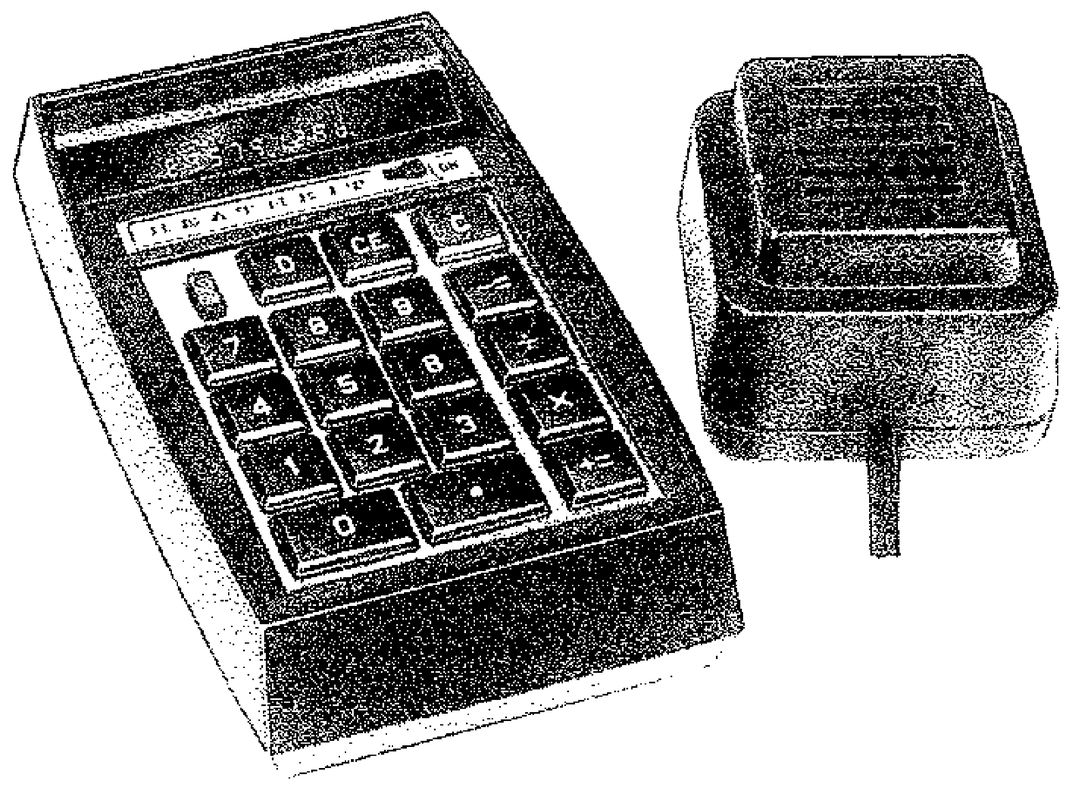
Assembly

of the

HEATHKIT

PORTABLE ELECTRONIC CALCULATOR

MODEL IC-2009



HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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INTRODUCTION

The Heathkit Model IC-2009 Portable Electronic Calculator adds, subtracts, multiplies, and divides with speed, accuracy, and convenience. Several features of the Calculator are: A large-scale integrated circuit, rechargeable nickel-cadmium battery, and an 8-digit, easy-to-read display.

A sophisticated integrated circuit (IC) is the heart of the all-solid-state circuit. This MOS/LSI* device performs all of the mathematical operations of the Calculator.

A constant number (K) can be entered into the Calculator to speed up repetitive calculations in multiplication and division. By sequencing the basic functions of the Calculator and using a constant, you can quickly complete complex mathematical calculations that would otherwise by very lengthy and tedious operations.

Operation as a portable unit is extended by a special "battery saver" circuit which turns off the display 15 seconds after the last digit or function entry. In this mode, up to eight hours of use are available and approximately five hours for the busiest figuring. After the display has automatically turned off, the last display can be recalled by simply pressing the display recall (D) key. Display recall will also occur upon the entry of another number or function.

A low battery condition is indicated by a special (L) display, warning you that it is time to charge the battery. There is, however, sufficient charge remaining which will allow approximately fifteen minutes of valid calculations. Battery charging is accomplished by plugging the Calculator into the Charger (furnished with the kit) that operates from a standard wall outlet. Continuous desk-top operation is obtained by keeping the Calculator connected to the Charger.

The attractive, modern styling and small size of the Calculator make it ideally suited for use anywhere. The Calculator and Charger are housed in high-impact-strength, plastic cabinets with a nonslip textured surface. The display is sloped for easy, wide-angle viewing.

Accessibility to all parts by the use of plug-in keyboard and display board make the Calculator easy to maintain. Whether you use the Calculator in business or for personal applications, you will find it to be a useful tool in your everyday calculations.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step procedures.

*MOS (Metal Oxide Semiconductor)/LSI (Large Scale Integration).

PARTS LIST

Check each part against the following list. The key numbers correspond to the numbers in the Parts Pictorial (fold-out from Page 9). Any part that is packed in an individual envelope with the part number on it should be placed back in the envelope after it is identified until it is called for in a step.

To order replacement parts: Use the Parts Order Form furnished with this kit. If one is not available, see "Replacement Parts" in the "Kit Builders Guide."

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
RESISTORS				
NOTE: The following resistor tolerances are 5% unless otherwise noted. 5% is *indicated by a fourth color band of gold, while 10% is indicated by a fourth* color band of silver.				
1/4-Watt				
A1	1-58-12	1	47 Ω (yellow-violet-black)	.10
A1	1-103-12	10	150 Ω (brown-green-brown)	.10
1/4-Watt (cont'd.)				
A1	1-118-12	2	620 Ω (blue-red-brown)	.10
A1	1-68-12	1	820 Ω (gray-red-brown)	.10
A1	1-97-12	5	2400 Ω (red-yellow-red)	.10
A1	1-76-12	8	4700 Ω (yellow-violet-red)	.10
A1	1-14-12	3	12 kΩ, 10% (brown-red-orange)	.10
A1	1-91-12	2	22 kΩ (red-red-orange)	.10
A1	1-86-12	1	470 kΩ (yellow-violet-yellow)	.10
CAPACITORS				
B1	20-183	2	120 pF mica	.25
B2	21-140	1	.001 μF disc	.10
B2	21-95	2	.1 μF disc	.15
B3	25-281	3	39 μF tantalum	.45

Y PART). No.	PARTS Per Kit	DESCRIPTION	PRICE Each

ODES

56-56	6	1N4149	.20
56-602	2	Germanium	.25
57-65	1	1N4002	.20

TE: Transistors and integrated circuits are marked for identification in one of following four ways:

1. Part number.
2. Type number. (On integrated circuits this refers only to the numbers; the letters may be different or missing.)
3. Part number and type number.
4. Part number with a type number other than the one listed.

ANSISTORS

417-168	4	TIS37	.45
417-808	4	2N3702	.35
417-809	5	2N3704	.35

TEGRATED CIRCUITS

UTION: The large integrated circuit (#443-618) can be damaged by static tricity. Do not remove it from its package until you are instructed to do so step.

