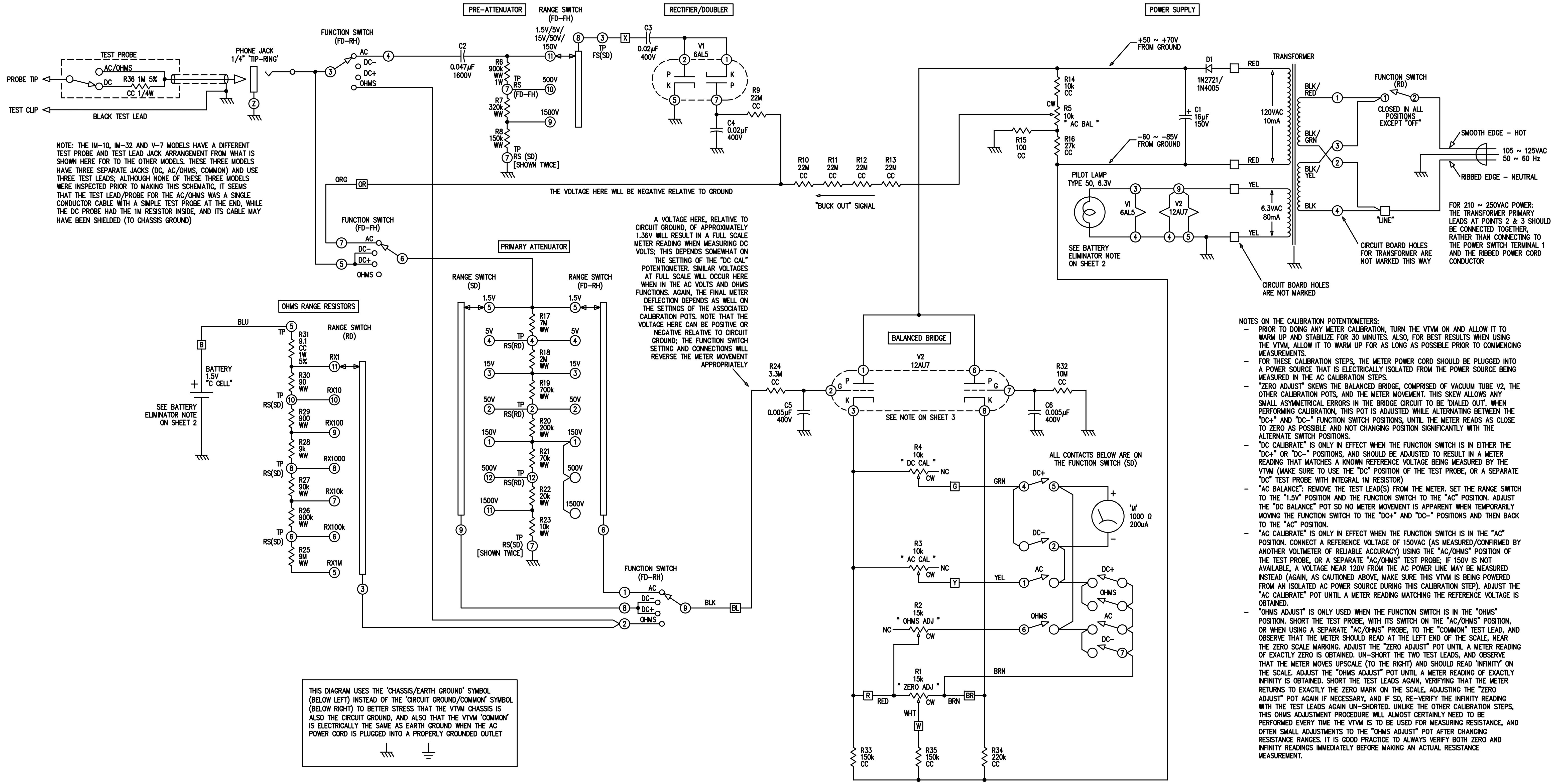


NOTES ON THE CALIBRATION POTENTIOMETERS:

- PRIOR TO DOING ANY METER CALIBRATION, TURN THE VTVM ON AND ALLOW IT TO WARM UP AND STABILIZE FOR 30 MINUTES. ALSO, FOR BEST RESULTS WHEN USING THE VTVM, ALLOW IT TO WARM UP FOR AS LONG AS POSSIBLE PRIOR TO COMMENCING MEASUREMENTS.
- FOR THESE CALIBRATION STEPS, THE METER POWER CORD SHOULD BE PLUGGED INTO A POWER SOURCE THAT IS ELECTRICALLY ISOLATED FROM THE POWER SOURCE BEING MEASURED IN THE AC CALIBRATION STEPS.
- "ZERO ADJUST" SKEWS THE BALANCED BRIDGE, COMPRISED OF VACUUM TUBE V2, THE OTHER CALIBRATION POTS, AND THE METER MOVEMENT. THIS SKEW ALLOWS ANY SMALL ASYMMETRICAL ERRORS IN THE BRIDGE CIRCUIT TO BE 'DIALED OUT'. WHEN PERFORMING CALIBRATION, THIS POT IS ADJUSTED WHILE ALTERNATING BETWEEN THE "DC+" AND "DC−" FUNCTION SWITCH POSITIONS, UNTIL THE METER READS AS CLOSE TO ZERO AS POSSIBLE AND NOT CHANGING POSITION SIGNIFICANTLY WITH THE ALTERNATE SWITCH POSITIONS.
- "DC CALIBRATE" IS ONLY IN EFFECT WHEN THE FUNCTION SWITCH IS IN EITHER THE "DC+" OR "DC−" POSITIONS, AND SHOULD BE ADJUSTED TO RESULT IN A METER READING THAT MATCHES A KNOWN REFERENCE VOLTAGE BEING MEASURED BY THE VTVM (MAKE SURE TO USE THE "DC" POSITION OF THE TEST PROBE, OR A SEPARATE "DC" TEST PROBE WITH INTEGRAL 1M RESISTOR)
- "AC BALANCE": REMOVE THE TEST LEAD(S) FROM THE METER. SET THE RANGE SWITCH TO THE "1.5V" POSITION AND THE FUNCTION SWITCH TO THE "AC" POSITION. ADJUST THE "DC BALANCE" POT SO NO METER MOVEMENT IS APPARENT WHEN TEMPORARILY MOVING THE FUNCTION SWITCH TO THE "DC+" AND "DC−" POSITIONS AND THEN BACK TO THE "AC" POSITION.
- "AC CALIBRATE" IS ONLY IN EFFECT WHEN THE FUNCTION SWITCH IS IN THE "AC" POSITION. CONNECT A REFERENCE VOLTAGE OF 150VAC (AS MEASURED/CONFIRMED BY ANOTHER VOLTMETER OF RELIABLE ACCURACY) USING THE "AC/OHMS" POSITION OF THE TEST PROBE, OR A SEPARATE "AC/OHMS" TEST PROBE; IF 150V IS NOT AVAILABLE, A VOLTAGE NEAR 120V FROM THE AC POWER LINE MAY BE MEASURED INSTEAD (AGAIN, AS CAUTIONED ABOVE, MAKE SURE THIS VTVM IS BEING POWERED FROM AN ISOLATED AC POWER SOURCE DURING THIS CALIBRATION STEP). ADJUST THE "AC CALIBRATE" POT UNTIL A METER READING MATCHING THE REFERENCE VOLTAGE IS OBTAINED.
- "OHMS ADJUST" IS ONLY USED WHEN THE FUNCTION SWITCH IS IN THE "OHMS" POSITION. SHORT THE TEST PROBE, WITH ITS SWITCH ON THE "AC/OHMS" POSITION, OR WHEN USING A SEPARATE "AC/OHMS" PROBE, TO THE "COMMON" TEST LEAD, AND OBSERVE THAT THE METER SHOULD READ AT THE LEFT END OF THE SCALE, NEAR THE ZERO SCALE MARKING. ADJUST THE "ZERO ADJUST" POT UNTIL A METER READING OF EXACTLY ZERO IS OBTAINED. UN-SHORT THE TWO TEST LEADS, AND OBSERVE THAT THE METER MOVES UPSCALE (TO THE RIGHT) AND SHOULD READ 'INFINITY' ON THE SCALE. ADJUST THE "OHMS ADJUST" POT UNTIL A METER READING OF EXACTLY INFINITY IS OBTAINED. SHORT THE TEST LEADS AGAIN, VERIFYING THAT THE METER RETURNS TO EXACTLY THE ZERO MARK ON THE SCALE, ADJUSTING THE "ZERO ADJUST" POT AGAIN IF NECESSARY, AND IF SO, RE-VERIFY THE INFINITY READING WITH THE TEST LEADS AGAIN UN-SHORTED. UNLIKE THE OTHER CALIBRATION STEPS, THIS OHMS ADJUSTMENT PROCEDURE WILL ALMOST CERTAINLY NEED TO BE PERFORMED EVERY TIME THE VTVM IS TO BE USED FOR MEASURING RESISTANCE, AND OFTEN SMALL ADJUSTMENTS TO THE "OHMS ADJUST" POT AFTER CHANGING RESISTANCE RANGES. IT IS GOOD PRACTICE TO ALWAYS VERIFY BOTH ZERO AND INFINITY READINGS IMMEDIATELY BEFORE MAKING AN ACTUAL RESISTANCE MEASUREMENT.

