V/Ω 29
F101 1/4A, 3AG FAST BLOW
28 32 31 33
F102 3A, 3AG FAST BLOW
mA 34
COM 27
GROUND CONNECTION FOR "COM" TERMINAL IS MADE AT R106
FS3 ACV C D
FS4 ACmA C D
WIRED RS7 7
RS8 18
OFF 3 1000V 200V 20V 5 2V 200mV
R105 100k WW 1/2W 1%
R104 100k WW 1/2W 1%
RS5 18
20M 2M 200k 20k 2k 200Ω
RS5 20
OFF 22 1000V 200V 3 20V 5 2V 200mV
R103, 1M "20M ADJ" 1 2 3 CW
Z101
1 1M
2 8.004M
3 896k
4 90k
5 90k
6 9003.5k
7 996.5
8 200Ω
SEE DIAGRAM AT RIGHT
DC VOLTAGE ATTENUATOR AND OHMS CURRENT CONTROL
RS9 22
OFF 1000V 200V 20V 2V 200mV 5
RS9
200Ω 2k 20k 200k 2M 18 20M
Z101 PINOUT
8 7 6 5 4 3 2 1
(SHOWN SCHEMATICALLY AT LEFT)
RS6
OFF 1000V/mA 200V/mA 20V/mA 3 2V/mA 200mV/μA 200Ω 2k 20k 5 200k 2M 20M
A/D CONVERTER FULL SCALE RANGE SELECT
18 FS2 DCV/Ω F E
FS1 DCmA C D
+12V R125 4.99k 1/8W 1% +8V CW 3 R124 5k "ZERO ADJ" 2 1 -8V R123 4.99k 1/8W 1% -12V
LOW IMPEDANCE INTEGRATOR OFFSET ADJUST
R126 2k 1/8W 1%
R128 2k 1/8W 1%
R127 10 1/8W 1%
R129 1k "2VFS ADJ" 1 2 3 CW
R131 17.8k 1/8W 1%
"RAMP DOWN" (t2) -Iref CURRENT SINK
Q5 TD101
R132 14.3k 1/8W 1%
R133 2k "NEG RANGE" 1 2 3 CW
R134 12k
R130 825 1/8W 1%
ZD2 6.2V-TC 0.5W 1N825(A)
R135 12k
400μA
R136 62k
Q4 X29A829
-12V
"RAMP DOWN" (t2) +Iref CURRENT SOURCE
Q7 TD401
R139 14.3k 1/8W 1%
R141 2k "POS RANGE" 1 2 3 CW
+12V
R137 12k
R138 825 1/8W 1%
ZD3 6.2V-TC 0.5W 1N825(A)
R142 12k
400μA
Q6 2N2712
R143 12k
R144 12k
FROM LOGIC (SHEET 2) IC7A PIN 14
FROM LOGIC (SHEET 2) IC7B PIN 8
C108 1.75μF 50V 10% MYLAR
FULL SCALE VOLTAGE HERE IS +/- 0~0.2V OR +/- 0~2V
FS2 DCV/Ω C D
R118 100k 1/8W 1%
INTEGRATOR
IC1 SL11862
C101 0.22μF 50V 10% MYLAR
C106 68pF 50V 5% MICA
DUAL SLOPE ANALOG/DIGITAL CONVERTER
F
TO LOGIC (SHEET 2) Q9 EMITTER
C104 0.005μF 50V
R115 1.5k
IC2 TOA8709
C102 220pF 50V 3% MICA
R114 1k 1/8W 1%
1mA
C111 0.01μF 50V
R117 909 1/8W 1%
R116 5.1k
Q3 2N2712
D5 1N914
ZD1 6.2V 0.4W 1N823(A)
R110 5.76k 1/8W 1%
R113 1k "20k ADJ" 2 CW 3
OHMS FUNCTION TEST CURRENT SOURCE
Q1 SPS1317
Q2 SPS1317
Q1 & Q2 FUNCTION AS A PAIR OF BACK-TO-BACK 6.5V ZENER DIODES
INTEGRATOR INPUT OVERVOLTAGE CLAMP
R119 10k 1/8W 1%
R121 10k 1/8W 1%
COMPARATOR
IC3 SN72710
C107 100pF 50V
TO LOGIC (SHEET 2) IC9C PIN8, ETC.
C422 0.1μF 3000V MYLAR
RS4 8
OFF 1000V 200V 20V 2V 200mV 6
AC VOLTAGE ATTENUATOR
R401 1M SEL 1/4W 5%
NOTE: MAXIMUM AC INPUT VOLTAGE IS 500V, INCLUDING IN THE 1000V RANGE.
R403 495k SEL
R404 495k SEL
R405 9000 SEL
R406 1000 SEL
C401 15pF 600V
C402 2~8pF "LO CAL"
C403 430pF 300V
C405 15~80pF "HI CAL"
C404 0.005μF 50V
R402 49.9k 1/8W 1%
RS3 20
OFF 1000V 22 200V 3 20V 2V 200mV 5 200Ω 9
AC VOLTAGE BUFFER
+12V R409 22k D16 FD333 D17 FD333 Q18 X29A829 Q17 2N4304 R408 6.8k -12V
RS3 16
1000V 200V 14 20V 2V 18 200mV
AC CURRENT ATTENUATOR BYPASS
R407 90k SEL
R411 10k SEL
C406 15μF 25V TANT
R413 10k 1/8W 1%
C412 39pF 50V
R414 1.5k
C416 33μF TANT 25V
C417 33μF TANT 25V
IC19 TOA8709
C415 3.3pF 25V
D18 FH1100
D19 FH1100
R418 10k 1/8W 1%
R419 10k 1/8W 1%
R421 50 "AC ADJ" 3 CW 2 1
R422 511 1/8W 1%
R412 100k 1/2W 5% FILM
R417 100k 1/2W 5% FILM
C413 33μF TANT 25V
C414 33μF TANT 25V
PRECISION RECTIFIER
+12V C409 10μF TANT 25V IC19 TOA8709(V) C411 10μF TANT 25V -12V
R423 30.1k 1/8W 1%
R424 30.1k 1/8W 1%
R425 30.1k 1/8W 1%
C418 2.2μF TANT 25V
C419 1μF TANT 25V
C421 0.68μF TANT 25V
LOW PASS FILTER
FS3 ACV E F
FS4 ACmA E F
FS4 ACmA A B
FS3 ACV A B
40
R416 500 "CURRENT ADJ" 1 2 3 CW
R415 8900 1/8W 1%
C408 15μF TANT 25V
C407 15μF TANT 25V
RS10 9
2k WIRED 200Ω
200μA 6 2mA 4 20mA 2 200mA 22 1000mA 20 OFF
R111 900 WW 3W 0.1%
R109 90 WW 3W 0.1%
R108 9 WW 3W 0.1%
R107 0.9 WW 3W 0.1%
R106 0.1 WW 2.5W 0.1% KELVIN
DC/AC CURRENT SHUNTS
ALL SHUNT VALUES ABOVE ARE GIVEN IN OHMS
D1 S-5A05
D3 S-5A05
D2 3A1
D4 3A1
R102 22k
R101 22k +12V -12V
AC/DC CURRENT OVERVOLTAGE CLAMP
R112 100k 1/8W 1%
FS1 DCmA E F
37 38 58 +12V -12V
+12V +12V +12V
IC1 SL11862 V+ V- 7 4
IC2 TOA8709(V) V+ V- 7 4
IC3 SN72710 V+ GND V- 11 2 6
C105 0.01μF 50V
C103 0.01μF 50V
C109 0.01μF 50V
R122 1.5k
-12V -12V -12V

AC CONVERTER CIRCUIT BOARD

AC CONVERTER NOTE:
THE HEATHKIT VERSION OF THIS IM-102 SCHEMATIC SHOWS SEVERAL MEANINGLESS CONTACT CONNECTIONS/CLOSURES ON RS3 & RS4 IN THE "OHMS" RANGES. THESE REFLECT ACTUAL CIRCUIT BOARD SWITCH CONNECTIONS WHICH ARE FOR BOARD LAYOUT CONVENIENCE, BUT WHICH ARE IRRELEVANT TO CIRCUIT OPERATION. SUCH SWITCH CONTACTS ARE IGNORED ON THIS VERSION OF THE SCHEMATIC.

LOGIC CIRCUITRY IS SHOWN ON SHEET 2 OF THIS DRAWING

NOTES AND OTHER INFORMATION ARE LOCATED ON SHEETS 3&4 OF THIS DRAWING

THIS SCHEMATIC WAS DRAWN, USING AUTOCAD, AS A MEANS TO GET A MORE LEGIBLE AND UNDERSTANDABLE SCHEMATIC FOR THE HEATHKIT IM-102. AN EFFORT HAS BEEN MADE TO SIZE AND SCALE COMPONENTS AND TEXT FOR THE LARGEST AND BEST VISIBILITY AND LEGIBILITY WHILE STILL FITTING ON A NORMAL 11 X 17" SHEET OF PAPER.

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HEATHKIT IM-102 DIGITAL MULTIMETER SCHEMATIC DIAGRAM

SHEET 1 OF 4

THE HIGH VOLTAGE (HV) SUPPLY IS ACTUALLY A PULSING DC SIGNAL, WITH AN AVERAGE VALUE OF ABOUT 95VDC. THIS IS NOT FILTERED, AND IS PROBABLY BENEFICIAL TO THE NIXIE TUBES AS A MEANS TO REDUCE 'CATHODE POISONING'.