443-618	1	TMS0103	23.30
443-619	2	SN75491	2.25
443-620	2	SN75492	2.25

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each

HARDWARE

#2 Hardware

F1	250-582	2	#2 x 1/4" screw	.05
F2	250-1172	2	2-56 x 1/4" screw	.05
F3	250-1112	2	2-56 x 3/4" screw	.05
F4	252-51	2	2-56 nut	.05
F5	253-126	2	#2 flat fiber washer	.05
F6	254-26	2	#2 lockwasher	.05

#4 Hardware

G1	250-52	4	4-40 x 1/4" screw	.05
G2	250-477	4	#4 x 3/4" screw	.05
G3	250-1171	2	#4 x 1-1/8" screw	.05
G4	253-43	4	#4 flat fiber washer (black)	.05
G5	255-182	4	Tapped spacer	.05

WIRE

89-49	1	Line cord	.45
134-848	1	Charger cord	.55
340-11	1	Bare wire (used only for soldering iron tip)	.05/ft
344-125	1	Black wire	.05/ft
344-127	1	Red wire	.05/ft
344-134	1	White wire	.05/ft

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
PLASTIC PARTS				
H1	92-82	1	Calculator top	.55
H2	92-83	1	Calculator bottom	.75
H3	92-84	1	Charger top	.35
H4	92-85	1	Charger bottom	
H5	204-1929	2	Circuit board bracket	.10
INSULATORS				
J1	75-192	1	Switch insulator	.10
	346-6	1	Sleeving	.05
	382-75	1	Foam pad	.10
	74-6	1	Roll tape	.25
	75-108	1	Insulator sheet (1-3/4" x 2")	.10
CONNECTORS				
K1	432-134	34	Connector socket (2 extra)	.10
K2	432-770	51	Connector pin (2 extra)	.10
K3	432-771	1	2-pin connector plug	.10
K4	432-797	2	Fuse connector	.10

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
MISCELLANEOUS				
L1	54-828	1	Power transformer	3.50
L2	60-79	1	Slide switch	.50
L3	64-614	1	Keyboard	10.90
	85-1285	1	Main circuit board	4.05
	85-1318	1	Display circuit board	.90
	100-1616	1	Set of selected parts consisting of the following:	.60
A1		1	Selected 3000 Ω, 1/4-watt (orange-black-red) resistor	
A1		1	Selected 1/4-watt resistor	
C1		1	Selected diode	
L4	260-53	4	Alligator clip	.10
L5	261-1	8	Rubber foot	.05
L6	411-292	1	Light emitting diode (LED) display	25.50
	418-30	1	Battery (DO NOT REMOVE THE TAPE OR INSULATION FROM THE ENDS OF THE BATTERY LEADS, AS THE BATTERY WILL BE DAMAGED IF THE BARED LEADS TOUCH TOGETHER.)	10.50

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
Miscellaneous (cont'd.)				
L7	421-48	1	Thermal fuse	.45
L8	446-611	1	Window	.30
	390-1007	1	Label set	.30
	390-1008	1	Trim label	.25
	391-34	1	Blue and white label	
	597-260	1	Parts Order Form	
	597-308	1	Kit Builders Guide	
		1	Assembly Manual (See front cover for part number.)	2.00
		1	Operation Manual (See front cover for part number.)	2.00
			Solder (Additional 3' rolls of solder, #331-6, can be ordered for 15 cents each.)	

The prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from a Heathkit Electronic Center to cover local sales tax, postage, and handling. Outside the U.S.A. parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties, and rates of exchange.

SPECIFICATIONS

DISPLAY

Readout	8-digit; 7-segment; single plane light emitting diode (LED).
Input Overflow	(E) indicates entry has exceeded 8-digits.
Output Overflow	(□) indicates result has exceeded 8-digits.
Low Battery	(L) indicates battery needs to be charged.

KEYBOARD

Eighteen Keys	10 number keys (0-9). 1 decimal key (.). 4 function keys +=, −=, x, ÷). 1 clear key (C). 1 clear entry key (CE). 1 display recall key (D).
One Slide Switch	1 constant switch (K).

CAPABILITIES

Functions	Addition. Subtraction. Multiplication. Division.

Computation Modes	Chain or constant.
Range	10^{-7} to 10^{8} (0.0000001 to 99999999.).
Decimal Point	Full floating, entry and result.
Locked Entry	When result exceeds 8-digit capacity.
Factor	Constant (K).
Clear Entry	(CE).
Clear Operation	(C).

GENERAL

Battery Saver	Blanks display except for center segment of center digit (–) for approximately 15 seconds after last number or function entry. Previous display may be recalled with "D" (display) key. Display will light by entering a number or function.
Operation	Portable (from internal battery). Calculator can also be operated while charging.
Operating Temperature	0 to 50 degrees C. (32 to 120 degrees F.)
Charger Input Voltage	120/240 volts AC, 50/60 Hz.

Charger Power Requirements	3 watts.
Operating Time	5 hours typical, depending on display and amount of use when starting with a fully charged battery.
Charge Time	14 hours with Calculator off.
Dimensions	Calculator, 5-1/2" long x 3-1/4" wide x 1-3/4" high. Charger, 2-1/2" long x 1-7/8" high x 2-1/4" wide.
Calculator Weight	12 ounces.
Charger Weight	10 ounces.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

CIRCUIT DESCRIPTION

Mathematical calculations are made possible through the use of many *interrelated circuits that are programmed to act in a timed* sequence. This "Circuit Description" will give you a better understanding of the circuit relationships within your Calculator and describe how they work together. Refer to the individual Figures as they are called for, and to the Schematic Diagram (fold-out from Page 75), while you read this information.

IC1

IC1 (Integrated Circuit 1) is the heart of your Calculator. This single "package" contains all the circuits that perform addition, subtraction, multiplication, and division. IC1 can perform these functions either individually or in a chain or constant mode.

Transistors Q1 through Q3 form an oscillator circuit (to be explained later) that *provides a signal to the Φ ("clock") input of IC1. This signal causes the internal* circuits of IC1 to repeatedly scan the inputs and to pulse the outputs in rapid sequence; this sequence is repeated over and over. This scanning principle, known as multiplexing, is a form of "time sharing" that allows some of the outputs of IC1 to be used for both keyboard inputs and display outputs.

IC1 is also internally programmed to provide protection against key double-entry and transient noise signals. Each time a key is pressed, *the IC* samples the key switch entry. The same entry is sampled 2.5 milliseconds later *to determine its validity. If the entry is proven valid, the IC either memorizes* and transfers that particular entry to the driving circuits that light the display, or performs the desired operation.

Automatic locking circuits, within the IC, prevent entry of more than eight digits into the Calculator while signaling more than eight digit entry with an "entry overflow" indication "E" in the extreme left-hand display position. These circuits also prevent further entry once the eight digit output capability has been reached. This condition is indicated by an "output overflow" signal "□" in the extreme left-hand display position.

KEYBOARD

Mathematical commands and numbers are entered into the Calculator through the individual keys of the keyboard. Each keyboard switch is connected between an input and output line of IC1. See Figure 4-1. Pressing the keys provide IC1 with the necessary information to perform the mathematics of the particular problem entered.