NOTES:

1) ALL RESISTANCES ARE SHOWN IN OHMS UNLESS MARKED 'k' (KILO) OR 'M' (MEGA). RESISTORS ARE 1/2W UNLESS INDICATED. RESISTORS ARE INDICATED "CC" FOR 'CARBON COMPOSITE' OR "WW" FOR 'WIREWOUND'. "CC" RESISTORS ARE 10% TOLERANCE, AND "WW" RESISTORS ARE 1% TOLERANCE UNLESS INDICATED.
2) POTENTIOMETERS R1 & R2 ARE DENOTED ON HEATHKIT ASSEMBLY DIAGRAMS WITH 'TERMINAL 1' ON THE CCW END OF THE ELEMENT, 'TERMINAL 3' ON THE CW END OF THE ELEMENT, AND 'TERMINAL 2' ON THE WIPER. THE ACTUAL POTS ARE NOT SO MARKED.
3) WHERE SPARE NUMBERED TERMINALS ARE USED AS SWITCH TIE POINTS, THEY ARE MARKED "TP" AND THE APPLICABLE SWITCH DESIGNATION IS GIVEN; IF NO "TP" OR DIFFERENT SWITCH PART DESIGNATION IS GIVEN, THE TERMINAL IS PART OF THE SAME ADJACENT SWITCH DECK AND SIDE. SEE THE SWITCH DECK DESIGNATION DIAGRAM ON SHEET 3 OF THIS DRAWING.
4) WHILE THIS SCHEMATIC IS DRAWN SPECIFICALLY FOR THE HEATHKIT IM-18 VTVM (MADE FROM 1968–1977), IT SHOULD BE CLOSELY APPLICABLE TO THE FOLLOWING EARLIER AND LATER HEATHKIT MODELS WHICH SHARE THE SAME EXACT CIRCUIT DESIGN, BUT WITH DIFFERENT CASE STYLES AND OTHER STYLING: V-7 (1954–1961), IM-11 ('61–68), IM-5218 ('77–83), AND THE BENCHTOP MODELS IM-13 ('63–69), IM-28 ('69–77), AND IM-5228 ('77–89). TO A SLIGHTLY LESSER EXTENT, OUTLIER MODELS IM-10 ('61–62) AND IM-32 ('62–63) PURPORTEDLY HAVE NEARLY THE SAME CIRCUIT AS THE AFOREMENTIONED MODELS.
5) CIRCUIT BOARD HOLES ARE DESIGNATED WITH A SMALL SQUARE SYMBOL □; NOT ALL HOLES HAVE LETTER DESIGNATIONS
6) SWITCH TERMINALS ARE DESIGNATED WITH A SMALL ROUND SYMBOL ○; THE INTERNAL NUMBERS SHOWN ON THIS DRAWING MATCH THE ORIGINAL HEATHKIT SCHEMATICS.
7) THE ORIGINAL HEATHKIT COMBINATION TEST PROBE & SWITCH IS SHOWN ON THIS DRAWING. AS THESE ARE "UNOBTAINIUM" NOW, THEY MAY BE REPLACED USING SEPARATE "AC/OHMS" AND "DC" (WITH 1M RESISTOR) PROBES AND TEST LEADS.
8) SEE SHEETS 2 & 3 OF THIS DRAWING FOR ADDITIONAL NOTES, DIAGRAMS, THEORY OF CIRCUIT OPERATION, AND DETAILS ON MAKING A BATTERY ELIMINATOR FOR USE WITH THE OMHS FUNCTION.
9) THE SELECTOR SWITCHES HAVE MULTIPLE DECKS, SOME WITH FRONT AND REAR HALVES, AND THEIR PLATE & WIPER ARRANGEMENTS ARE COMPLEX, WHICH IN MOST CASES CANNOT BE CLEARLY DEPICTED USING COMPOSITE SYMBOLOGY. INSTEAD, THIS SCHEMATIC USES DIFFERENT STYLES OF SWITCH SYMBOLS, DEPENDING ON WHICH BEST SUITS THE SWITCH OPERATION. WHERE SWITCH SECTIONS ARE JOINED USING DIAGONAL LINES, THIS INDICATES SHARED WIRING TERMINALS.
10) REFER TO SHEET 3 FOR A DIAGRAM SHOWING THE RANGE AND FUNCTION SWITCH DECKS AND THEIR DESIGNATIONS.
11) TO AVOID CLUTTER, THE VARIOUS SECTIONS OF THE RANGE SWITCH AND FUNCTION SWITCH ARE NOT SHOWN HERE WITH INTERCONNECTING DASHED LINES. THE ACTIVE POSITIONS ARE SPELLED OUT FOR EVERY INSTANCE OF EACH SWITCH.
12) THE FUNCTION SWITCH IS SHOWN, FOR CLARITY, WITH ONLY THE "AC", "DC−", "DC+" AND "OHMS" POSITIONS. THE FIFTH POSITION "OFF" IS SEGREGATED HERE AS A SIMPLE SWITCH LOCATED IN THE POWER SUPPLY SECTION OF THIS DRAWING.