HV 95VDC

R225 10k — V201 " UNITS " B5859S NIXIE TUBE
R224 10k — V202 " TENS " B5859S NIXIE TUBE
R223 10k — V203 " HUNDREDS " B5859S NIXIE TUBE

RS1: OFF, 1000V/mA, 200V/mA, 20V/mA, 2V/mA, 200mV/µA, 200Ω, 2k, 20k, 200k, 2M, 20M

WIRED

R226 22k

40kHz CLOCK OSCILLATOR
VCC +3.5V
R214 22k
IC9A — 40kHz — C206 0.001µF 100V 2%
IC9B — C207 0.001µF 100V 2%
R215 22k "40kHz ADJ" R216 10k 1 CW
D8 1N191 GERMANIUM

IC18 CµL9960 DECODER DRIVER
IC15 CµL9960 DECODER DRIVER
IC12 CµL9960 DECODER DRIVER
IC17 CµL9959 BUFFER STORAGE
IC14 CµL9959 BUFFER STORAGE
IC11 CµL9959 BUFFER STORAGE
IC16 CµL9958 DECADE COUNTER
IC13 CµL9958 DECADE COUNTER
IC10 CµL9958 DECADE COUNTER
CARRY

UNITS, TENS, HUNDREDS COUNTERS, ETC.

R221 33k — R219 120k — DS204 A261 "1" — Q13 ETS083 — R222 2.4k
R204 33k — R203 120k — DS207 A261 "OVER" — Q10 ETS083 — R205 2.4k — D7 2x FH6259 — D6 — R201 560 — Q8 2N2712 — Q9 2N2712

RS2: OFF, 1000V, 200V, 20V, 2V, 200mV
FS2 DCV/Ω — FS1 DCmA

R211 33k — DS205 NE-51H "+" — R218 2.4k — Q12 ETS083
DS206 NE-51H "-" — R212 2.4k — Q11 ETS083

IC8 MC778P — "1 STORAGE"
IC4 MC776P — "OVER STORAGE"
IC4 MC776P — "POL STORAGE"

IC9F
IC8 MC778P — R217 6.8k
IC5 MC778P — R213 6.8k
IC5 MC778P
IC6A — "8000 DETECT"

THOUSANDS COUNTER & 2000 & 4000 DIVIDER/COUNTERS

"1" & "OVER" STORAGE CONTROL

FROM ANALOG (SHEET 1) IC1 PIN 6

TO ANALOG (SHEET 1) Q4 BASE VIA R144
TO ANALOG (SHEET 1) Q6 BASE VIA R143

Iref CONTROL LOGIC
IC7A, IC7C, IC7B

DIGIT DISPLAY STORAGE CONTROL
Iref ENABLE

C201 220pF 100V 3% — R202 2.4k
C202 0.001µF 50V — R206 6.8k
RAMP DOWN LATCH — IC6C, IC6D, IC6B
C203 0.001µF 50V — R207 2.4k — IC9D — IC9E

INTEGRATOR RAMP ZERO CROSSING DETECTED
FROM ANALOG (SHEET 1) IC3 PIN9
ZERO CROSSING PULSE SHAPER
C205 0.001µF 50V — R209 2.4k
C204 0.001µF 50V — R208 2.4k
IC9C — IC7D

NOTE:
THE DIGITAL CIRCUITRY ON THE IM-102 IS ENTIRELY COMPRISED OF 'RTL' (RESISTOR-TRANSISTOR LOGIC), RATHER THAN THE LATER TTL AND CMOS TYPES.

EACH RTL LOGIC 'GATE' WAS BUILT USING RESISTORS AS THE INPUT NETWORK LOGIC AND BIPOLAR JUNCTION TRANSITORS (BJTs) AS THE SWITCHING DEVICES. RTL IS THE EARLIEST CLASS OF TRANSISTORIZED DIGITAL LOGIC CIRCUIT, DATING FROM 1961. FAMOUSLY, THE APOLLO SPACECRAFT GUIDANCE COMPUTERS WERE BASED ON RTL LOGIC ICs.

RTL USES A + POWER SUPPLY OF TYPICALLY 3.5V, RATHER THAN TTL'S MORE FAMILIAR 5V OR THE 3.3V COMMON WITH MODERN LOW VOLTAGE CMOS (LVCMOS), AND THE LOGIC LEVELS ARE 0V FOR LOGIC 'LOW' AND 3.5V FOR LOGIC 'HIGH'. THE 'NOR' GATE IS THE SIMPLEST TYPE, USING ONLY ONE TRANSISTOR, HOWEVER A LATER IMPROVED TOPOLOGY USES ONE TRANSISTOR FOR EACH INPUT OF THE NOR GATE.

RTL WAS SIMPLE, BUT HAD LIMITING DISADVANTAGES SUCH AS HIGH POWER CONSUMPTION AND HEAT GENERATION IN THE RESISTORS AND TRANSISTORS, AND A TYPICAL MAXIMUM NUMBER OF THREE INPUTS PER GATE DUE TO NOISE ISSUES, AND A VERY SMALL FAN-OUT (NUMBER OF OTHER GATE INPUTS DRIVEN BY A GATE OUTPUT).

VCC +3.5V

IC4 MC776P	IC5 MC778P	IC6 MC724P	IC7 MC717P	IC8 MC778P	IC9 MC789P	IC10 CµL9958	IC11 CµL9959	IC12 CµL9960	IC13 CµL9958	IC14 CµL9959	IC15 CµL9960	IC16 CµL9958	IC17 CµL9959	IC18 CµL9960
VCC 11	VCC 11	VCC 11	VCC 11	VCC 11	VCC 11	VCC 14	VCC 16	VCC 16	VCC 14	VCC 16	VCC 16	VCC 14	VCC 16	VCC 16
GND 4	GND 4	GND 4	GND 4	GND 4	GND 4	GND 7	GND 8	GND 8	GND 7	GND 8	GND 8	GND 7	GND 8	GND 8

NOTE:
IC11 & IC14 ALSO HAVE THEIR PIN 9 CONNECTED TO CIRCUIT GROUND, AS A CONVENIENCE IN THE CIRCUIT BOARD LAYOUT; THESE PINS ARE NOT CONNECTED INTERNALLY IN THE TWO IC'S.

ANALOG CIRCUITRY IS SHOWN ON SHEET 1 OF THIS DRAWING

NOTES AND OTHER INFORMATION ARE LOCATED ON SHEETS 3&4 OF THIS DRAWING

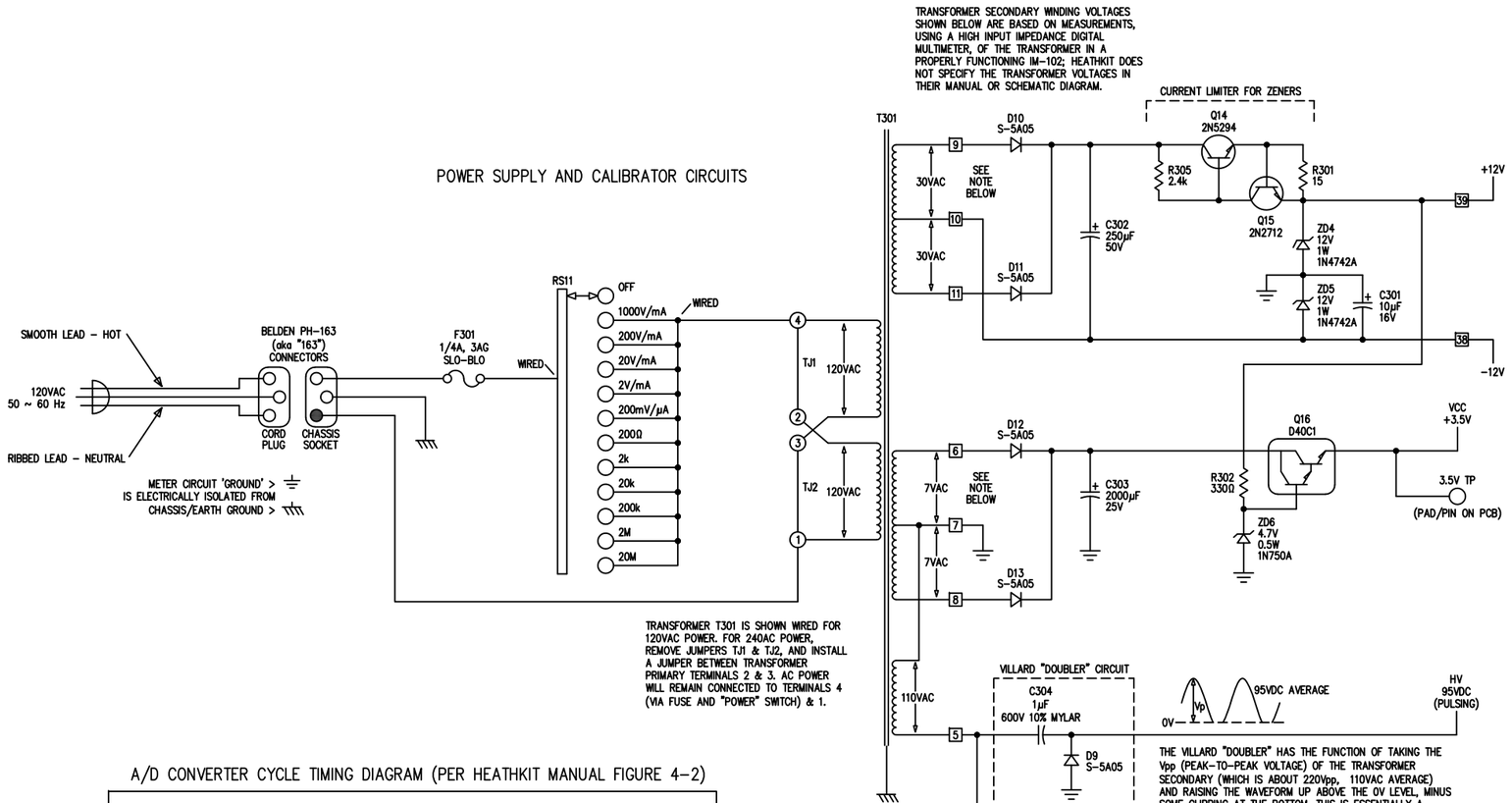
THIS SCHEMATIC WAS DRAWN, USING AUTOCAD, AS A MEANS TO GET A MORE LEGIBLE AND UNDERSTANDABLE SCHEMATIC FOR THE HEATHKIT IM-102. AN EFFORT HAS BEEN MADE TO SIZE AND SCALE COMPONENTS AND TEXT FOR THE LARGEST AND BEST VISIBILITY AND LEGIBILITY WHILE STILL FITTING ON A NORMAL 11 X 17" SHEET OF PAPER.