As each output (D1 through D11) of IC1 is sequentially pulsed, the internal logic circuitry "keeps track" of which output is being pulsed. When the number 5 key (as an example) is pushed, the pulse signal is coupled from D5 through the keyboard to the KN (number) input of IC1. This is internally registered as a *number 5. Using the same output (D5), but instead push the "+=" key, this* pulse would be coupled through the keyboard to the KO (operation) input of IC1. This would then be registered as a command to add, or total. Since both of these keys (5 and +=) would not normally be pushed at the same time, there is no confusion as to what operation is desired.

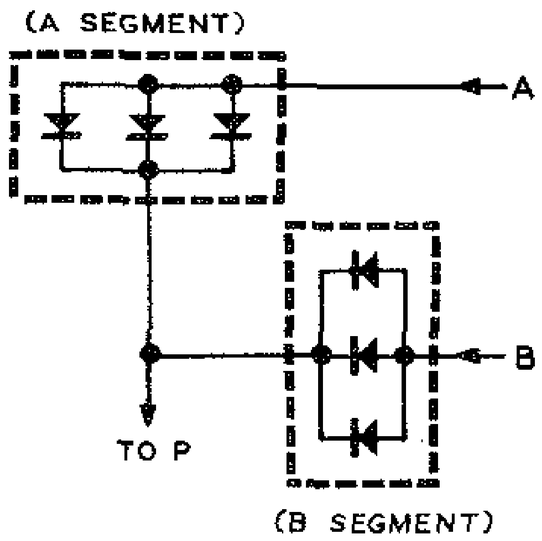


Figure 4-2A

PLAY CIRCUIT

LED (Light Emitting Diode) display is driven by IC2, IC3, IC4, and IC5 n receive control signals from IC1. These control signals form numbers on isplay by the method illustrated in Figures 4-2A and 4-2B.

segments (A, B, C, D, E, F, G, and DP) of each digit position are composed *any small junction diodes which emit light when current flows through* . All diodes of all segments have one end (the cathode) connected to P of digit. The other end (the anode) of all diodes in the A segment are ected to A. Likewise, all the anodes of the diodes in the B segment are ected to B. This is shown in Figure 4-2A. Current flowing from A to P d "light" the A segment.

gure 4-2B, the method of forming a "3" is illustrated. Current flowing from , C, D, and G to P causes the A, B, C, D, and G segments to light. Since *ents E and F are not energized, they do not light.*

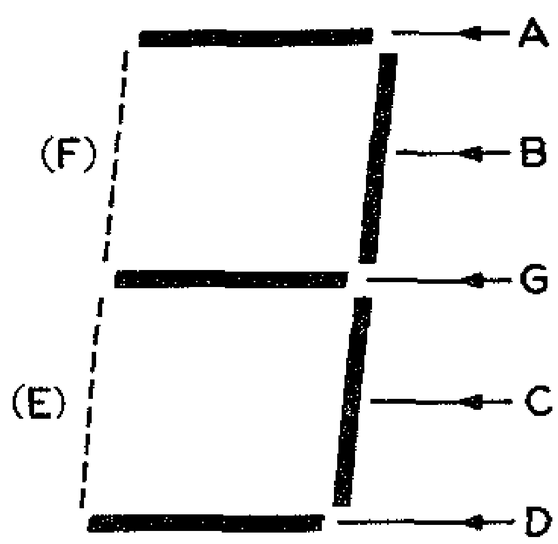


Figure 4-2B

Figure 4-3 shows the driving circuits required to light the numeral 3 in the last *digit section (extreme right-hand position) of the LED.*

To form the lighted numeral 3, IC1 supplies a turn-on signal through its SA, SB, SC, SD, and SG outputs. (Notice that these outputs are labeled to stand for Segment A, Segment B, etc.) These signals cause IC4 and IC5 to connect the required voltage to be applied to the anodes of segments A, B, C, D, and G of all eight digits of the LED. At the same time, IC1 supplies a turn-on signal through its D1 output to IC2. IC2 connects P1 (the cathode of all the segment diodes in the last digit) to ground creating a current path. This lights the segments to display the numeral 3 at the last (right-hand) digit position.

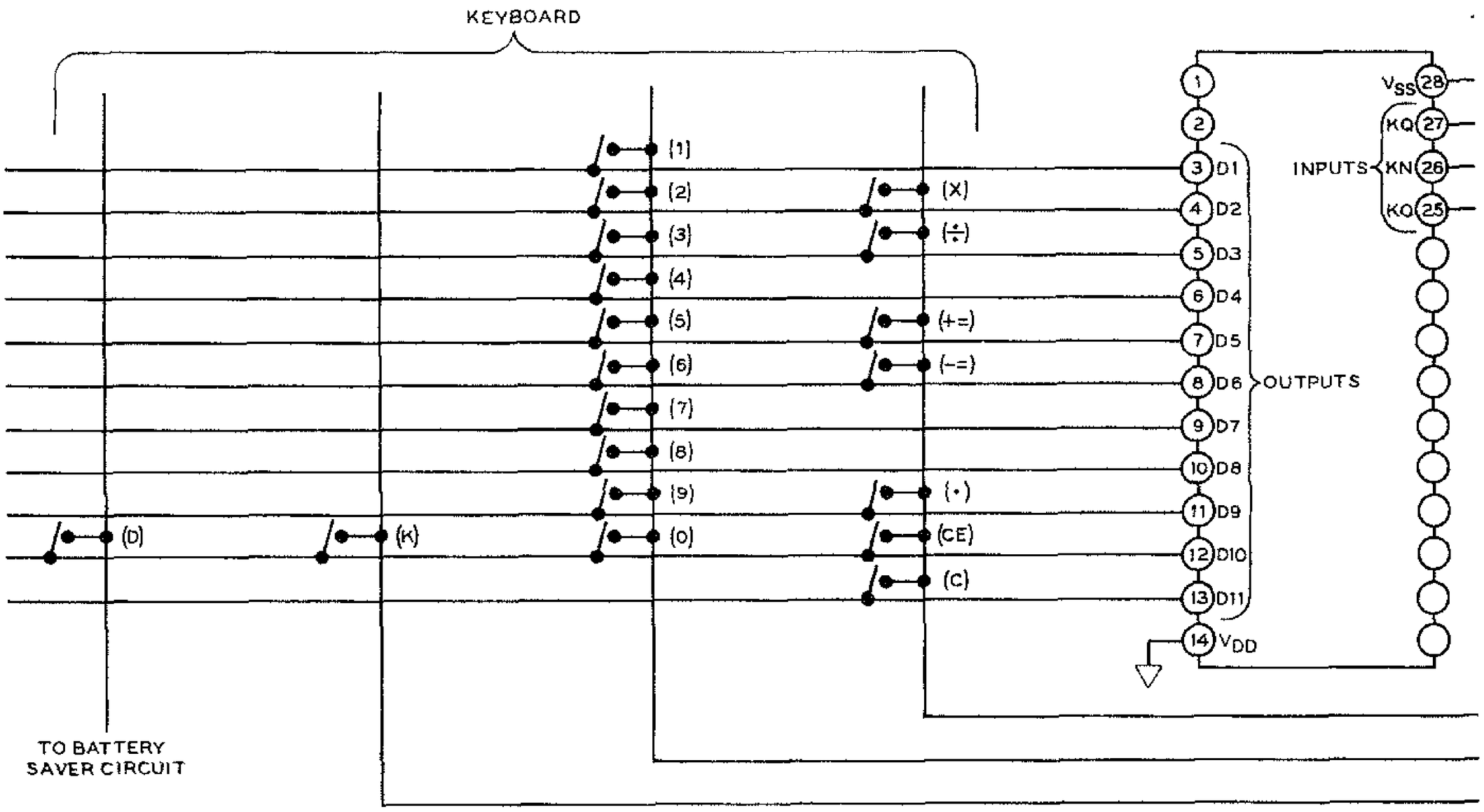

KEYBOARD
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(0)
(D)
(K)
(X)
(÷)
(+=)
(−=)
(·)
(CE)
(C)
TO BATTERY
SAVER CIRCUIT
1
2
3 D1
4 D2
5 D3
6 D4
7 D5
8 D6
9 D7
10 D8
11 D9
12 D10
13 D11
14 VDD
OUTPUTS
INPUTS
VSS 28
KQ 27
KN 26
KQ 25