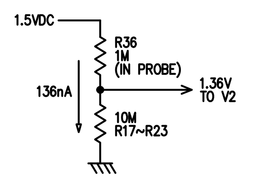
THIS SCHEMATIC WAS DRAWN, USING AUTOCAD, AS A MEANS TO GET A MORE LEGIBLE AND UNDERSTANDABLE SCHEMATIC FOR THE HEATHKIT IM-18 AND RELATED MODELS. AN EFFORT HAS BEEN MADE TO SIZE AND SCALE COMPONENTS AND TEXT FOR THE LARGEST AND BEST VISIBILITY AND LEGIBILITY WHILE STILL FITTING ON A NORMAL 11 X 17" SHEET OF PAPER.

HEATHKIT IM-18 VTVM (ALSO FOR SIMILAR MODELS) SCHEMATIC DIAGRAM

REVISION A 1-12-2023

EXAMPLE CALCULATIONS USING SIMPLIFIED FUNCTION CIRCUITS

DC VOLTS

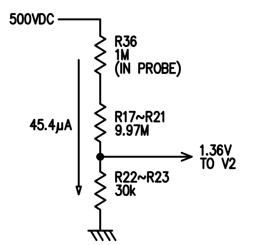


THE 1.5V RANGE IS USED FOR THIS EXAMPLE

THE TOTAL DC VOLTS ATTENTUATOR IS COMPRISED OF RESISTORS ADDING UP TO 11M. THIS ESTABLISHES THE VTVM'S INPUT IMPEDANCE AS 11M. ASSUMING THE INPUT VOLTAGE IS 1.5V,

1.5V / 11M = 136nA
136nA x 10M = 1.36V

SO, WITH A FULL RANGE INPUT OF 1.5V, THE ATTENUATOR PRODUCES 1.36V AND PRESENTS IT TO THE INPUT OF THE BALANCE BRIDGE METER CIRCUIT, WHICH IN THE DC FUNCTION IS CALIBRATED TO GIVE A FULL SCALE READING FOR A 1.36V SIGNAL, AND THE METER IS SCALED TO INDICATE 1.5VDC IN THAT POSITION.



THE 500V RANGE IS USED FOR THIS EXAMPLE

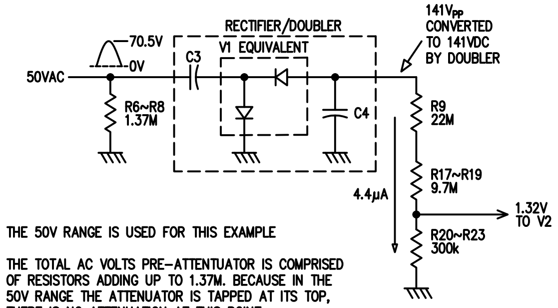
THE RESISTOR ATTENUATOR IS TAPPED AT THE 500V NODE, HOWEVER THE TOTAL RESISTANCE REMAINS THE SAME AT 11M. ASSUMING THE INPUT VOLTAGE IS 500V,

500V / 11M = 45.4µA
45.4µA x 30k = 1.36V

SO, WITH A FULL RANGE INPUT OF 500V, THE ATTENUATOR PRODUCES 1.36V AND PRESENTS IT TO THE INPUT OF THE BALANCE BRIDGE METER CIRCUIT, THE SAME AS WITH THE 1.5V EXAMPLE ABOVE, AND THE METER IS SCALED TO INDICATE 500VDC IN THAT POSITION.

THIS DIAGRAM USES THE 'CHASSIS/EARTH GROUND' SYMBOL (BELOW LEFT) INSTEAD OF THE 'CIRCUIT GROUND/COMMON' SYMBOL (BELOW RIGHT) TO BETTER STRESS THAT THE VTVM CHASSIS IS ALSO THE CIRCUIT GROUND, AND ALSO THAT THE VTVM 'COMMON' IS ELECTRICALLY THE SAME AS EARTH GROUND WHEN THE AC POWER CORD IS PLUGGED INTO A PROPERLY GROUNDED OUTLET

AC VOLTS



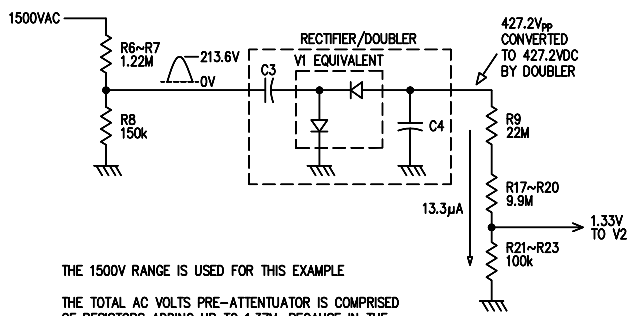
THE 50V RANGE IS USED FOR THIS EXAMPLE

THE TOTAL AC VOLTS PRE-ATTENUATOR IS COMPRISED OF RESISTORS ADDING UP TO 1.37M. BECAUSE IN THE 50V RANGE THE ATTENUATOR IS TAPPED AT ITS TOP, THERE IS NO ATTENUATION AT THIS POINT.

THE INPUT IN THIS EXAMPLE IS ASSUMED TO BE A 50V (RMS) SINE WAVE. SINCE THE FOLLOWING RECTIFIER/DOUBLER CIRCUIT (SEE EXPLANATION AT RIGHT OF THIS DRAWING) IS CONCERNED WITH RECTIFYING THE AC AND THEN CAPTURING THE PEAK-TO-PEAK VOLTAGE V_{PP}, THE RMS VOLTAGE IS CONVERTED TO V_P BY MULTIPLYING BY 1.41, GIVING 70.5V_P (THE PEAK-TO-PEAK VOLTAGE WOULD BE TWICE THAT, OR 141V_{PP}). THIS IS APPLIED TO THE PRIMARY VOLTAGE ATTENUATOR. ASSUMING THE RANGE SWITCH IS SET TO THE 50V, THE TOTAL ATTENUATOR RESISTANCE IS 32M, SO

141V / 32M = 4.4µA
4.4µA x 300k = 1.32V

SO, WITH A FULL RANGE INPUT OF 50V, THE ATTENUATOR PRODUCES 1.32V AND PRESENTS IT TO THE INPUT OF THE BALANCE BRIDGE METER CIRCUIT, WHICH IN THE AC FUNCTION IS CALIBRATED TO GIVE A FULL SCALE READING FOR A 1.32V SIGNAL, AND THE METER IS SCALED TO INDICATE 50VAC IN THAT POSITION.