HEATHKIT IM-102 DIGITAL MULTIMETER SCHEMATIC DIAGRAM

SHEET 2 OF 4

REVISION A 11-21-2023

POWER SUPPLY AND CALIBRATOR CIRCUITS

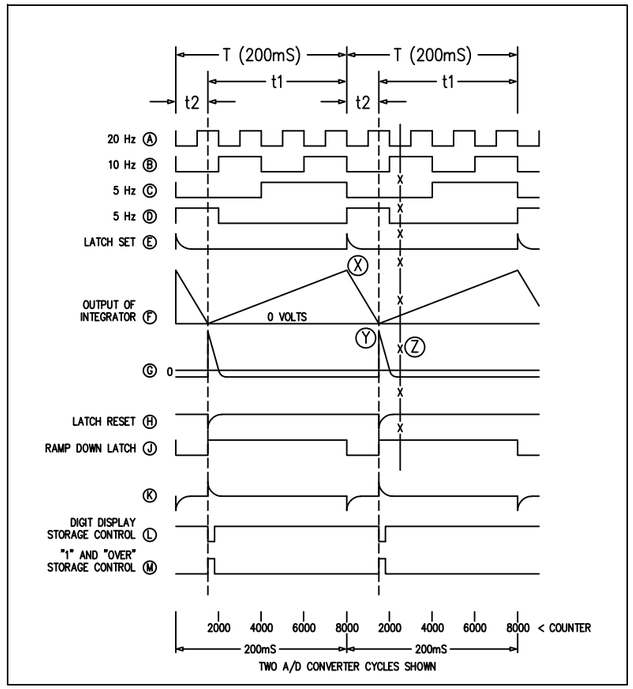


- WHEN THE METER FUNCTION SWITCH 'FS' IS IN THE DCV/Ω POSITION, THE METER WILL DISPLAY THE AVERAGE VALUE OF A HALF-WAVE VOLTAGE. WITH THE AC/DC SWITCH (IN THE AC CALIBRATE CIRCUIT) IN THE 'DC' POSITION, AND THE METER'S RANGE SWITCH 'RS' SET TO THE 20V POSITION, AND THE METER'S RED TEST LEAD (PLUGGED INTO THE V/Ω JACK) TOUCHING THE THE 'TP' PAD ON THE CIRCUIT BOARD, THE 'TP ADJ' TRIM POTENTIOMETER IS SET TO DISPLAY '+9.00'. THIS IS THE AVERAGE VALUE OF THE HALF-WAVE SIGNAL FROM THE 110VAC WINDING OF T301, AFTER ATTENUATION BY THE R306, R303, R304 VOLTAGE DIVIDER AND RECTIFICATION BY D15. BY THE FORMULA RMS = 1.11 x AVERAGE V, THE 9V AVERAGE IS EQUIVALENT TO 9.99 +Vrms.
- WITH THE SAME METER FUNCTION AND RANGE SETTINGS, AND THE V/Ω TEST LEAD STILL ON THE 'TP', THE AC/DC SWITCH IS THEN MOVED TO THE 'AC' POSITION. D14 IS NOW CONNECTED AND A FULL-WAVE VOLTAGE IS APPLIED TO THE VOLTAGE DIVIDER'S 'TP ADJ' TRIM POT, GIVING 19.998 +Vrms (TWICE 9.99V). THE 'AC ADJ' TRIM POTENTIOMETER ON THE 'AC CONVERTER' CIRCUIT BOARD IS ADJUSTED TO DISPLAY 'OVER 0.00' (MEANING 20V) AS THE CLOSEST POSSIBLE RMS VOLTAGE TO WHICH ADJUSTMENT CAN BE MADE.

- THIS DC CALIBRATOR CIRCUIT IS NOT PART OF THE PCB'S OF THE IM-102, AND IS A SEPARATE ASSEMBLY PROVIDED BY HEATHKIT AS PART OF THE KIT.
- THE BLACK LEAD OF THE CALIBRATOR SERVES AS ITS ON/OFF 'SWITCH'. THE 1.35V CELL IS CONNECTED INTO THE CIRCUIT WHENEVER THE 'BLACK LEAD' IS CLIPPED ONTO 'FOIL 1' OF THE CALIBRATOR. HAVE THE BLACK LEAD CONNECTED TO 'FOIL 1' FOR THE FOLLOWING STEPS.
- R502 IS ADJUSTED AT THE FACTORY (SET TO EXACTLY 250 OHMS AND THEN SEALED) SO THAT EXACTLY 200mV APPEARS ACROSS R503, AND THUS BETWEEN TERMINALS 'FOIL 0.2' AND 'FOIL 1'. THIS PROVIDES A STANDARD VOLTAGE FOR USE IN CALIBRATING THE METER'S 200mV RANGE (CONNECT THE METER'S 'V/Ω' TEST LEAD TO 'FOIL 0.2' AND THE 'COM' TEST LEAD TO 'FOIL 0.2' FOR THIS).
- LEAVE THE METER'S TWO TEST LEADS CONNECTED TO THE SAME FOILS. WITH DISCONNECT THE CALIBRATOR 'BLACK LEAD' FROM 'FOIL1', AND CONNECT THE CALIBRATOR'S 'RED LEAD' TO THE 3.5V TEST POINT ON THE METER'S MAIN PCB, ADJUST R505 (IT WILL BE ABOUT 3k) SO THE DISPLAY READS 'OVER +00.0' ON THE METER'S 200mV RANGE, WHICH MEANS EXACTLY 200mV. WHEN THIS CONDITION EXISTS, THE CURRENT THROUGH R503, R504, R505 AND R506 WILL PROVIDE A 2V DROP ACROSS THE COMBINATION OF R503 AND R504, AND THUS ACROSS CALIBRATOR TERMINALS 'FOIL 1' AND 'FOIL 2'. THIS VOLTAGE DROP IS USED AS A STANDARD TO ADJUST THE '2VFS ADJ' TRIM POTENTIOMETER FOR A METER DISPLAY OF 'OVER +.000' (CHANGE THE METER'S RANGE TO 2V, AND MOVE THE METER'S 'V/Ω' TEST LEAD FROM 'FOIL 0.2' TO 'FOIL 2' FOR THIS).

THIS 'DC CALIBRATOR' CIRCUIT FIRST USES THE KNOWN MERCURY CELL VOLTAGE OF 1.35V AND THE KNOWN RESISTOR DIVIDER OF R501, R502, R503 TO PRODUCE A KNOWN 200mV ACROSS R503 FOR CALIBRATING THE METER'S 200mV RANGE USING THE "POS RANGE" AND "NEG RANGE" TRIM POTS. THEN, THIS CIRCUIT SWITCHES FROM USING THE MERCURY CELL FOR ITS POWER TO USING THE APPROXIMATE 3.5V FROM THE METER'S POWER SUPPLY, AND WITH THE RESISTANCES OF R506, R504 AND R503, ALONG WITH THE NOW-CALIBRATED 200mV RANGE OF THE METER, TO CALIBRATE R505 SO THAT THE METER STILL READS 200mV ACROSS R503; UNDER THESE CONDITIONS, THE SAME CURRENT THROUGH R504 WILL DROP 1.8V, WHICH PLUS R503'S 200mV GIVES A KNOWN 2V FROM 'FOIL 1' TO 'FOIL 2', AND THE METER CAN NOW BE CONNECTED ACROSS THOSE POINTS TO ALLOW CALIBRATING THE 2V RANGE USING THE '2VFS ADJ' TRIM POT. (THE HEATHKIT MANUAL'S DESCRIPTION OF THIS IS VERY INCOMPLETE).