Figure 4-1

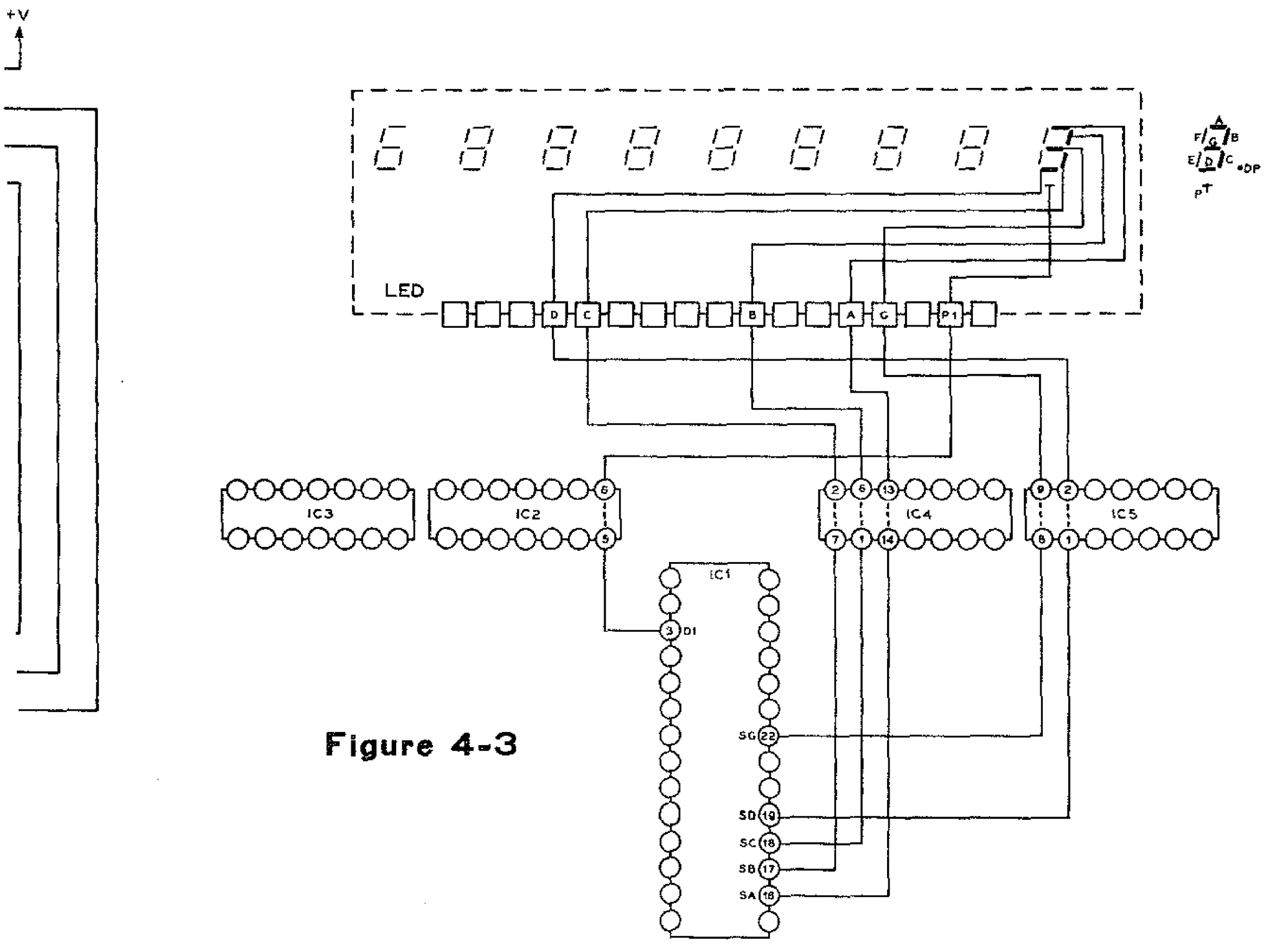

+V
LED
D
C
B
A
G
P1
F
B
E
C
DP
IC3
IC2
IC4
IC5
IC1
3 D1
SG 22
SD 19
SC 18
SB 17
SA 16

Figure 4-3

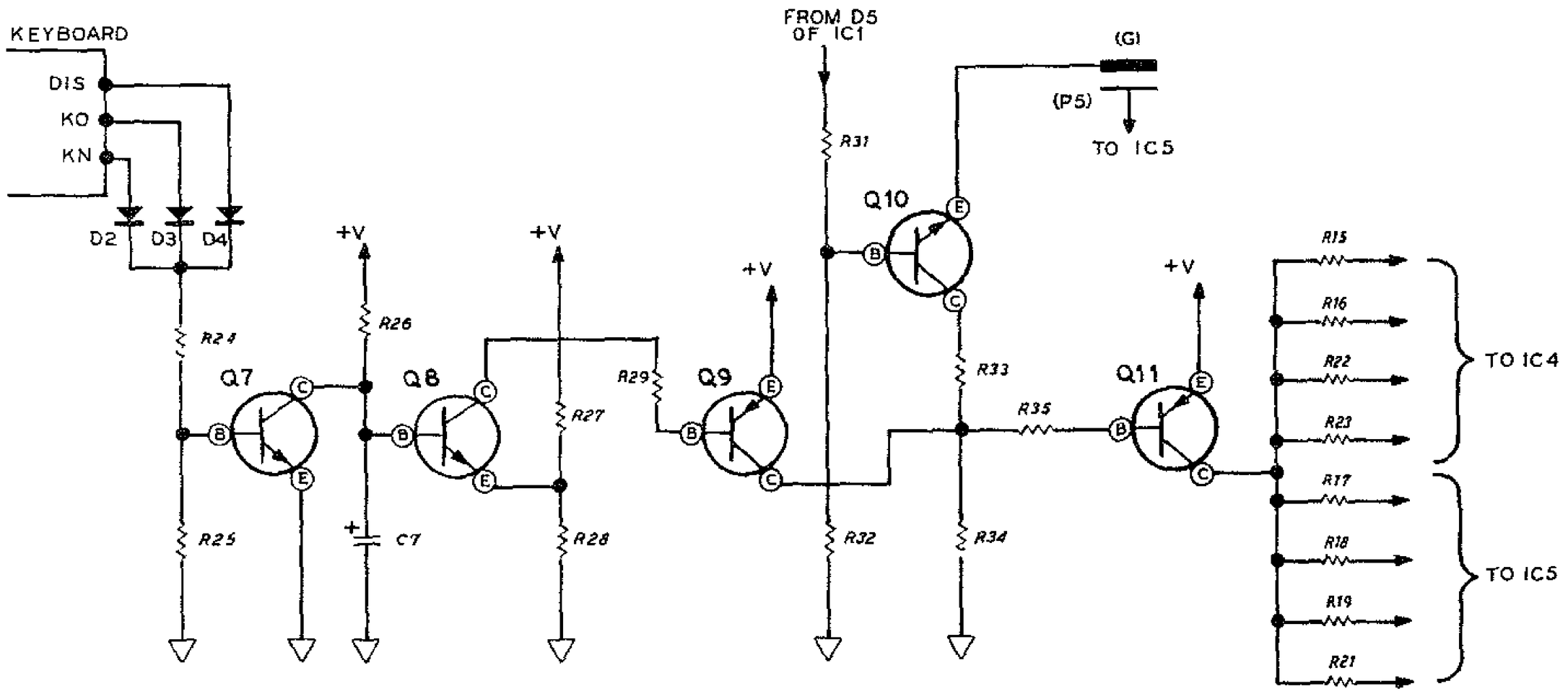
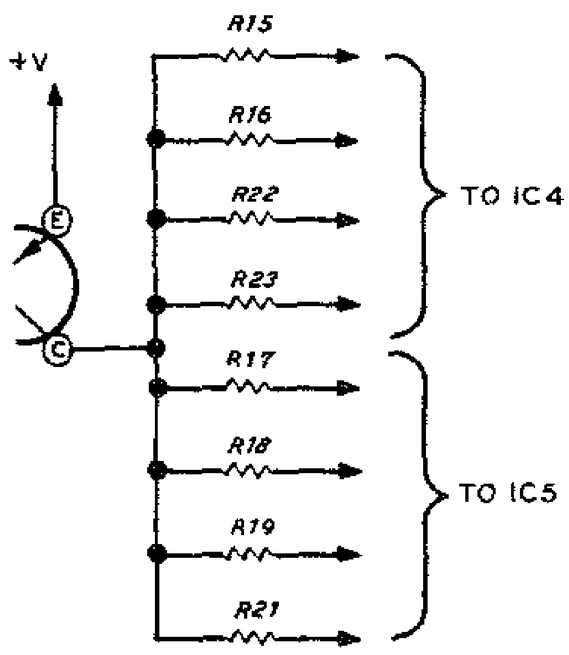

KEYBOARD
DIS
KO
KN
D2
D3
D4
R24
R25
Q7
+V
R26
C7
Q8
R27
R28
R29
Q9
FROM D5
OF IC1
R31
R32
Q10
R33
R34
(G)
(P5)
TO IC5
Q11
R35
+V
R15
R16
R22
R23
TO IC4
R17
R18
R19
R21
TO IC5