THE 1500V RANGE IS USED FOR THIS EXAMPLE

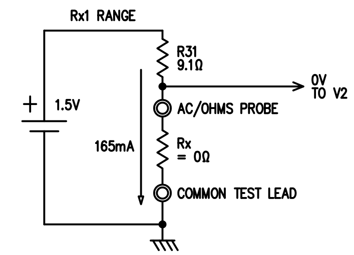
THE TOTAL AC VOLTS PRE-ATTENTUATOR IS COMPRISED OF RESISTORS ADDING UP TO 1.37M. BECAUSE IN THE 1500V RANGE THE ATTENUATOR IS TAPPED AT NEAR ITS BOTTOM, THE ATTENUATION RESULTS IN 151.5VAC AT THIS POINT. AS IN THE EXAMPLE ABOVE, THIS NEEDS TO BE CONSIDERED AS A PEAK VOLTAGE, SO, MULTIPLYING BY 1.41 GIVES 213.6V_P. BECAUSE OF THE ACTION OF THE RECTIFIER/DOUBLER, THE AC IS CONVERTED TO A DC VOLTAGE EQUIVALENT TO THE PEAK-TO-PEAK VALUE Vp X 2, OR 427.2V_{PP}, GIVING 427.2VDC.

THIS IS APPLIED TO THE PRIMARY VOLTAGE ATTENUATOR. BECAUSE OF THE PRE-ATTENUATOR ACTION, THE PRIMARY ATTENUATOR IS LIMITED TO NO MORE THAN THE ATTENUATION FOR THE 150V RANGE. THE TOTAL ATTENUATOR RESISTANCE IS 32M, SO

427.2V / 32M = 13.3µA
13.3µA x 100k = 1.33V (LET'S CALL IT 1.32V)

SO, WITH A FULL RANGE INPUT OF 1500V, THE ATTENUATOR PRODUCES 1.32V AND PRESENTS IT TO THE INPUT OF THE BALANCED BRIDGE METER CIRCUIT, WHICH IN THE AC FUNCTION IS CALIBRATED TO GIVE A FULL SCALE READING FOR A 1.32V SIGNAL, AND THE METER IS SCALED TO INDICATE 1500VAC IN THAT POSITION.

OHMS



THE Rx1 RANGE IS USED FOR THIS EXAMPLE

THE RANGE SWITCH CONNECTS ONLY ONE OF THE OHMS RANGE RESISTORS, R31, TO BE IN SERIES WITH THE RESISTOR UNDER TEST, Rx. START BY ASSUMING THAT Rx IS 0 OHMS (TEST PROBE & COMMON TEST LEAD SHORTED TOGETHER).

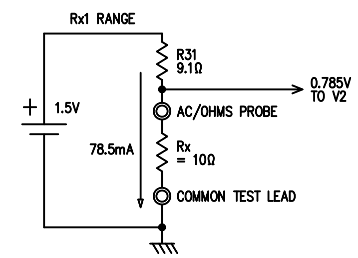
THE OVERALL RESISTANCE IS 9.1Ω + 0Ω = 9.1Ω

1.5V / 9.1Ω = 165mA

THE VOLTAGE DROP ACROSS Rx IS WHAT THE METER CIRCUIT LOOKS AT, SO

165mA x 0Ω = 0V

THIS CAUSES THE METER TO REMAIN AT ITS FAR LEFT POSITION, WHERE ITS NEEDLE POINTS AT THE 0 POSITION ON THE OHMS SCALE, GIVING A READING OF 0 OHMS.



WITH THE RANGE REMAINING THE SAME, AND ASSUMING THAT Rx IS NOW 10 OHMS,

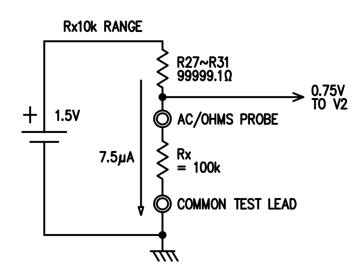
THE OVERALL RESISTANCE IS 9.1Ω + 10Ω = 19.1Ω

1.5V / 19.1Ω = 78.5mA

78.5mA x 10Ω = 0.785V

WE ARE NOT SURE AT THIS STAGE EXACTLY WHAT THE BALANCED BRIDGE METER CIRCUIT IS CALIBRATED FOR IN THE OHMS FUNCTION, BUT ASSUMING THAT APPROXIMATELY 1.6V FROM THIS CIRCUIT TO THE BALANCED BRIDGE (V2 PIN 2) WILL GIVE A FULL SCALE READING,

1.6V / 2 = 0.8V FOR A HALF SCALE DEFLECTION, SO THE 0.785V CALCULATED ABOVE WILL BE GIVE AN APPROXIMATELY HALF SCALE METER DEFLECTION, AND THE OHMS SCALE IS MARKED 10 AT THAT POSITION, GIVING A 10Ω READING.



WITH THE Rx10k RANGE SELECTED, AND ASSUMING NOW THAT Rx IS 100k OHMS,

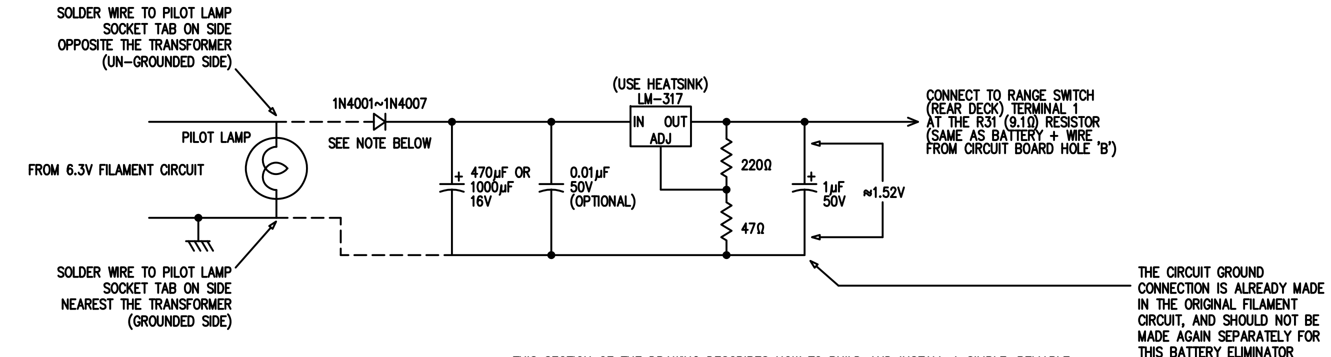
THE OVERALL RESISTANCE IS 99999.1Ω + 100k = 199999.1Ω

1.5V / 199999.1Ω = 7.5µA

7.5µA x 100k = 0.75V

WHICH PER THE PREVIOUS EXAMPLE IS ASSUMED TO GIVE AN APPROXIMATELY HALF SCALE METER DEFLECTION, AND WITH THE OHMS SCALE BEING MARKED 10 AT THAT POSITION, THIS GIVES 10 X 10k = 100k.