A/D CONVERTER CYCLE TIMING DIAGRAM (PER HEATHKIT MANUAL FIGURE 4-2)



LETTERED CIRCLES LIKE THIS Ⓐ (A ~ M ONLY) CORRESPOND TO SIMILAR MARKINGS ON THIS DRAWING'S SHEETS 1 & 2

ACTIVE COMPONENT IDENTIFICATION AND SUBSTITUTES

DIODES

IDENTIFIER	HEATH PN	MANUFACTURER PN	POSSIBLE SUBSTITUTE	DESCRIPTION
D1,3	57-71	S-5A05 *	BY550-100	GP RECTIFIER DIODE, PIV=100V, 5A
D9	57-71	S-5A05 *	1N5060	GP RECTIFIER DIODE, PIV=400V, 1A
D10,11,12,13	57-71	S-5A05 *	1N5059/1N5060	GP RECTIFIER DIODE, PIV=200V, 1A
D14, 15	57-27	1N2071	1N4005 (1AMP)	GP RECTIFIER DIODE, PIV=600V, 750mA
D5	56-28	1N914	1N4148	SMALL SIGNAL, FAST SWITCHING, PIV=100V, 500mA
D6, 7	56-78	FH6259	1N914/1N4148	SILICON DIODE, 0.7V FORWARD DROP, LOW POWER
D8	56-26	1N191		GERMANIUM DIODE, PIV=90V, 500mA
D16, 17	56-93	FD333	FDH333	SILICON DIODE, PIV=125V, 150mA, FAST
D18, 19	56-87	FH1100	1N5711	SILICON SCHOTTKY DIODE, PIV=70V, 15mA
D2, 4	57-42	3A1	1N5403	SILICON DIODE, PIV=300V, 3A

* HEATHKIT USED THE S-5A05 IN SEVERAL PARTS OF THE IM-102 CIRCUIT. WHILE PREPARING THIS DOCUMENT, NO DATASHEET FOR THAT DIODE COULD BE LOCATED; HEATHKIT DOCUMENTS INDICATE THAT IT WAS THEIR PROPRIETARY DEVICE. SOME ONLINE CROSS REFERENCES INCORRECTLY IDENTIFY IT AS A ZENER DIODE. THERE IS A MODERN PART 5A05, WHICH IS A GENERAL PURPOSE SILICON RECTIFIER DIODE, BUT WITH ITS LOWLY 50V RATING IT IS CLEARLY INADEQUATE AS A SUBSTITUTE FOR SOME OF THE S-5A05 APPLICATIONS IN THIS CIRCUIT, AND THUS THE SIMILARITY IN THE PART NUMBER IS MISLEADING. ACCORDINGLY, THE ABOVE TABLE'S 'POSSIBLE SUBSTITUTES' COLUMN SHOWS THE DIODE TYPE USED BY THE EQUIVALENT WESTON 1240 METER'S CIRCUIT, ACCORDING TO REQUIRED VOLTAGE RATING.

ZENER DIODES

IDENTIFIER	HEATH PN	MANUFACTURER PN	POSSIBLE SUBSTITUTE	DESCRIPTION
ZD1	56-91	1N823	1N823A	6.2V ZENER, 400mW
ZD2, ZD3	56-71	1N825A		6.2V ZENER, 500mW, TEMP COMPENSATED
ZD4, ZD5	56-90	1N4742A		12V ZENER, 1W
ZD6	56-59	1N750A	1N5230B, 1N4732A	4.7V ZENER, 500mW (1W FOR 1N4732A)

TRANSISTORS

IDENTIFIER	HEATH PN	MANUFACTURER PN	POSSIBLE SUBSTITUTE	DESCRIPTION
Q1, 2	417-271	SPS1317		PNP BJT, FUNCTIONS AS A 6.5V 3mA ZENER
Q3, 6, 8, 9, 15	417-67	2N2712		NPN BJT, 18V, 100mA
Q4	417-201	X29A829	2N5354	PNP BJT, SUBSTITUTE PER WESTON 1240 VERSION
Q18	417-201	X29A829	2N4126	PNP BJT, SUBSTITUTE PER WESTON 1240 VERSION
Q5	417-191	SPRAGUE TD101		DUAL NPN BJT, MAX: VCBO=60V,VCEO=30V,VEBO=5V
Q7	417-261	SPRAGUE TD401		DUAL PNP BJT, MAX: VCBO=40V,VCEO=30V,VEBO=5V
Q10, 11, 12, 13	417-173	ETS083	2N2509	NPN BJT, HI VOLT, MAX: VCBO=124V,VCEO=80V,VEBO=7V
Q14	417-175	2N5294		NPN BJT, POWER, TO-220, VCBO=80V,VCEO=70V,Ic=4A MAX
Q16	417-272	D40C1		NPN BJT DARLINGTON, TO-202, VCB=80V,VCEO=30V,Ic=0.5A
Q17	417-140	2N4304		N-CHANNEL JFET

DISPLAYS

IDENTIFIER	HEATH PN	MANUFACTURER PN	POSSIBLE SUBSTITUTE	DESCRIPTION
V201, 202, 203	411-264	B-5859S	NL950S	NIXIE COLD-CATHODE TUBE (BURROUGHS & NATIONAL)
DS205, 206	412-49	NE-51H		NEON LAMP, USED FOR + AND – POLARITY INDICATIONS
DS204, 207	412-63	A261		NEON LAMP, USED FOR "1" (THOUSANDS) AND "OVER"

INTEGRATED CIRCUITS (ICs) ARE NOT LISTED HERE, SINCE THEY HAVE NO PRACTICAL MODERN SUBSTITUTES (BEING OLD 'RTL' TYPES), AND ARE DESCRIBED ADEQUATELY ON THE OTHER SCHEMATIC DRAWINGS.

ANALOG & DIGITAL CIRCUITRY IS SHOWN ON SHEETS 1&2 OF THIS DRAWING

NOTES AND OTHER INFORMATION ARE LOCATED ON SHEET 4 OF THIS DRAWING

THIS SCHEMATIC WAS DRAWN, USING AUTOCAD, AS A MEANS TO GET A MORE LEGIBLE AND UNDERSTANDABLE SCHEMATIC FOR THE HEATHKIT IM-102. AN EFFORT HAS BEEN MADE TO SIZE AND SCALE COMPONENTS AND TEXT FOR THE LARGEST AND BEST VISIBILITY AND LEGIBILITY WHILE STILL FITTING ON A NORMAL 11 X 17" SHEET OF PAPER.

HEATHKIT IM-102 DIGITAL MULTIMETER SCHEMATIC DIAGRAM

SHEET 3 OF 4

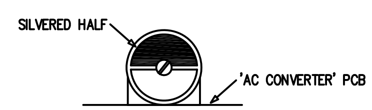
REVISION C 12-31-2023

GENERAL NOTES (APPLICABLE TO ALL SHEETS OF THIS DRAWING)

