific applications requiring high-rate charge, and for overcharge capability, are also available. Contact the nearest GE Sales Office for more information on batteries with special capabilities.

REVERSE POLARITY — When batteries of multiple-cell construction are completely discharged, small differences in the ampere-hour capacity of individual cells cause one cell to reach complete discharge sooner than others.

The voltage and capacity of the other cells in the series string cause current to continue to flow through the completely discharged cell. This cell may then be subject to reversal of electrode polarity. Should this happen frequently, excess gas pressures may be generated and venting may occur.

When using a sealed, multiple-cell battery, a ten percent greater capacity than needed should be specified to help prevent cell reversal.

Where practical, it is best to have the battery cut off during discharge at a safe voltage level of 1.0V/cell to prevent deep discharge and the likelihood of cell reversal.

For more information on General Electric rechargeable nickel-cadmium batteries, or for design assistance on whatever your battery-powered application, contact your nearest General Electric Sales Office. Or, write General Electric Company, Battery Products Section, P. O. Box 114, Gainesville, Florida 32601.

GENERAL ELECTRIC

GEA-9337A
(SUPERSEDES GEA 7678C)
11-70 (25M) 6320

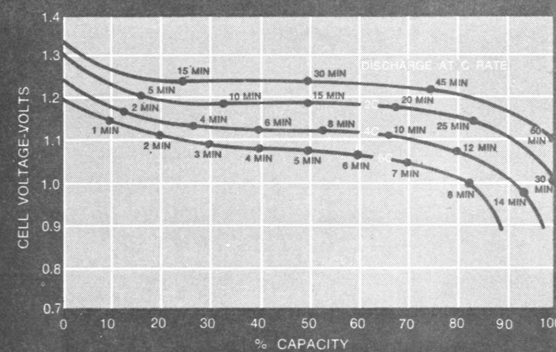

Fig. 2 Typical discharge characteristics of sealed cylindrical cells at 20°C.

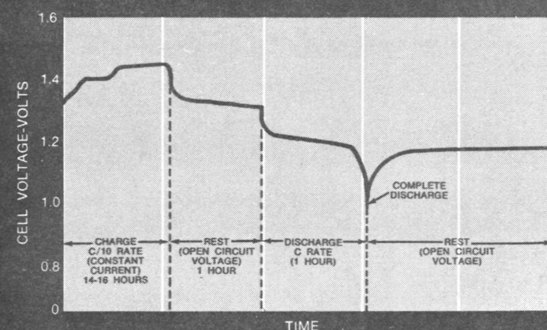

Fig. 3 Typical voltage levels at 20°C.

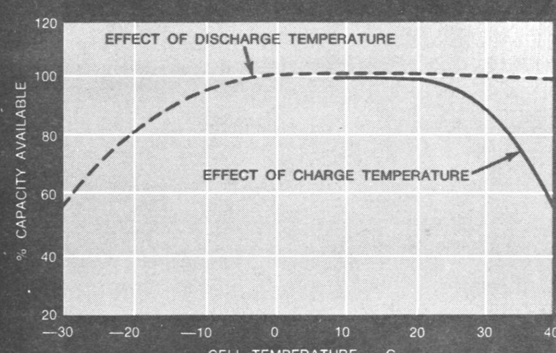

Fig. 4 Typical curve showing percent capacity available versus temperature.

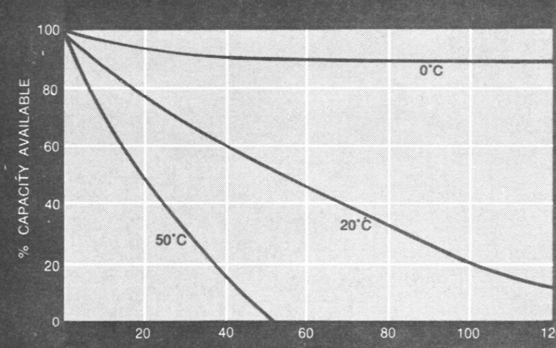

Fig. 5 Typical self-discharge curves.