BATTERY ELIMINATOR



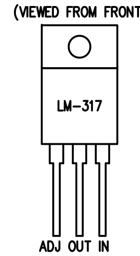
NOTE:
IT IS CRITICAL THAT THE BATTERY ELIMINATOR BE WIRED TO THE PILOT LAMP SOCKET WITH THE ELIMINATOR'S DIODE CONNECTING TO THE UN-GROUNDED SIDE OF THE FILAMENT CIRCUIT. SOME OF THE VTVM MODELS MIGHT BE LAID OUT SUCH THAT THE ABOVE RECOMMENDED ORIENTATION RELATIVE TO THE TRANSFORMER IS NOT APPLICABLE

CAVEAT:
ESPECIALLY IN THE LOWER RESISTANCE RANGES, e.g. THE Rx1 RANGE, THE CURRENT IN THE OHMS CRUCUIT CAN BE AS HIGH AS 165mA. THIS CAN QUICKLY DEPLETE THE BATTERY, WHICH IS A GOOD REASON TO INSTALL A BATTERY ELIMINATOR. HOWEVER, MOST VTVM BATTERY ELIMINATORS GET THEIR POWER FROM THE TRANSFORMER'S FILAMENT SECONDARY, AND AT LEAST IN THE HEATHKIT DESIGNS THAT 6.3V WINDING IS RATED FOR ONLY 80mA, MOST OF WHICH IS CONSUMED BY THE LOW RESISTANCE LOADS OF THE VACUUM TUBE FILAMENTS AND THE PILOT LAMP. SO, IT IS POSSIBLE FOR THE WORST CASE LOAD ON THE FILAMENT WINDING TO BE 80mA + 165mA, OR 245mA!

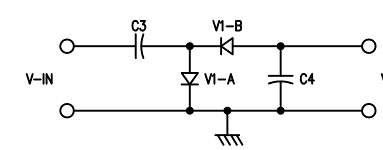
EVEN THOUGH RATED AT 80mA, THE TRANSFORMER CAN SUPPLY THAT HIGHER CURRENT, ALBEIT WITH A SMALL DROP IN VOLTAGE; THE BATTERY ELIMINATOR'S VOLTAGE REGULATOR WILL DEAL WITH THAT. BUT IT IS ADVISABLE TO TAKE ONLY BRIEF RESISTANCE MEASUREMENTS, ESPECIALLY WHILE IN THE LOWER RESISTANCE RANGES, TO AVOID TRANSFORMER STRESS.

- THIS SECTION OF THE DRAWING DESCRIBES HOW TO BUILD AND INSTALL A SIMPLE, RELIABLE AND ACCURATE BATTERY ELIMINATOR.
- THE IN4001 DIODE HAS A MORE THAN ADEQUATE VOLTAGE RATING FOR THIS CIRCUIT, BUT HIGHER VOLTAGE DIODES SUCH AS THE COMMON 1N4002, IN4003, ETC; MAY BE USED.
- THE TWO RESISTORS CAN BE 1/4W, 5%, BUT FOR BEST OUTPUT VOLTAGE ACCURACY THEY SHOULD BOTH BE 1% TOLERANCE PARTS.
- IF WHEN USING THIS ELIMINATOR WITH THE 47Ω RESISTOR, THE OUTPUT VOLTAGE (REFERENCED TO CIRCUIT/CHASSIS GROUND) IS LESS THAN 1.5V, INCREASE THE RESISTANCE BY ADDING A SMALL VALUE RESISTOR (e.g. 3.9Ω) IN SERIES WITH THE 47Ω, OR USE A 51Ω RESISTOR INSTEAD OF THE 47Ω RESISTOR, OR USE A 100Ω TRIMMER POTENTIOMETER IN PLACE OF THE RESISTOR, AND SET IT TO APPROXIMATELY THE CENTER OF ITS ROTATION.
- THE FORMULA FOR FINDING THE ELIMINATOR'S OUTPUT VOLTAGE ACCORDING TO THE TWO RESISTOR VALUES IS: V-OUT = 1.25 x (1+(47Ω/220Ω)), SO SOLVING PROGRESSES AS 47/220 = 0.214, THEN 0.214+1 = 1.214, THEN 1.214x1.25 = 1.52 VOLTS.
- IT IS ADVISABLE TO USE A SMALL HEATSINK WITH THE LM-317; THIS CAN BE A SMALL PIECE OF ALUMINUM OR A COMMERCIALLY PRODUCED VERSION. THE LM-317 MAY ALSO HAVE ITS EXCESS HEAT REMOVED BY MOUNTING IT TO THE SHEET METAL SUB-CHASSIS (BRACKET) WHICH HOLDS THE "BATTERY –" CONNECTOR AND THE STRAIN RELIEF FOR THE AC POWER CORD, BUT IF THIS METHOD IS USED, THE REAR SIDE OF THE LM-317 AND ESPECIALLY ITS METAL TAB 'MUST' BE ELECTRICALLY ISOLATED FROM THE CHASSIS; THERE ARE COMMERCIALLY AVAILABLE KITS FOR THIS PURPOSE, CONSISTING OF AN INSULATOR FOR THE MOUNTING SCREW AND AN INSULATING WAFER FOR THE REAR SURFACE.
- WHEN SUCH A BATTERY ELIMINATOR IS INSTALLED IN THE VTVM, DO NOT HAVE THE BATTERY INSTALLED IN THE BATTERY HOLDER !!!

(VIEWED FROM FRONT)

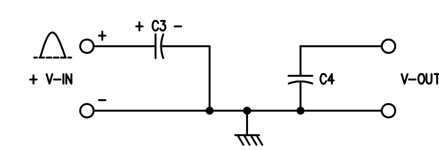


RECTIFIER/DOUBLER



THE ABOVE DIAGRAM DEPICTS THE "RECTIFIER/DOUBLER" SUB-CIRCUIT, SUBSTITUTING THE V1 TWIN RECTIFIER TUBE WITH AN EQUIVALENT PAIR OF NORMAL SOLID STATE DIODES, IDENTIFIED AS V1-A & V1-B.