1) RESISTORS ARE CARBON COMPOSITE (CC) 1/2W, 5% UNLESS MARKED DIFFERENTLY. RESISTOR VALUES WITHOUT A KILO (k) OR MEGA (M) SUFFIX ARE IN OHMS (Ω); THAT SYMBOL IS SHOWN AS LITTLE AS POSSIBLE HEREIN SINCE IT LOOKS TOO MUCH LIKE OTHER ROUND LETTERS/NUMERALS. 'WW' SUFFIX MEANS WIRE-WOUND RESISTOR. RESISTORS MARkED AS "1/8W 1%" ARE IDENTIFIED BY HEATH ONLY AS "PRECISION" RESISTORS; THEY APPEAR TO BE FILM TYPE, BUT MIGHT BE ANOTHER TYPE. 'KELVIN' MEANS A RESISTOR WITH TWO LEADS AT EACH END; THE MAIN CURRENT PASSES THROUGH THE RESISTOR USING ONE OF THE LEADS AT EACH END, WITH THE REMAINING TWO LEADS BEING USED TO MEASURE THE VOLTAGE DROP ACROSS THE RESISTOR. 'SEL' MEANS THAT THE RESISTOR WAS FACTORY SELECTED FOR BEST ACCURACY.
2) ON TRIM POTENTIOMETERS (TRIM POTS), HEATH'S SCHEMATIC OFTEN SHOWS INCORRECT PIN NUMBERING AND/OR WITH THE WIPER SHOWN CONNECTED TO THE WRONG END OF THE RESISTIVE ELEMENT. ALL TRIM POTS AND THEIR PCB CONNECTIONS HAVE BEEN INSPECTED AND THIS NEW SCHEMATIC CONFORMS TO THE PHYSICAL REALITY. ALSO, HEATH'S SCHEMATIC DOES NOT SHOW WHICH DIRECTION ON TRIM POTS IS CLOCKWISE (CW); THAT INFORMATION HAS BEEN ADDED HEREIN. EXCEPT FOR R216 (40kHz ADJ), R303 (TP ADJ), AND R416 (CURRENT ADJ), WHICH ARE ALL SINGLE TURN TYPES, ALL OTHER TRIM POTS ARE EITHER 10 TURN OR 15 TURN TYPES.
3) HEATHKIT DID NOT SPECIFY MOST CAPACITOR VOLTAGES IN THE MANUAL OR REPLACEMENT PARTS LIST, AND STUDY OF A WORKING IM-102 METER REVEALED THAT MOST CAPACITORS WERE NOT PHYSICALLY MARKED WITH THEIR VOLTAGE. WHERE CAPACITOR VOLTAGES ARE SHOWN ON THIS SCHEMATIC, THEY ARE (FOR THE MOST PART) BEST GUESSES BASED ON AVAILABLE EVIDENCE. CAPACITORS ARE CERAMIC DISK TYPE UNLESS INDICATED OTHERWISE. CAPACITORS SHOWN AS POLARIZED (WITH +) ARE ELECTROLYTIC TYPE UNLESS INDICATED OTHERWISE.
4) CERTAIN SMALL POLARIZED CAPACITORS, IDENTIFIED IN THE HEATHKIT MANUAL AS 'ELECTROLYTICS', ON PHYSICAL INSPECTION APPEAR TO BE TANTALUM TYPES, AND ARE IDENTIFIED AS SUCH ON THIS NEW DOCUMENTATION.
5) ALL SWITCHES SHOWN, WITH THE EXCEPTION OF THE 'AC/DC' SLIDE SWITCH IN THE 'AC CALIBRATE' CIRCUIT, ARE ALL PART OF EITHER THE 'RANGE' SWITCH (RS) OR THE FUNCTION SWITCH (FS). THE SUFFIX SHOWN FOR EACH CONTACT (FS) OR GANG/WAFER (RS) IS AS SHOWN ON THE ORIGINAL HEATHKIT SCHEMATIC DIAGRAM. FOR CLARITY, THIS RE-DRAWN SCHEMATIC SEPARATES MOST GANGS/WAFERS OF 'RS' INTO SECTIONS WHENEVER THE FUNCTIONALITY DIFFERS BETWEEN TWO OR MORE PORTIONS OF THE GANG/WAFER; THIS IS DEPICTED WITH A DIAGONAL PAIR OF LINES SHOWING THE 'BREAK'. ON THE RANGE SWITCH (RS), FOR THE POSITIONS PERTAINING TO VOLTAGE OR CURRENT, EACH INCIDENCE OF THESE ON THIS SCHEMATIC IS MARKED WITH ONLY THE PERTINENT UNITS (V OR mA), UNLESS A PARTICULAR PART OF THE SWITCH SERVES FOR BOTH TYPES OF UNITS.
6) DIGITAL IC'S HAVING MULTIPLE 'GATES' (e.g. INVERTERS, FLIP-FLOPS, NOR GATES) ARE DENOTED HEREIN WITH LETTER SUFFIXES, A, B, C, ETC; ACCORDING TO THE ORIGINAL HEATH SCHEMATIC. THESE SUFFIXES ARE ARBITRARY AND INCONSISTENTLY APPLIED, COMPARED TO OTHER ICS'S OF THE SAME TYPE.
7) A ROUND SYMBOL WITH A SINGLE OR TWO-DIGIT NUMBER, e.g. ⑤ CORRESPONDS TO A SWITCH PIN-OUT CHART IN THE HEATH MANUAL PAGE 96. THIS SWITCH'S COMPLEX INTERNAL CONTACT ARRANGEMENT OFTEN RESULTS IN A SINGLE PIN SERVING MULTIPLE CONTACTS. SOME SWITCH PINS ARE CONNECTED TO THE PCB'S, ETC; VIA DISCRETE WIRING RATHER THAN BY BEING DIRECTLY SOLDERED TO HOLES IN THE CIRCUIT BOARDS; THESE INSTANCES ARE DENOTED AS 'WIRED' IN THESE SCHEMATICS. WHERE THIS SYMBOL APPEARS SEPARATELY FROM A SWITCH, THIS MEANS THAT IT IS A COMMON PIN SHARED BY TWO SECTIONS OF THE SAME SWITCH GANG/WAFER, AS SHOWN ON THE SCHEMATIC.
8) A ROUND SYMBOL WITH A SINGLE LETTER, e.g. Ⓐ CORRESPONDS TO 'A/D CONVERTER' TIMING CYCLE WAVEFORMS AS SHOWN IN HEATHKIT MANUAL FIGURE 4-2 (REPRODUCED IN THIS DRAWING SET ON SHEET 3).
9) SOME SECTIONS OF RANGE SWITCH 'RS' HAVE NONSENSICAL CONTACT CONFIGURATIONS, PROBABLY RESULTING FROM UNUSED REMNANTS OF THE SWITCH STRUCTURE WHICH WERE LEFT IN PLACE OUT OF CONVENIENCE. SWITCH CONTACT ARRANGEMENTS WHICH HAVE BEEN IDENTIFIED AS USELESS AND CONFUSING HAVE BEEN OMITTED IN THESE NEW DRAWINGS.
10) SOME RANGE SWITCH POSITIONS ARE USED FOR BOTH VOLTAGE AND CURRENT MEASUREMENTS, AND THUS ARE MARKED WITH THE NUMERICAL PART OF THE RANGE ONLY. FOR EXAMPLE, '1000' MEANS EITHER 1000V OR 1000mA. IN THE CASE OF THE LOWEST VOLTS/CURRENT RANGE, THE DIFFERENCE IS SPELLED OUT AS 200mV AND 200μA, SINCE THE UNITS ARE DIFFERENT. THE OHMS (RESISTANCE) RANGES DO NOT DO DOUBLE-DUTY.
11) CONTACTS THAT ARE PART OF FUNCTION SWITCH 'FS' ARE DESIGNATED WITH TERMINALS IDENTIFIED WITH SINGLE LETTERS, A, B, C, ETC; THESE CORRESPOND TO A SWITCH PIN-OUT CHART IN THE HEATH MANUAL PAGE 96, AND ARE CONSISTENT WITH THE HEATH SCHEMATIC DESIGNATIONS. HOWEVER, WHERE HEATH'S SCHEMATIC SHOWS ALL FOUR POSITIONS ASSOCIATED WITH EACH 'FS' SWITCH CONTACT, THIS NEW SCHEMATIC SHOWS ONLY THE PERTINENT CONTACT INFORMATION ACCORDING TO WHICH SWITCH POSITION WILL RESULT IN THE ASSOCIATED SWITCH CONTACT CLOSING.
12) A SQUARE SYMBOL WITH A TWO-DIGIT NUMBER, e.g. [31] CORRESPONDS TO HOLES IN THE TWO PCB'S WHERE DISCRETE WIRING IS CONNECTED. THIS ALSO PERTAINS TO SHORT WIRE JUMERS CONNECTING BETWEEN THE MAIN PCB AND THE 'AC CONVERTER' PCB. THESE DESIGNATIONS ARE CONSISTENT WITH THE HEATH SCHEMATIC DIAGRAM. NUMBERS 22~41 ARE USED.
13) POWER SUPPLY PINS ON THE IC'S HAVE HEREIN BEEN SHOWN GROUPED TOGETHER NEAR THE BOTTOMS OF THE APPLICABLE SHEETS, RATHER THAN HAVE THEM CLUTTERING UP THE REST OF THE FUNCTIONAL SCHEMATICS.
14) COMPONENT DESIGNATIONS OF CAPACITORS AND RESISTORS ARE 'GEOGRAPHICAL' IN THAT THEIR MOST SIGNIFICANT DIGIT DESIGNATES WHICH SECTION OF THE OVERALL CIRCUIT THEY BELONG TO. USING RESISTORS AS AN EXAMPLE, R1XX PARTS ARE USED IN THE ANALOG CIRCUITRY, R2XX PARTS ARE USED IN THE DIGITAL CIRCUIT, R3XX ARE IN THE POWER SUPPLY CIRCUIT (ALL OF THESE SO FAR ARE ON THE MAIN PCB), R4XX ARE ON THE 'AC CONVERTER' CIRCUIT BOARD, AND R5XX ARE PART OF THE 'DC CALIBRATOR' CIRCUIT BOARD WHICH WAS PRE-ASSEMBLED IN THE HEATHKIT FACTORY AND INCLUDED IN THE IM-102 KIT, TO BE USED ONLY DURING CALIBRATION (ASSUMING NO OTHER TEST EQUIPMENT WAS AVAILABLE TO USE INSTEAD). THE SAME PREFIX ASSOCIATIONS ARE APPLICABLE TO CAPACITORS, EXCEPT THERE ARE NO C5XX PARTS. FOR RESISTORS AND CAPACITORS, MOST EVEN DECADES, e.g. R100, R120, C110) ARE UNUSED, ALTHOUGH THERE ARE SOME EXCEPTIONS TO THIS. SEMICONDUCTORS, SWITCHES, DISPLAY COMPONENTS, ETC' DO NOT FOLLOW THE GEOGRAPHICAL LOCATION SCHEME.
15) WHILE THE IM-102 FRONT PANEL IS MARKED WITH A '1000' RANGE, SUGGESTING BOTH 1000V AND 1000mA MAXIMUM READINGS, THE ACTUAL MAXIMUMS ARE: (DCV) +/-1000V, (ACV) 500V, (DCmA & ACmA) 2000mA (ACTUALLY READS UP TO 1999mA).
16) THE IM-102 IS HEATH'S CLONE OF THE FUNCTIONALLY IDENTICAL WESTON 1240 DIGITAL MULTIMETER. BOTH HEATH AND WESTON WERE PART OF THE SAME PARENT COMPANY AT THE TIME THESE MODELS WERE DEVELOPED. THE ELECTRONIC CIRCUITRY IS VIRTUALLY IDENTICAL BETWEEN THE TWO, ALTHOUGH FOR DISCRETE SEMICONDUCTORS, WESTON GENERALLY USED COMMON 'OFF THE SHELF' PARTS, MANY OF WHICH ARE STILL AVAILABLE TODAY, WHILE HEATH TRIED TO USE FUNCTIONALLY SIMILAR PARTS THAT THEY ALREADY HAD IN THEIR INVENTORY FROM OTHER MODELS OF EQUIPMENT. THE "ACTIVE COMPONENT IDENTIFICATION AND SUBSTITUTES" CHARTS ON SHEET 3 OF THIS DRAWING SET SHOWS THE WESTON EQUIVALENTS (WHERE DIFFERENCES EXIST) AS SUBSTITUTES FOR THE HEATHKIT PARTS.
17) THE HEATHKIT SCHEMATIC, AS WELL AS THEIR MANUAL, BOTH HAVE NUMEROUS ERRORS, ESPECIALLY IN DESCRIPTIVE TEXT THAT HEATH ENGINEERS APPARENTLY PARAPHRASED FROM THE ORIGINAL WESTON DOCUMENTATION, AND IN THE SCHEMATIC DEPICTIONS OF THINGS LIKE NPN VERSUS PNP TRANSISTORS WHICH CAN EASILY LOOK LIKE EACH OTHER ON THE WESTON ORIGINAL SCHEMATIC. GREAT EFFORT HAS BEEN EXPENDED IN TRYING TO CORRECT ALL SUCH ERRORS IN THIS NEW DOCUMENTATION.