Figure 4-6


+V
R15
R16
R22
R23
R17
R18
R19
R21
TO IC4
TO IC5
E
C

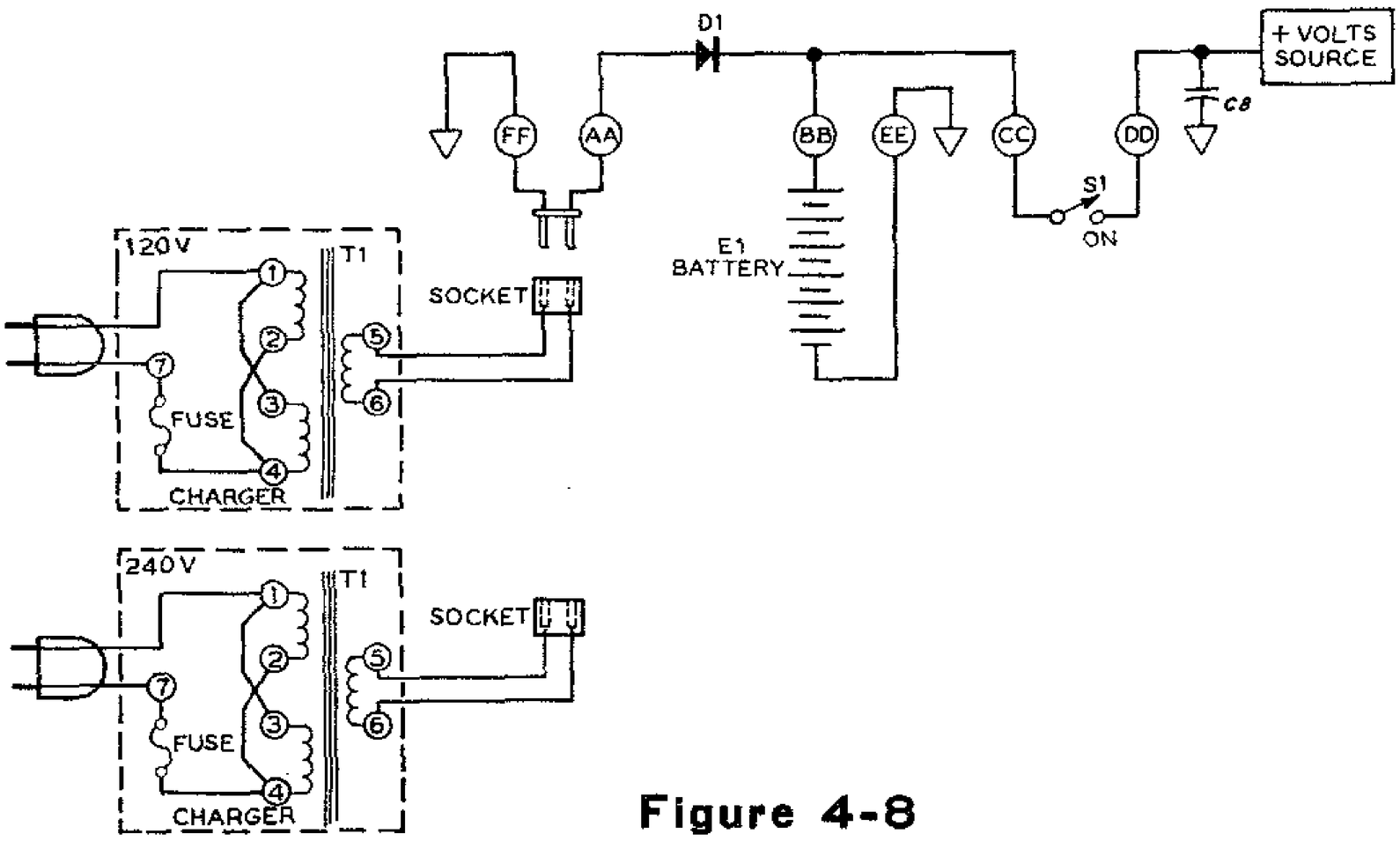

120V
240V
T1
FUSE
CHARGER
SOCKET
D1
FF
AA
BB
EE
CC
DD
E1
BATTERY
S1
ON
+ VOLTS SOURCE
C8

Figure 4-8

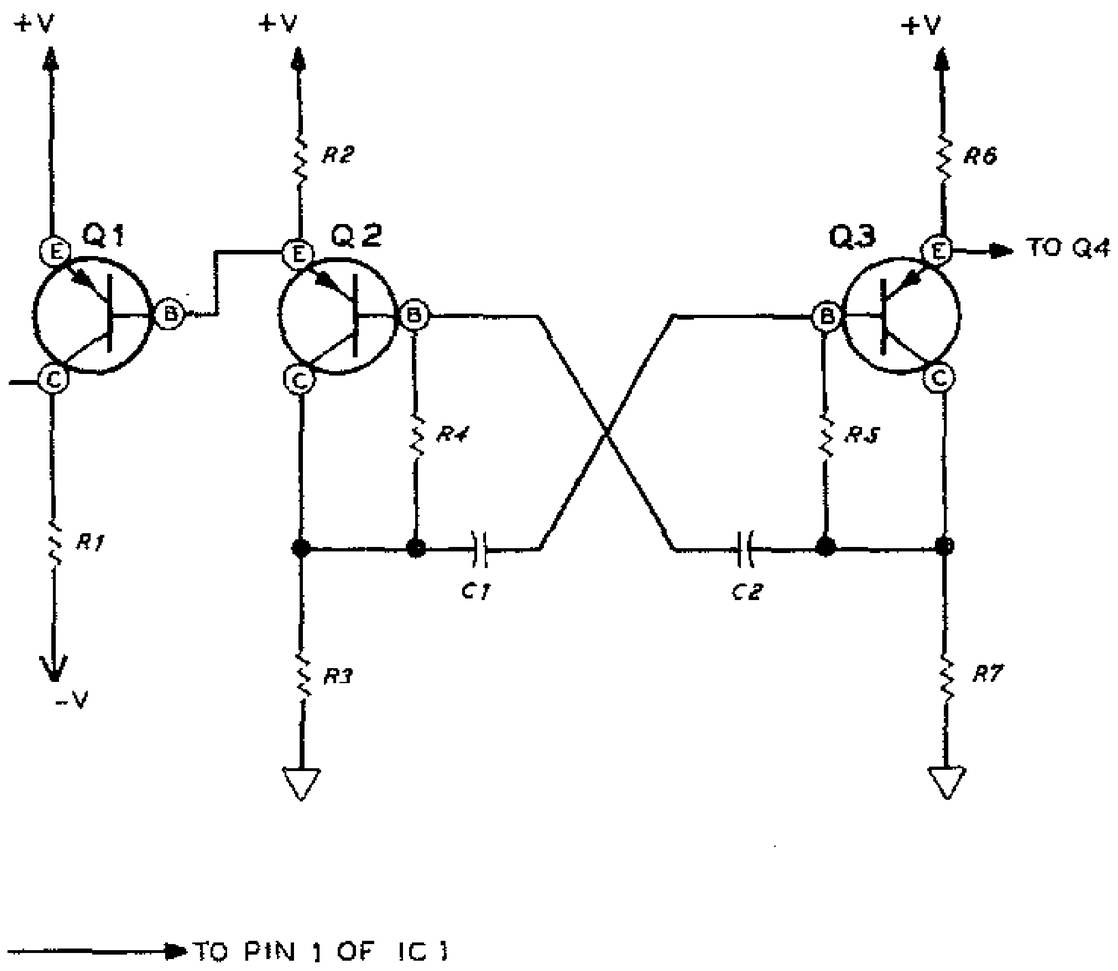


Figure 4-4

CLOCK CIRCUIT

The pulsating of the internal circuits of IC1 is caused by the signal to the Φ (clock) input. This signal comes from transistor circuits Q1 through Q3 as shown in Figure 4-4.

Transistors Q2 and Q3 form a multivibrator circuit which drives Q1 with a square wave to turn it off and on. When Q1 is on, the Φ input of IC1 is connected to a positive voltage. When Q1 is off, the Φ input of IC1 is connected to a negative voltage through resistor R1. This provides the required signal to the Φ input of IC1.

PLUS-TO-MINUS VOLTAGE CONVERTER

Figure 4-5 shows the circuit that is responsible in developing the necessary negative voltage required at various points in the Calculator.