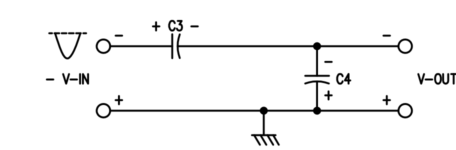
THIS TYPE OF RECTIFIER/DOUBLER IS KNOWN AS A "GREINACHER CIRCUIT", NAMED AFTER HEINRICH GREINACHER, WHO INVENTED IT IN 1913.



THE ABOVE DIAGRAM DEPICTS THE EQUIVALENT CIRCUIT WHEN V-IN IS A POSITIVE VOLTAGE (REFERENCED TO CIRCUIT/CHASSIS GROUND). BECAUSE THE VOLTAGE IS POSITIVE, V1-A IS FORWARD BIASED AND ACTS LIKE A VIRTUAL SHORT CIRCUIT, AND IS DEPICTED AS SUCH IN THE DIAGRAM. MEANWHILE, V1-B IS REVERSE BIASED AND ACTS LIKE AN OPEN CIRCUIT, ALSO INCLUDED IN THE ABOVE DEPICTION.

DURING THE POSITIVE HALF CYCLE OF THE AC SIGNAL BEING MEASURED VIA V-IN, C3 IS EFFECTIVELY CONNECTED ACROSS THE INPUT VOLTAGE AND IS CHARGED TO THAT LEVEL, WITH THE CHARGE POLARITY AS INDICATED.

C4 IS CONNECTED TO THE OUTPUT (V-OUT), BUT THE VERY HIGH IMPEDANCE THERE MEANS THAT THIS CAPACITOR'S VOLTAGE IS MONITORED, BUT NOT DEPLETED.



THE ABOVE DIAGRAM DEPICTS THE EQUIVALENT CIRCUIT WHEN V-IN IS A NEGATIVE VOLTAGE (REFERENCED TO CIRCUIT/CHASSIS GROUND). BECAUSE THE VOLTAGE IS NEGATIVE, V1-A IS REVERSE BIASED AND ACTS LIKE AN OPEN CIRCUIT, AND IS DEPICTED AS SUCH IN THE DIAGRAM. MEANWHILE, V1-B IS FORWARD BIASED AND ACTS LIKE AN VIRTUAL SHORT CIRCUIT, ALSO INCLUDED IN THE ABOVE DEPICTION.

DURING THE NEGATIVE HALF CYCLE OF THE AC SIGNAL BEING MEASURED VIA V-IN, C3 IS EFFECTIVELY CONNECTED IN SERIES WITH THE INPUT VOLTAGE, WHICH IS THE OPPOSITE POLARITY OF WHAT IT WAS PREVIOUSLY, BUT WITH THE SAME PEAK VOLTAGE LEVEL. SINCE THE CHARGE ON C3 IS THE SAME SERIES POLARITY AS THE INPUT VOLTAGE, THEIR VOLTAGES ADD AND RESULT IN DOUBLE THE INPUT VOLTAGE.

C4 IS NOW CONNECTED IN PARALLEL WITH THE SERIES-CONNECTED INPUT AND C3, AND THUS IS CHARGED TO THE SAME LEVEL AS THEIR SUMMED VOLTAGES. SINCE C4 IS STILL CONNECTED TO THE OUTPUT (V-OUT), AND THIS CAPACITOR'S VOLTAGE IS MONITORED, BUT NOT DEPLETED, BY THE OUTPUT CIRCUIT, THUS THE MONITORING CIRCUIT SEES A VOLTAGE THAT IS BOTH RECTIFIED FROM THE ORIGINAL AC VOLTAGE, AND ALSO HAS DOUBLE THE PEAK VOLTAGE OF THE INPUT, EFFECTIVELY A DC VERSION OF THE PEAK-TO-PEAK VOLTAGE PRESENT AT THE INPUT. DUE TO THE HIGH IMPEDANCE OF THE MONITORING CIRCUIT, C4 HOLDS ITS CHARGE THROUGH THE SUBSEQUENT POSITIVE HALF CYCLE OF THE AC SIGNAL.

THE V-OUT VOLTAGE IS NEGATIVE WITH RESPECT TO CIRCUIT/CHASSIS GROUND, BUT THE SUBSEQUENT BALANCED BRIDGE & METER SWITCHING CIRCUIT RESULTS IN AN EFFECTIVE SECOND POLARITY REVERSAL WHICH PRODUCES THE EXPECTED NORMAL METER DEFLECTION.

SPECIFICATIONS

DC VOLTS:
- 7 RANGES (1.5V, 5V, 15V, 50V, 150V, 500V, 1500V)
- INPUT IMPEDANCE = 11MΩ (WITH 1M IN DC PROBE)
- CIRCUIT IS BALANCED BRIDGE USING TWIN TRIODE
- ACCURACY = +/-3% OF FULL SCALE

AC VOLTS:
- 7 RANGES (1.5V, 5V, 15V, 50V, 150V, 500V, 1500V)
- INPUT IMPEDANCE = 1MΩ SHUNTED BY 35pF (MEASURED AT PROBE JACK)
- METER SCALE HAS BOTH RMS AND PEAK-TO-PEAK RANGES (RMS IS ONLY VALID FOR SINE WAVEFORMS)
- FREQUENCY RESPONSE (BASED IN 5V RANGE) = +/- 1dB FROM 25Hz TO 1MHz (FROM 600Ω SOURCE)
- ACCURACY = +/-5% OF FULL SCALE, DUE TO VARIATIONS IN RECTIFIER CIRCUIT COMPONENTS

OHMS:
- 7 RANGES (Rx1, Rx10, Rx100, Rx1000, Rx10k, Rx100k, Rx1M)
- MEASUREMENT RANGE = 0.1Ω ~ 1000MΩ USING INTERNAL 1.5V CELL (BATTERY)

GENERAL:
- METER MOVEMENT IS 200µA, 1k
- RESISTOR DIVIDERS ARE 1% TOLERANCE
- VACUUM TUBES (1x 12AU7 TWIN TRIODE, 1x 6AL5 TWIN DIODE
- BATTERY = 1.5V "C" CELL, OR AFTERMARKET BATTERY ELIMINATOR
- POWER REQUIREMENT = 10W
- CABINET SIZE = 7-3/8"H x 4-11/16"W x 4-1/8"D *
- WEIGHT = 3.5 POUNDS *
- * SIZE AND WEIGHT ARE APPLICABLE TO PORTABLE VERSIONS (V-1, IM-11, IM-18, IM-5218), NOT TO BENCHTOP UNITS (IM-13, IM-28, IM-5228), OR THE IM-10 OR IM-32

REVISION A 1-12-2023

HEATHKIT IM-18 VTVM
(ALSO FOR SIMILAR MODELS)
SCHEMATIC DIAGRAM
SHEET 2 OF 3

OTHER NOTES ABOUT THE VTVM CIRCUIT

PRE-ATTENUATOR:

THE 6AL5 TWIN RECTIFIER TUBE "V1" CANNOT WITHSTAND VOLTAGES MUCH HIGHER THAN 400V, SO IN THE 500V AND 1500V RANGES A PRE-ATTENUATOR CIRCUIT COMPRISED OF R6~R8 IS USED TO REDUCE THE INPUT VOLTAGE TO A SAFE LEVEL FOR THE TUBE. SINCE THE RECTIFIER/DOUBLER CIRCUIT OUTPUT IS APPLIED TO THE PRIMARY ATTENUATOR'S VOLTAGE DIVIDER COMPRISED OF R17~R23, IT IS IMPORTANT TO NOT ATTENUATE 'TWICE' WHILE IN THOSE TWO HIGHEST RANGES. SO FOR AC VOLTS ONLY, THE 500V AND 1500V RANGE SWITCH POSITIONS ARE CONNECTED TO THE SAME POINT IN THE ATTENUATOR AS THE 150V RANGE.