ABBREVIATED CALIBRATION PROCEDURE

1) INSTEAD OF A STEP-BY-STEP WRITTEN DESCRIPTION OF THE CALIBRATION, THE HEATHKIT MANUAL INSTEAD USED A CHART. IT IS INTENDED TO DESCRIBE CALIBRATION WITHOUT USING ANY ADDITIONAL TEST EQUIPMENT, NOT EVEN A VOM OR MULTIMETER, WITH THE ASSUMPTION THAT A BUYER OF THE IM-102 DID NOT ALREADY OWN OR HAVE ACCESS TO OTHER TEST EQUIPMENT. THE FOLLOWING PROCEDURE HAS BEEN SOMEWHAT SIMPLIFIED AND ORIENTED TOWARDS RE-CALIBRATION OF IM-102'S THAT HAVE ALREADY BEEN ASSEMBLED AND PREVIOUSLY CALIBRATED, AND ARE NOW ONLY TO BE RE-CALIBRATED, PERHAPS AFTER REPAIR AND/OR RESTORATION. THESE FOLLOWING STEPS DO NOT MAKE USE OF THE INTEGRAL 'AC CALIBRATE' CIRCUIT OR THE SEPARATE 'DC CALIBRATOR' CIRCUIT BOARD; AVAILABILITY OF BASIC LABORATORY EQUIPMENT IS ASSUMED. WHEN SETTINGS SUCH AS '200mV/DCVΩ' ARE SHOWN, THEY ARE TO BE INTERPRETED AS 'RANGE SWITCH SET TO 200mV AND FUNCTION SWITCH SET TO DCVΩ'. THE PROCEDURE ASSUMES THAT THE METER CIRCUIT IS PROPERLY FUNCTIONING; FAILURE TO ACHIEVE THE RESULTS SPECIFIED IN THESE STEPS PROBABLY INDICATES THAT SOME ASPECT OF THE METER CIRCUIT REQUIRES TROUBLESHOOTING.
2) SHORT TOGETHER V/Ω AND COM FRONT PANEL JACKS. SET 200mV/DCVΩ , ROTATE "ZERO ADJ" TRIM POT FOR A METER READING OF 00.0 AND ALTERNATING +/- POLARITY INDICATIONS.
3) UNPLUG THE LINE CORD FROM THE IM-102 METER. CONNECT THE V/Ω AND COM JACKS, VIA THE TEST LEADS, TO THE PRIMARY SIDE OF THE POWER TRANSFORMER T301'S TERMINALS 1 & 2 (ACROSS THE PRIMARY WINDINGS). RE-CONNECT THE LINE CORD TO THE METER. THE FOLLOWING IS CRITICAL, ESPECIALLY IN THE 20V SETTING; THE LAST (LEAST SIGNIFICANT) DIGIT OF THE DISPLAY MAY VARY, AND EXPECT ALTERNATING +/- POLARITY INDICATIONS. SET 1000/DCVΩ. ROTATE THE "40kHz ADJ" TRIM POT FOR A READING OF '000'. CHANGE THE SETTING TO 200/DCVΩ , ROTATE THE TRIM POT FOR A READING OF '00.0'. CHANGE THE SETTING TO 20/DCVΩ, ROTATE THE TRIM POT FOR A READING OF '0.00'. DISCONNECT THE LINE CORD FROM THE METER, DISCONNECT THE TEST LEADS FROM THE TRANSFORMER, AND RE-CONNECT THE LINE CORD TO THE METER.
4) CONNECT THE V/Ω AND COM TEST LEADS TO AN ACCURATE 200mVDC STANDARD, WITH THE (V/Ω RED) TEST LEAD TO THE POSITIVE SIDE OF THE SOURCE. SET 200mV/DCVΩ . ROTATE THE "POS RANGE" TRIM POT FOR A READING OF 'OVER +00.0'. IF THE DISPLAY INCREASES (COUNTS UP) CONTINUOUSLY, THIS SUGGESTS A POOR CONNECTION WITH THE TEST SETUP.
5) CONNECT THE V/Ω AND COM TEST LEADS TO AN ACCURATE 200mVDC STANDARD, WITH THE (V/Ω RED) TEST LEAD TO THE NEGATIVE SIDE OF THE SOURCE. SET 200mV/DCVΩ . ROTATE THE "NEG RANGE" TRIM POT FOR A READING OF 'OVER -00.0'.
6) REPEAT STEPS 4 & 5 TO VERIFY ALL IS WELL SO FAR.
7) CONNECT THE V/Ω AND COM TEST LEADS TO AN ACCURATE 2VDC STANDARD, WITH THE (V/Ω RED) TEST LEAD TO THE POSITIVE SIDE OF THE SOURCE. SET 2V/DCVΩ . ROTATE THE "2VFS" TRIM POT FOR A READING OF 'OVER +.000'.
8) CONNECT THE V/Ω AND COM TEST LEADS TO AN ACCURATE 20kΩ STANDARD (WITHIN 0.05% TOLERANCE). SET 20kΩ/DCVΩ . ROTATE THE "20k ADJ" TRIM POT FOR A READING OF 'OVER 0.00'. IF A PRECISION REFERENCE RESISTOR IS NOT AVAILABLE, SELECT A STABLE RESISTOR WITH A VALUE SLIGHTLY LESS THAN 20kΩ, AND MEASURE ITS RESISTANCE WITH AN ACCURATE MULTIMETER, THEN WITH THE RESISTOR CONNECTED TO THE IM-102, ROTATE "20k ADJ" TRIM POT FOR A READING MATCHING THAT OF THE OTHER METER.
9) PERFORM THE SAME PROCEDURE AS WITH STEP 8 ABOVE, BUT USE A 20M REFERENCE RESISTOR, AND SET 20MΩ/DCVΩ. ROTATE THE "20M ADJ" TRIM POT FOR A READING OF 'OVER 0.00'. DUE TO THE HIGH RESISTANCE AND LOW CURRENT, 30 OR 40 SECONDS MAY ELAPSE BEFORE A STABLE, ACCURATE READING IS OBTAINED ON THE IM-102. DO NOT HOLD THE TEST LEADS IN YOUR HANDS FOR THIS STEP; USE CLIPS TO MAKE THE CONNECTIONS TO THE RESISTOR. AS WITH STEP 8, YOU CAN INSTEAD MEASURE SOME OTHER REFERENCE THAT IS SOMEWHAT LESS THAN 20M AND USE THAT AS A REFERENCE VALUE. REPEAT STEPS 8 & 9 TO VERIFY ALL IS STILL OK WITH THE CAILBRATION.
10) USE ANOTHER MULTIMETER TO MEASURE A CLEAN, SINUSOIDAL AC VOLTAGE, FOR EXAMPLE FROM THE LINE VOLTAGE OR FROM A FUNCTION GENERATOR SET TO OUTPUT AN AC SINCE WAVE SIGNAL. WRITE DOWN THE VOLTAGE READING. IT IS CRITICAL THAT THE WAVEFORM OF THE AC VOLTAGE IS NOT SIGNIFICANTLY NON-SINUSOIDAL OR OTHERWISE CORRUPTED BY SWITCHING CIRCUITS, ETC. AS AN ALTERNATIVE, SEE THE SEPARATE BOX FOR USING THE IM-102'S INTEGRAL 'AC CALIBRATE' CIRCUIT. CONNECT THE V/Ω AND COM TEST LEADS TO THE SAME AC VOLTAGE SOURCE (NOT AT THE SAME TIME AS THE OTHER METER IS CONNECTED). SET THE VOLTAGE RANGE APPROPRIATELY FOR THE TYPE OF AC SIGNAL BEING MEASURED (FOR EXAMPLE, 200V IF MEASURING 120VAC LINE VOLTAGE), AND THE FUNCTION SWITCH TO AC VOLTS (ACV). ROTATE THE "AC ADJ" TRIM POT ON THE 'AC CONVERTER' PCB FOR A READING THAT MATCHES THE VOLTAGE NUMBER WRITTEN DOWN AS DESCRIBED ABOVE.
11) CONNECT THE RED TEST LEAD TO THE mA JACK AND THE BLACK LEAD TO THE COM JACK. CONNECT THE TEST LEADS IN SERIES WITH A 10mA AC CURRENT SOURCE (VERIFY THE AVERAGE RMS CURRENT USING ANOTHER METER). SET 20mA/ACmA . ROTATE THE "CURRENT ADJ" TRIM POT ON THE 'AC CONVERTER' PCB FOR A READING OF 10.00.
12) THE "TP ADJ" TRIM POT IS NOT ADJUSTED IN THIS PROCEDURE, BECAUSE IT ONLY SERVES TO SET UP THE 'AC CALIBRATE CIRCUIT', WHICH IS NOT BEING USED.
13) THERE ARE TWO TRIM CAPACITORS ON THE 'AC CONVERTER' PCB, C402 "LOW CAL" AND C405 "HIGH CAL", AND THEY ARE IDENTIFIED BY SILK SCREENED LETTERING ON THE CIRCUIT BOARD. ADJUST BOTH OF THESE TRIM CAPS SO THAT THE SILVERED HALF OF EACH PLATE (SEMI-CIRCULAR SHAPE) IS POSITIONED AWAY FROM THE CIRCUIT BOARD SURFACE (AND THE NON-SILVERED SEMI-CIRCULAR HALF POSITIONED TOWARDS THE CIRCUIT BOARD SURFACE). SEE DETAIL DIAGRAM BELOW. THIS CENTERS THE CAPACITY OF EACH TRIM CAP WITHIN ITS RANGE. THIS SETTING IS ADEQUATE FOR MOST APPLICATIONS OF THE METER.