Figure 2

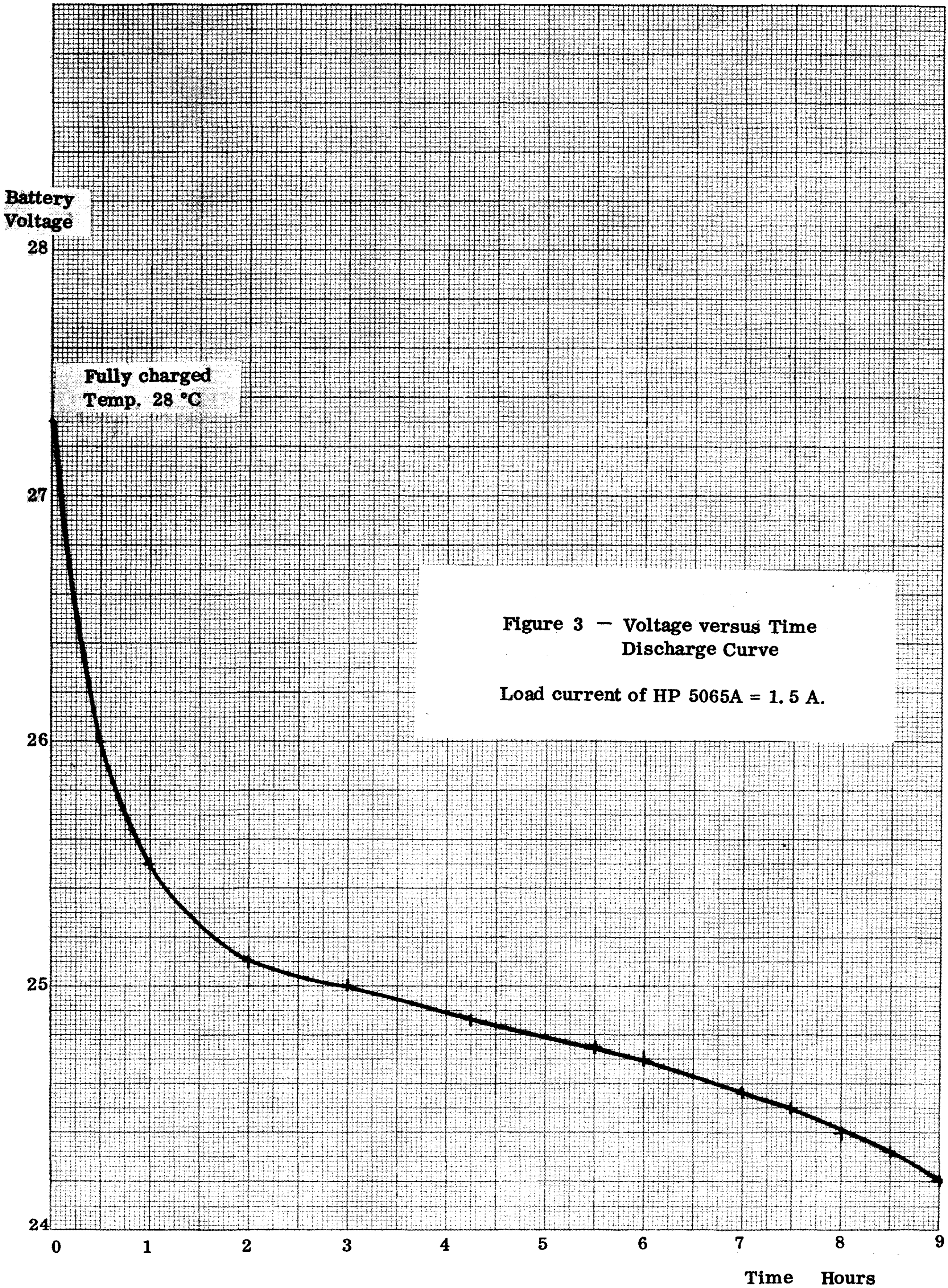

Figure 3 — Voltage versus Time
Discharge Curve

Load current of HP 5065A = 1.5 A.