"BUCK OUT" SIGNAL:

THE RECTIFIER/DOUBLER CIRCUIT (SEE SPECIAL NOTES ON THAT CIRCUIT ON SHEET 2) IS CONFIGURED SO THAT ITS OUTPUT IS NEGATIVE WITH RESPECT TO CIRCUIT/CHASSIS GROUND. THIS IS COMPENSATED FOR BY THE FUNCTION SWITCH'S REVERSED METER CONNECTIONS WHEN IN ITS AC POSITION. SINCE THE 6AL5 TUBE IS NOT A PERFECT RECTIFIER, THE RECTIFIER/DOUBLER CIRCUIT OUTPUT IS SLIGHTLY MORE NEGATIVE THAN IT SHOULD BE TO GET AN ACCURATE METER READING. TO REMEDY THIS, A SLIGHTLY POSITIVE VOLTAGE FROM THE "AC BALANCE" POTENTIOMETER IS MIXED INTO THE RECTIFIER/DOUBLER CIRCUIT'S OUTPUT.

PEAK HOLD:

BESIDES ITS FUNCTION AS PART OF THE VOLTAGE DOUBLER CIRCUIT, CAPACITOR C4 ALSO SERVES TO HOLD ITS VOLTAGE AT THE PEAK LEVEL OF THE RECTIFIED SIGNAL BEING MEASURED. THIS AMOUNTS TO A "PEAK HOLD" FUNCTION, AND THUS THE VTVM PERFORMS AS A PEAK-READING AC VOLTMETER WHEN THE FUNCTION SWITCH IS IN THE "AC" POSITION. HOWEVER, THE METER FACE HAS DISTINCT SCALES FOR READING THE AC VOLTAGES AS "RMS" AND AS "PEAK-TO-PEAK" VOLTAGES.

BALANCED BRIDGE:

THE TWIN TRIODE TUBE "V2" IS CONFIGURED AS THE TOP HALF OF A BALANCED BRIDGE CIRCUIT. THE SIGNAL FROM THE VTVM'S FRONT-END PRESCALING CIRCUITS, AT V2 PIN 2, WILL BE 0V WHEN THE SIGNAL (VOLTS OR OHMS) BEING MEASURED IS ZERO, AND THE MAXIMUM VOLTAGE AT THIS POINT WILL BE ROUGHLY IN THE 1.36V~1.57V RANGE WHEN THE SIGNAL BEING MEASURED IS EQUAL TO THE MAXIMUM VOLTAGE OF THE CURRENTLY SELECTED RANGE (OR WHEN THE RESISTANCE BEING MEASURED IS TOO HIGH FOR THE SELECTED RANGE; "INFINITY"). THE OTHER SIDE OF THE TUBE, AT V2 PIN 7, IS CONNECTED TO CIRCUIT GROUND VIA A RESISTOR. SO WHEN THE INPUT SIGNAL IS 0V, BOTH SIDES OF THE TUBE HAVE 0V INPUTS, THUS THEY BOTH CONDUCT EQUALLY FROM THEIR 'PLATE' (P) TO THEIR 'CATHODE' (K), SO THEIR CATHODE VOLTAGES ARE THE SAME. SINCE THE METER MOVEMENT IS CONFIGURED AS A VOLTMETER, DUE TO BEING CONNECTED IN SERIES WITH ONE OF THE CALIBRATION POTENTIOMETERS, AND SINCE IT IS CONNECTED BETWEEN THE TWO CATHODES, IT SEES A 0V DIFFERENCE, AND THUS GIVES A 0V (FULL LEFT OF SCALE) READING.

BUT WHEN THE INPUT SIGNAL AT V2 PIN 2 HAS A VOLTAGE GREATER THAN 0V, THAT SIDE OF THE TUBE CONDUCTS MORE, AND THUS ITS CATHODE VOLTAGE IS GREATER, SO THE METER MOVEMENT SEES AN INCREASED VOLTAGE DIFFERENCE AND ACCORDINGLY GIVES A GREATER READING (MORE TOWARDS THE RIGHT OF THE SCALE).

IF A NEGATIVE VOLTAGE IS APPLIED TO V2 PIN2, THAT SIDE OF THE TUBE CONDUCTS LESS; THIS IS POSSIBLE BECAUSE THE CIRCUIT GROUND (AND THE BALANCED BRIDGE) IS HELD AT A VOLTAGE ROUGHLY HALFWAY BETWEEN THE + AND THE – SIDES OF THE POWER SUPPLY BY THE ACTION OF RESISTORS R14, R5, R16 AND R15, SO SIGNALS AT THE BALANCED BRIDGE CAN GO NEGATIVE WITH RESPECT TO THE VOLTAGE AT CIRCUIT GROUND. WHEN THE LEFT SIDE OF THE TUBE IS CONDUCTING LESS THAN THE RIGHT SIDE, ITS CATHODE VOLTAGE WILL BE LESS THAN THE RIGHT SIDE CATHODE, SO THE METER MOVEMENT SEES A NEGATIVE VOLTAGE AND WILL TRY TO INDICATE LESS THAN A ZERO READING (THE FULL LEFT SCALE POSITION). FOR NEGATIVE DC VOLTS, THE FUNCTION SWITCH SHOULD BE IN THE "DC–" POSITION, WHICH REVERSES THE POLARITY OF THE METER MOVEMENT CONNECTIONS TO THE BALANCED BRIDGE, SO THE METER CAN STILL GIVE 'UPSCALE' READINGS. FOR AC VOLTS, THE RECTIFIER/DOUBLER CIRCUIT PRODUCES A NEGATIVE OUTPUT VOLTAGE, BUT AGAIN THE FUNCTION SWITCH REVERSES THE METER MOVEMENT CONNECTIONS WHEN ITS IS IN THE "AC" POSITION, RESULTING IN AN UPSCALE READING. IN THE OHMS FUNCTION, THE BATTERY ONLY PROVIDES POSITIVE VOLTAGE RELATIVE TO CIRCUIT GROUND, SO THERE IS NO POSSIBILITY OF A NEGATIVE READING (UNLESS THE VTVM'S TEST LEADS ARE CONNECTED TO AN EXTERNAL VOLTAGE RATHER THEN TO AN ISOLATED RESISTANCE).