1) ALTERNATIVE TO CALIBRATION STEP 10 ABOVE (USING THE IM-102'S 'AC CALIBRATE' CIRCUIT)
2) CONNECT THE RED TEST LEAD TO THE METER'S VΩ JACK. DISCONNECT THE BLACK TEST LEAD FROM THE METER. SET 20V/DCVΩ. CONNECT RED TEST LEAD TO THE 'TP' PAD ON THE METER'S MAIN PCB (LOCATED NEAR THE "TP ADJ" TRIM POT).
3) PLACE THE 'AC CALIBRATE' CIRCUIT'S AC-DC SWITCH IN THE DC POSITION. ROTATE THE "TP ADJ" TRIM POT FOR A +9.00 READING; THE READING WILL VARY SEVERAL DIGITS IN BOTH DIRECTIONS FROM THE IDEAL CENTER READING.
4) CHANGE THE FUNCTION SWITCH TO THE ACV POSITION. PLACE THE AC-DC SWITCH IN THE AC POSITION. ROTATE THE "AC ADJUST" TRIM POT ON THE 'AC CONVERTER' PCB FOR A READING OF 0.00, WHICH MIGHT VARY SLIGHTLY IN BOTH DIRECTIONS FROM THE IDEAL VALUE.
5) REPEAT STEPS 3 & 4 AGAIN TO VERIFY CORRECT ADJUSTMENT.

SPECIFICATIONS

DC VOLTS
- ACCURACY (USING LABORATORY CALIBRATION SOURCES)
  - 200mV RANGE: >100MΩ IMPEDANCE, +/-0.1% +/-1 DIGIT ACCURACY, 350V OVERLOAD PROTECT
  - 2V RANGE: >1000MΩ IMPEDANCE, +/-0.1% +/-1 DIGIT ACCURACY, 350V OVERLOAD PROTECT
  - 20V/200V/1000V RANGE: 10MΩ IMP., +/-0.1% +/-1 DIGIT ACCURACY, 1000V OVERLOAD PROTECT
- OVERRANGE CAPABILITY: 20% MINIMUM (SUBJECT TO OVERLOAD PROTECTION LIMITS)
- RESOLUTION (200mV RANGE): 100μV
- TEMPERATURE INFLUENCE: +/-0.005%/DEG C, +/-0.1 DIGIT/DEG C
- NORMAL MODE REJECTION: 35dB MINIMUM AT 60Hz
- COMMON MODE REJECTION: 80dB MINIMUM WITH 1k UNBALANCE AT 60Hz

AC VOLTS (AVERAGE RESPONDING, RMS CALIBRATED)
- OVERLOAD PROTECTION
  - 200mV RANGE: 1MΩ IMPEDANCE AT 150pF, 250V RMS OVERLOAD PROTECTION
  - 2V RANGE: 1MΩ IMPEDANCE AT 150pF, 250V OVERLOAD PROTECTION
  - 20V RANGE: 1MΩ IMPEDANCE AT 150pF, 500V OVERLOAD PROTECTION
  - 200V RANGE: 1MΩ IMPEDANCE AT 150pF, 500V OVERLOAD PROTECTION
  - 1000V RANGE: 1MΩ IMPEDANCE AT 150pF, 500V OVERLOAD PROTECTION
- ACCURACY
  - 200mV RANGE: 40Hz~10kHz FREQUENCY RANGE, +/-0.5% +/- 1 DIGIT
  - 2V RANGE: 10kHz~20kHz FREQUENCY RANGE, +/-1.0% +/- 1 DIGIT
  - 20V RANGE: 40Hz~5kHz FREQUENCY RANGE, +/-0.75% +/- 1 DIGIT
  - 200V RANGE: 5kHz~10kHz FREQUENCY RANGE, +/-1.5% +/- 1 DIGIT
  - 1000V RANGE: 40Hz~7.5kHz FREQUENCY RANGE, +/-1.5% +/- 1 DIGIT
- RESOLUTION (200mV RANGE): 100μV
- TEMPERATURE INFLUENCE: +/-0.05%/DEG C, +/-0.1 DIGIT/DEG C 40Hz~10kHz
+/-0.1%/DEG C, +/-0.2 DIGIT/DEG C 10kHz~20kHz

DC AMPS
- ACCURACY (USING LABORATORY CALIBRATION SOURCES)
  - 200μA RANGE: 0.2V VOLTAGE DROP, +/-0.25% +/-1 DIGIT
  - 2mA RANGE: 0.2V VOLTAGE DROP, +/-0.2% +/-1 DIGIT
  - 20mA RANGE: 0.2V VOLTAGE DROP, +/-0.2% +/-1 DIGIT
  - 200mA RANGE: 0.2V VOLTAGE DROP, +/-0.3% +/-1 DIGIT
  - 2A RANGE: 0.2V VOLTAGE DROP, +/-0.5% +/-1 DIGIT
- RESOLUTION (200μA RANGE): 100nA
- OVERLOAD PROTECTION: 3A, ANY RANGE, BY FUSE AND CLAMPING DIODES

AC AMPS (40Hz TO 10kHZ)
- ACCURACY
  - 200μA RANGE: 0.2V VOLTAGE DROP, +/-0.75% +/-1 DIGIT
  - 2mA RANGE: 0.2V VOLTAGE DROP, +/-0.7% +/-1 DIGIT
  - 20mA RANGE: 0.2V VOLTAGE DROP, +/-0.7% +/-1 DIGIT
  - 200mA RANGE: 0.2V VOLTAGE DROP, +/-0.8% +/-1 DIGIT
  - 2A RANGE: 0.2V VOLTAGE DROP, +/-1% +/-1 DIGIT
- RESOLUTION (200μA RANGE): 100nA
- OVERLOAD PROTECTION: 3A, ANY RANGE, BY FUSE AND CLAMPING DIODES

RESISTANCE
- ACCURACY (USING LABORATORY CALIBRATION SOURCES)
  - 200Ω RANGE: 1mA TEST CURRENT, +/-0.5% +/-1 DIGIT, 250V RMS OVERLOAD PROTECTION *
  - 2k RANGE: 100μA TEST CURRENT, +/-0.25% +/-1 DIGIT, 250V RMS OVERLOAD PROTECTION *
  - 20k RANGE: 10μA TEST CURRENT, +/-0.25% +/-1 DIGIT, 250V RMS OVERLOAD PROTECTION
  - 200k RANGE: 10μA TEST CURRENT, +/-0.25% +/-1 DIGIT, 250V RMS OVERLOAD PROTECTION
  - 2M RANGE: 1μA TEST CURRENT, +/-1% +/-1 DIGIT, 250V RMS OVERLOAD PROTECTION
  - 20M RANGE: 100nA TEST CURRENT, +/-1% +/-1 DIGIT, 250V RMS OVERLOAD PROTECTION

  * BY FUSE AND CLAMPING DIODES (THESE TWO RANGES BORROW THE PROTECTION OF THE AC AMPS CIRCUIT)

GENERAL
- SIZE: 4"H x 9.5"W x 10"D
- WEIGHT: APPROX. 5.6 POUNDS
- DISPLAY:
  - MAXIMUM COUNT: 1999 (3-1/2 DIGITS)
  - OVERRANGE INDICATION: AUTOMATIC "OVER" BEYOND 1999
  - POLARITY INDICATION: AUTOMATIC "+" OR "-"
  - DISPLAY UPDATE RATE: 5 PER SECOND, NON-BLINKING
  - NUMERIC DISPLAY TYPE: SIDE-VIEWING NEON GLOW TUBES (NIXIE TYPE) WITH INTEGRAL DECIMAL POINTS
  - INPUT RANGE: MANUALLY SELECTED (NOT AUTO-RANGING)
- POWER REQUIREMENT:
  - VOLTAGE: 120VAC OR 240VAC
  - TOLERANCE: +15%, -10% OF RATED VOLTAGE
  - FREQUENCY: 50~60Hz
  - POWER DRAIN: 6W NOMINAL
- VOLTAGE ISOLATION:
  - METER CIRCUIT ISOLATED FROM CHASSIS/EARTH/POWER LINE GROUND
  - METER MAY BE OPERATED 500V ABOVE POWER LINE GROUND POTENTIAL
- OPERATING TEMPERATURE: 10 DEG C TO 40 DEG C

BASIC CIRCUIT OPERATION

THE IM-102 METER CAN MEASURE AC AND DC VOLTS, AC AND DC CURRENT (mA), AND RESISTANCE (OHMS). ALL OF THE INPUTS ARE SCALED AND/OR CONVERTED TO BASIC MEASURING RANGES OF 0~200mV OR 0~2V, DEPENDING ON THE RANGE SWITCH SETTING. THESE BASIC PRE-SCALED SIGNALS ARE MEASURED BY A HIGH IMPEDANCE BIPOLAR A/D (ANALOG TO DIGITAL) CONVERTER WHICH OPERATES ON THE DUAL-SLOPE PRINCIPLE, WHICH HAS THE ADVANTAGE IS REJECTING MOST ERRORS DUE TO INSTABILITY OF THE ELECTRONIC COMPONENTS USED IN THE CONVERTER, INCLUDING THOSE INACCURACIES RESULTING FROM TEMPERATURE CHANGES.