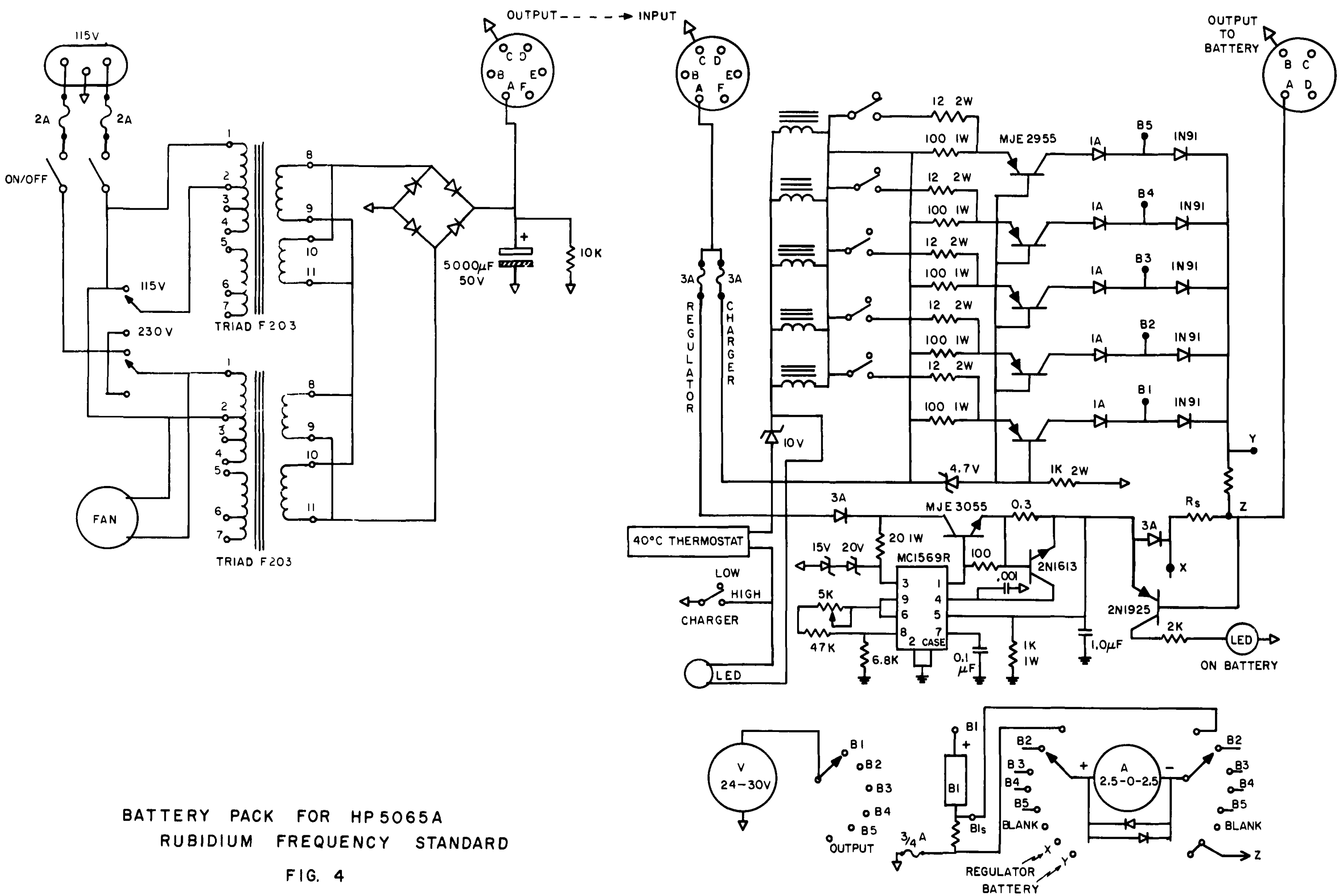

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FIG. 4