A signal from Q3 (1/2 the multivibrator) is used to turn transistor Q4 off and on. With Q4 turned on, Q5 is turned on and Q6 is turned off by a signal coupled through C4. Under these conditions a current path is developed through Q5, C5, and D6 which causes capacitor C5 to charge. When Q3 turns Q4 and Q5 off, Q6 is turned on. The positive end of C5 is then connected to ground through Q6 and forces the other end of C5 to go negative. This reverse biases D6 and forward biases D5, and applies the negative voltage to C6 which acts as a filter. This on-off change in Q3 (and Q4) causes an accumulated charge at C6 which becomes the negative source voltage. Capacitor C3 acts to minimize radio interference signals.

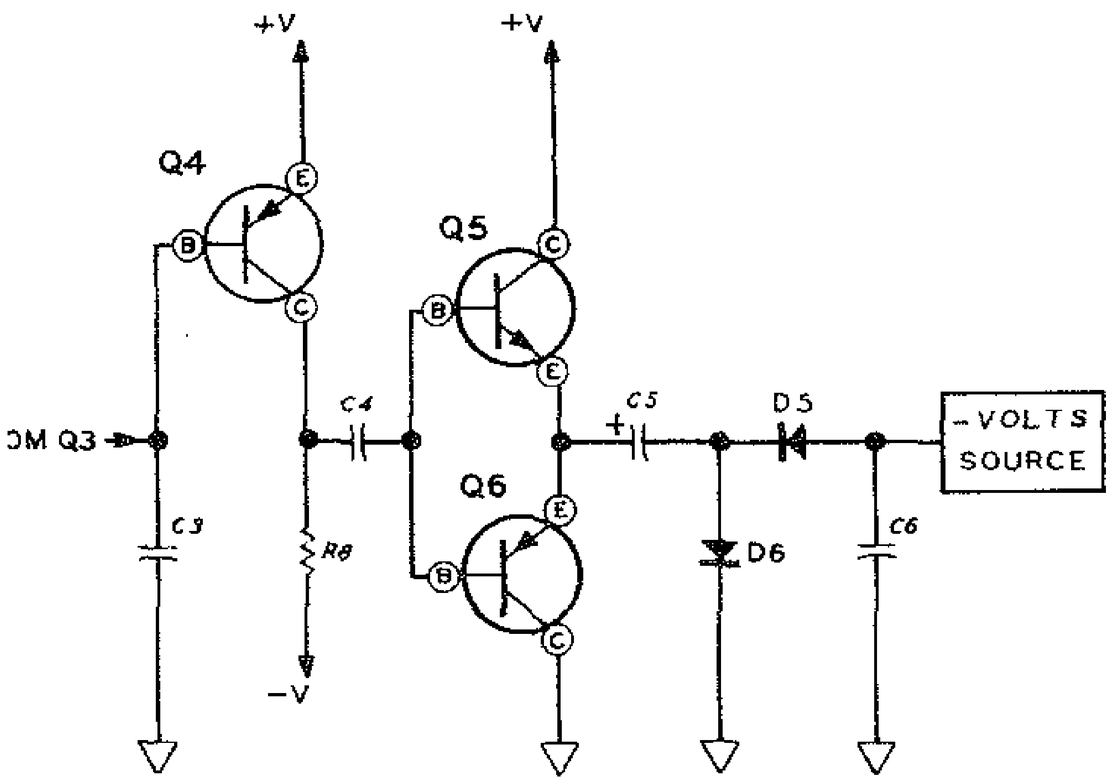


Figure 4-5

BATTERY SAVER CIRCUIT

To conserve battery power and extend operating time, the Display is automatically turned off 15 seconds after the last number or operation entry into the Calculator. This is accomplished by the circuit shown in Figure 4-6 (fold-out from Page 70).