THE DUAL-SLOPE ACTION OPERATES WITHIN A CYCLE WHICH REPEATS EVERY 200mS (FIVE TIMES EVERY SECOND). EACH CYCLE IS ARRANGED TO OCCUR WITHIN 8000 PULSES OF A 40kHZ CLOCK OSCILLATOR, AND EACH CYCLE IS DIVIDED INTO TWO TIME ELEMENTS, t1 AND t2. DURING TIME ELEMENT t1, AN INTEGRATOR CIRCUIT CAUSES A VOLTAGE TO "RAMP UP", CHARGING A CAPACITOR. DURING TIME ELEMENT t2, THE INTEGRATOR DISCHARGES "RAMP DOWN"; THE TIME REQUIRED TO DISCHARGE THE CAPACITOR IS COUNTED, DECODED AND DISPLAYED WITH A READING PROPORTIONAL TO THE VALUE BEING MEASURED. THE INTEGRATOR IS CONFIGURED TO EXPECT AN INPUT OF EITHER 0~200mV OR 0~2V, DEPENDING ON THE RANGE SELECTION, AND THIS CORRESPONDS TO HOW THE METER'S FRONT END CIRCUITRY PRE-SCALES THE INPUTS. THE SCALED INPUT SIGNAL VOLTAGE TO THE INTEGRATOR AFFECTS THE RATE OF THE RAMP'S SLOPE, AND THUS ITS PEAK VOLTAGE. BECAUSE THE INTEGRATOR IS 'BIPOLAR', ITS RAMP VOLTAGES CAN ALSO BE NEGATIVE (LESS THAN 0V), SUCH THAT THE "RAMP UP" VOLTAGE ACTUALLY DECREASES, AND THE "RAMP DOWN" VOLTAGE INCREASES; THIS IS DETECTED BY LOGIC CIRCUITS WHICH CONTROL OPERATION OF THE INTEGRATOR CHARGE AND DISCHARGE, AND ALSO CONTROL THE DISPLAY OF "+" AND "-" POLARITY INDICATIONS ON THE DC VOLTS AND DC mA FUNCTIONS.

DC VOLTAGES ARE CONDITIONED BY VARIOUS DEGREES OF ATTENUATION, EXCEPT FOR THE 200mV AND 2V RANGES, WHICH ARE ALREADY WITHIN THE NATIVE RANGES OF THE A/D CONVERTER. AC VOLTAGES USE A DIFFERENT ATTENUATOR FROM THE ONE USED FOR DC VOLTAGE, AND THIS IS FOLLOWED BY A PRECISION RECTIFIER OP-AMP CIRCUIT WHICH CONVERTS THE AC SIGNAL INTO A DC ONE CORRESPONDING TO THE AVERAGE RMS VALUE OF THE SINUSOIDAL AC INPUT SIGNAL. DC CURRENTS ARE PASSED THROUGH A PRECISION SHUNT RESISTANCE, AND THE DC VOLTAGE DROPPED ACROSS THE SHUNT IS PROPORTIONAL TO THE CURRENT, AND IS THEN MEASURED JUST LIKE DC VOLTAGE. AC CURRENTS ARE PASSED THROUGH THE SAME SHUNT AS WITH DC CURRENT, AND THE DROPPED VOLTAGE IS RECTIFIED BY THE SAME PRECISION RECTIFIER AS WITH AC VOLTS. RESISTANCE IS MEASURED BY PASSING AN INTERNALLY GENERATED PRECISION CONSTANT CURRENT THROUGH THE RESISTANCE UNDER TEST, AND THE DROPPED VOLTAGE ACROSS THAT RESISTANCE IS PROPORTIONAL TO THE RESISTANCE, AND IS THEN MEASURED IN THE SAME WAY AS DC VOLTAGE.

THE DIGITAL LOGIC SECTION OF THE METER CIRCUIT FOLLOWS THE ANALOG SECTION DESCRIBED ABOVE, AND IT ALSO REACHES BACK TO CONTROL THE A/D CONVERTER'S INTEGRATOR ACCORDING TO WHICH PART OF THE TIMED CYCLE THE CIRCUIT IS IN, AND WHETHER POSITIVE OR NEGATIVE VOLTAGES OR CURRENTS ARE BEING INPUT. THE LOGIC ALSO HANDLES THE COUNTING OF THE PULSES WITHIN EACH CYCLE, AND DISPLAYS THE PORTION OF THE CYCLE COUNT WHICH IS PROPORTIONAL TO THE MEASURED VALUE, AND THEN CONDITIONS THAT COUNTED VALUE FOR DISPLAY. THE LOGIC DETECTS OVERRANGE CONDITIONS ACCORDING TO BOTH THE LOGICAL COUNT AS WELL AS THE ACTUAL INTEGRATOR OUTPUT VOLTAGE, AND CONTROLS THE "OVER" RANGE INDICATOR. FINALLY, THE LOGIC DETECTS + AND - POLARITIES AND CONTROLS THE APPROPRIATE POLARITY INDICATORS.

ALL DIGITAL LOGIC IS COMPRISED OF THE OLD STYLE 'RTL' (RESISTOR TRANSISTOR LOGIC) INTEGRATED CIRCUITS (ICs), WHICH USE ONLY 3.5VDC FOR POWER AND THEIR 'HIGH' LOGIC LEVELS.

SOME OPERATIONAL DETAILS

1) ALLOW THE METER A 15 MINUTE WARM-UP TO INSURE BEST ACCURACY.
2) ALL CIRCUITS ARE PROTECTED AGAINST OVERLOADS, EITHER THROUGH RESISTOR-DIODE NETWORKS, OR THROUGH TRANSISTOR CLAMPING, AND/OR THROUGH FUSES LOCATED INSIDE THE CHASSIS.
3) IT IS NORMAL FOR THE RIGHT HAND (LEAST SIGNIFICANT) DIGIT OF THE DISPLAY TO ALTERNATE ONE NUMBER ON SUCCESSIVE COUNTS.
4) "DO NOT EXCEED" INPUT VALUES ARE SHOWN IN A CHART ON THE REAR OF THE METER.
5) THE DISPLAY'S "OVER" RANGE INDICATOR WILL FLICKER WHEN THE INPUT SIGNAL IS HIGHER THAN THE SETTING OF THE RANGE SWITCH, BUT WILL REMAIN ON STEADILY WHEN THE INPUT REACHES A MORE EXTREME OVERLOAD CONDITION.
6) ONE OR THE OTHER OF THE "+" AND "-" INDICATORS WILL ALWAYS ILLUMINATE WHEN MEASURING DC VOLTS OR DC CURRENT, AND BOTH WILL BE OFF WHEN MEASURING AC VOLTS OR CURRENT OR RESISTANCE.
7) THE PROPER DECIMAL POINT LOCATION IS DETERMINED AUTOMATICALLY BY THE RANGE SWITCH.
8) THE DISPLAY CAN SHOW VALUES AS LOW AS 0 AND AS HIGH AS 1999. THE METER DESIGN ALLOWS UP TO A 20% OVER-RANGE ON ALL RANGES EXCEPT FOR 1000 (SEE NOTE 9 BELOW). DO NOT 'FLOAT' THE METER'S 'COM' INPUT MORE THAN 500V ABOVE THE POWER LINE GROUND, AS THIS CAN RESULT IN DAMAGE TO THE INSTRUMENT.
9) WHEN THE DISPLAY READS "OVER" (FLICKERING) AND THE NUMERICAL DISPLAY IS 000 (IRRESPECTIVE OF DECIMAL POINT POSITION), THIS MEANS A READING OF EXACTLY 2000 (ONE DIGIT HIGHER THAN 1999). EXCEPT FOR THE 1000 RANGE, IT IS POSSIBLE TO THEN EXCEED THE VIRTUAL 2000 COUNT, UP TO 20%. FOR EXAMPLE, IF THE METER IS IN THE 20V RANGE AND A 24 VOLT SIGNAL IS INPUT, THE DISPLAY WILL SHOW "OVER 4", AND THE USER CAN ASSUME THE VIRTUAL 20 PART AND 'READ' A VALUE OF 24. OVERRANGE READINGS HIGHER THAN 20% ARE UNRELIABLE.

ANALOG & DIGITAL CIRCUITRY IS SHOWN ON SHEETS 1&2 OF THIS DRAWING

NOTES AND OTHER INFORMATION ARE LOCATED ON SHEET 3 OF THIS DRAWING

THIS SCHEMATIC WAS DRAWN, USING AUTOCAD, AS A MEANS TO GET A MORE LEGIBLE AND UNDERSTANDABLE SCHEMATIC FOR THE HEATHKIT IM-102. AN EFFORT HAS BEEN MADE TO SIZE AND SCALE COMPONENTS AND TEXT FOR THE LARGEST AND BEST VISIBILITY AND LEGIBILITY WHILE STILL FITTING ON A NORMAL 11 X 17" SHEET OF PAPER.

HEATHKIT IM-102 DIGITAL MULTIMETER SCHEMATIC DIAGRAM

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