In the "normal mode" of performing a calculation, a voltage is applied through D2, or D3, or D4 and R24 to the base of Q7. This turns Q7 on, which discharges C7. Under this condition, Q8 and Q9 are turned off to remove the positive voltage from the junction of resistors R33, R34, and R35. Current can now flow through R34 and R35 and the emitter-base junction of Q11. This turns on Q11 which then connects the segment driver resistors, R15 through R23, to the positive voltage which permits the segments of the LED to light.

With no entries from the keyboard, Q7 is turned off and C7 begins to charge through R26. When the voltage at the base of Q8 becomes high enough, Q8 and Q9 turn on. The positive voltage from Q9 that is applied to the junction of R33, R34, and R35 turns Q11 off and thus removes the positive voltage from the segment driver resistors, R15 through R23. This action turns off all the lighted segments of the LED. However, the positive voltage from Q9 through R33 turns Q10 on each time D5 of IC1 is pulsed. A positive voltage is now applied to the G segment of the LED and at the same time P5 is grounded by IC3 to light the G segment of the center digit of the LED. Thus indicating that the battery saver circuit is in operation.

Pressing the D key, or any number or operation key, causes Q7 to turn on. This discharges C7 to ground and returns the Calculator to its "normal mode." The D key will make the last display reappear, while pressing any other key will make the LED light but the display may be different depending on the key entry.

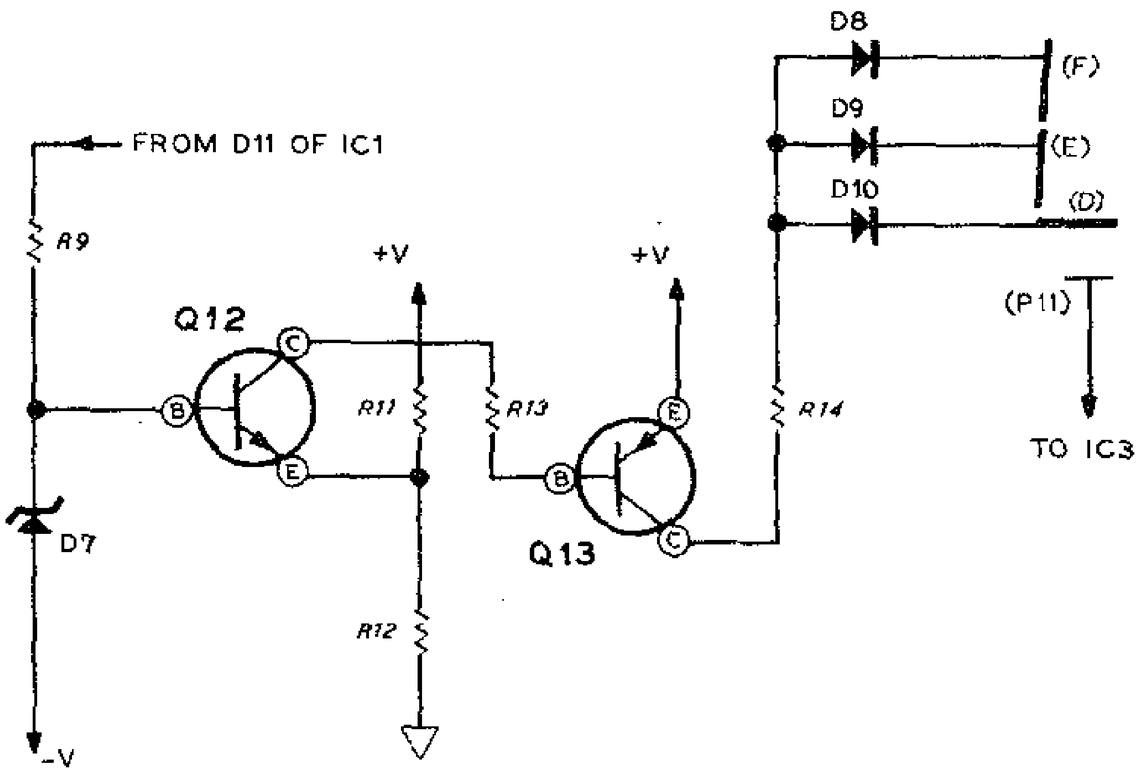


Figure 4-7

LOW VOLTAGE INDICATOR

The circuit which warns that the battery requires charging is shown in Figure 4-7.

Each time D11 of IC1 is pulsed, zener diode D7 is driven into its zener region where the voltage drop across D7 is constant. With this constant voltage drop, and one end of D7 being connected to the negative voltage supply, the base voltage of Q12 must change by the same amount that the negative voltage changes. As the negative voltage drops (approaches zero), the cathode of D7 is forced positive. At some point, the base of Q12 becomes forward biased and turns on Q12 and in turn Q13. With Q13 turned on, a positive voltage is applied through D8, D9, and D10 to the E, F, and D segments of the LED. At the same time P11 of the LED is grounded by IC3 to make an "L" light in the left-most digit of the LED. The value of R12 is selected to match the actual zener voltage of D7 and the value of R11.

CHARGER AND BATTERY CIRCUIT

The battery and charger circuits are shown in Figure 4-8 (fold-out from Page 70).

When S1 is closed, the battery (E1) is connected to power the Calculator regardless of whether the Charger is connected or not.

With the Charger connected to the Calculator but not plugged into an AC outlet, D1 is reversed biased to protect the battery from being discharged by transformer T1. When the Charger is connected to the AC line, the stepped-down voltage from the secondary of T1 is applied through D1 to charge the battery.

The secondary of T1 is a special high-resistance winding which limits the current to a safe value. Fuse, F1, protects the transformer from a short circuit on the secondary of T1. Capacitor C8 filters any ripple on the positive voltage source.

MAIN CIRCUIT BOARD

+7.5
R2 620
R6 620
Q1
Q2
Q3
Q4
Q5
Q6
R1 2400
R3 4700
R4 22K
R5 22K
R7 4700
R8 4700
C1 120pF
C2 120pF
C3 .001
C4 .1
C5 39
C6 .1
-6.4
+7.2
3.9
5.0
-2.9
D5
D6
-6.4VDC SOURCE

LED

E
P5

D9
D10
D8

Q12
Q13
R11 3000
R12
R13 4700
R14 47
R9 12K 10%
D7
0.8
**

IC3
13 +V 01 04 03 05 06
02 12 -V 14 15 11 16

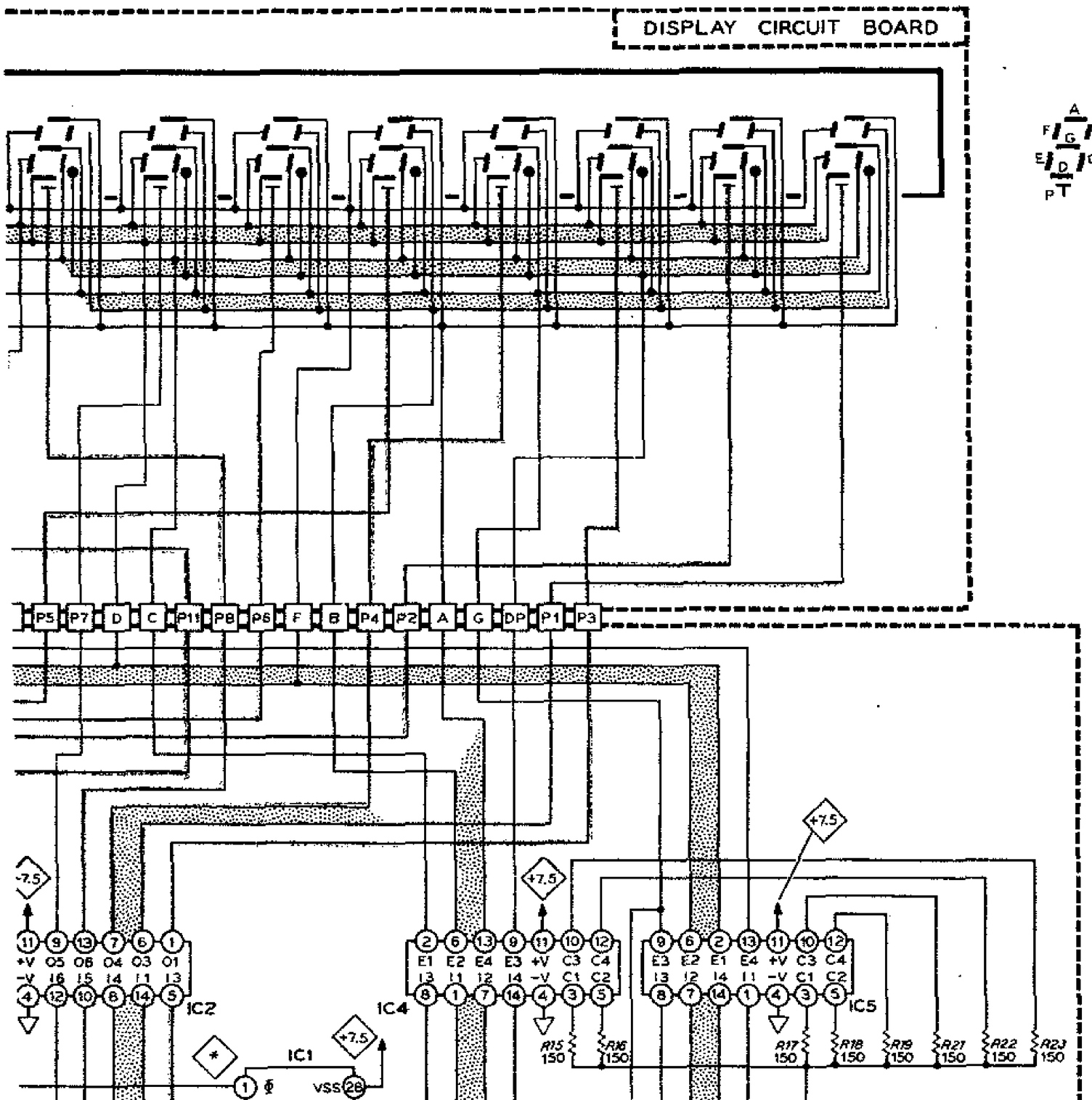
D1
+7.5VDC SOURCE
C8 39
FF BLK
AA RED
BB RED
EE BLK
CC RED
DD RED
PLUG
SOCKET
7.6V BATTERY £1
S1 ON

T1
AC INPUT
THERMAL FUSE TF1
16 VAC (NOT CONNECTED)
CHARGER 240 VAC 50/60 HZ

N1 N4 N7 N9 KN KQ N8 DIS N10 N3 KO N11 N6 N2 N5
D4 D2 D3
K D CE C
7 8 9 =
4 5 6 ×
1 2 3 X
0 . +=

R24 2400
R25 12K 10%
R26 470K
R27 2400
R28 2400
R29 4700
Q7
Q8
C7 39
5.5
0.0
4.5
7.0
4.4

KEYBOARD



SCHEMATIC OF THE HEATHKIT®

ELECTRONIC PORTABLE CALCULATOR

MODEL IC-2009

NOTES:

1. ALL RESISTORS ARE 1/4 WATT. RESISTOR VALUES ARE IN OHMS (K=1000).
2. ALL RESISTORS ARE 5% UNLESS MARKED OTHERWISE.
3. ALL CAPACITOR VALUES ARE IN µF UNLESS MARKED OTHERWI
4. REFER TO THE CIRCUIT BOARD X-RAY VIEWS AND PHOTOGRAP FOR THE PHYSICAL LOCATION OF PARTS.
5. ▽ THIS SYMBOL INDICATES A CIRCUIT GROUND.
6. □ THIS SYMBOL INDICATES A CIRCUIT BOARD CONNECTO PIN AND SOCKET.
7. ○ THIS SYMBOL INDICATES A LETTERED CIRCUIT BOARD CONNECTION.
8. ♦ THIS SYMBOL INDICATES A SELECTED PART FROM THE S LABELED PART #100-1616.
9. SEE THE IDENTIFICATION CHART FOR PROPER IDENTIFICATIOI DIODES, TRANSISTORS, AND INTEGRATED CIRCUITS.
10. NC DENOTES NO CONNECTION.

VOLTAGE MEASUREMENTS

NOTES:

1. BATTERY FULLY CHARGED (MINIMUM 14 HOURS).
2. CHARGER DISCONNECTED.
3. DISPLAY " 0 ".
4. VOLTAGES MEASURED WITH A HIGH IMPEDANCE VOLTMETER FR THE POINT INDICATED TO GROUND (SPACER). VOLTAGES MAY VARY ±10%.
5. ▭ DENOTES A VOLTAGE WITH CIRCUIT IN BATTERY SAVER MODE.
6. ⬭ DENOTES A VOLTAGE WITH THE BATTERY SAVER CIRCUIT OVER-RIDDEN. KEYBOARD REMOVED AND 4700Ω TEST RESISTOR BETWEEN DIS AND N10 AS SHOWN IN INSET DRAWIN (FOLD-OUT FROM PAGE 74).
7. ◇ DENOTES A VOLTAGE WITH THE CIRCUIT IN EITHER NORM OR BATTERY SAVER MODE. VOLTAGES MAY BE SLIGHTLY HIGHER IN BATTERY SAVER MODE.
8. ◇* VOLTAGE MAY VARY FROM -2.0 TO 2.0 VOLTS.
9. ◇** VOLTAGE MAY VARY FROM 0.0 TO 0.2 VOLTS.