DUE TO IMPERFECTIONS IN V2 AND COMPONENT TOLERANCES AND OTHER CIRCUIT VARIABLES, THERE CAN BE A SLIGHT ASYMMETRICAL RESPONSE IN THE BALANCED BRIDGE CIRCUIT, RESULTING IN THE BRIDGE NOT BEING PERFECTLY BALANCED. THUS, THE METER DOES NOT GIVE A READING OF EXACTLY ZERO IN RESPONSE TO AN INPUT OF 0 VOLTS. TO COMPENSATE, RESISTORS R33~R35 AND "ZERO ADJUST" POTENTIOMETER R1 ARE ARRANGED TO ALLOW SLIGHTLY SKEWING THE BRIDGE IN ORDER TO FACILITATE RE-BALANCING IT. THIS ADJUSTMENT MAY NEED TO BE MADE FAIRLY OFTEN, ESPECIALLY IF THE VTVM IS NOT FULLY WARMED UP, OR IF V2 IS AGING, OR FOR OTHER REASONS.

CENTER SCALE "0":

IN ADDITION TO THE "ZERO ADJUST" FUNCTIONALITY DESCRIBED IN THE ABOVE PARAGRAPH, THIS CONTROL CAN ALSO BE USED TO OBSERVE TRENDING. THE "ZERO ADJUST" CIRCUIT HAS ENOUGH SPAN TO ALLOW PLACING THE METER'S POINTER AT THE CENTER OF TRAVEL WHEN THERE IS NO SIGNAL BEING INPUT TO THE VTVM. THE LOWEST SCALE OF THE METER CONSISTS SIMPLY OF A "– 0 +" MARK, AND USING THE "ZERO ADJUST" THE POINTER CAN BE SET TO THIS POSITION. NOW, WHEN THE INPUT IS NEGATIVE, THE METER WILL POINT TO THE LEFT OF THIS "0" POSITION, AND WHEN THE INPUT IS POSITIVE, THE METER WILL POINT TO THE RIGHT OF THIS "0" POSITION. IT SHOULD ALSO BE POSSIBLE IN SOME SITUATIONS TO USE THE "ZERO ADJUST" TO ESTABLISH AS "FALSE ZERO" OR "NULL" POSITION AT THE "– 0 +" SCALE MARKING AND THEN USE THE VTVM TO COMPARE DIFFERENT INPUT SIGNALS AGAINST THIS NULL REFERENCE.

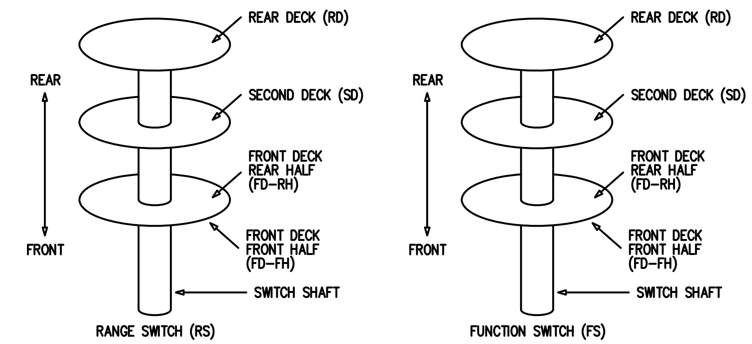
POWER SUPPLY:

THE AC LINE VOLTAGE ENTERS THE VTVM VIA THE POWER CORD. THE "GROUND" WIRE IS CONNECTED TO THE CHASSIS, WHICH IS ALSO THE CIRCUIT GROUND. THE "HOT" WIRE (SMOOTH INSULATION SURFACE) IS SWITCHED BY PART OF THE FUNCTION SWITCH, APPLYING THE AC POWER TO THE VTVM'S TRANSFORMER WHENEVER THE FUNCTION SWITCH IS NOT IN THE "OFF" POSITION. THE "NEUTRAL" WIRE (RIBBED INSULATION SURFACE) IS CONNECTED DIRECTLY TO THE OTHER SIDE OF THE TRANSFORMER.

THE TRANSFORMER'S PRIMARY WINDING CONSISTS OF TWO COILS, EACH OF WHICH NEEDS APPROXIMATELY 120V. WHEN USING THE VTVM ON A 120V MAINS VOLTAGE (105~125VAC), THE TWO PRIMARY WINDINGS ARE CONNECTED IN PARALLEL ACROSS THE INCOMING LINE VOLTAGE; TWO PRIMARY WIRES ARE CONNECTED DIRECTLY TO THE FUNCTION SWITCH'S REAR DECK TERMINAL 1, AND THE OTHER TWO PRIMARY WIRES ARE CONNECTED TO ONE OF TWO HOLES ON THE CIRCUIT BOARD MARKED "LINE"; THE OTHER HOLE IS WHERE THE RIBBED "NEUTRAL" LINE CORD WIRE TERMINATES. USING THE VTVM ON A 240V MAINS VOLTAGE (210~250VAC), THE TWO PRIMARY WINDINGS ARE CONNECTED IN SERIES ACROSS THE INCOMING MAINS VOLTAGE; ONE PRIMARY WIRE CONNECTS TO THE FUNCTION SWITCH'S REAR DECK TERMINAL 1, AND ANOTHER CONNECTS TO THE HOLE ADJACENT TO THE "LINE" HOLE ON THE CIRCUIT BOARD, AND THE TWO REMAINING PRIMARY WIRES ARE CONNECTED TOGETHER USING A WIRE NUT OR SIMILAR INSULATED DEVICE. IT IS IMPORTANT TO CONNECT SPECIFIC PRIMARY WIRES TO THESE DIFFERENT POINTS; USE THE TRANSFORMER WINDING COLOR CODES SHOWN ON SHEET 1 OF THIS DRAWING.

THE TRANSFORMER HAS TWO SECONDARY WINDINGS. THE "FILAMENT" WINDING SUPPLIES 6.3VAC AT UP TO 80mA, AND IT DIRECTLY FEEDS THE THREE FILAMENTS OF THE TWO VACUUM TUBES "V1" AND "V2", AS WELL AS THE 6.3V PILOT LAMP (AND OPTIONALLY A BATTERY ELIMINATOR CIRCUIT). THE OTHER WINDING PRODUCES 120VAC AT UP TO 10mA; THIS IS HALF-WAVE RECTIFIED BY SOLID STATE DIODE "D1" AND FILTERED BY ELECTROLYTIC CAPACITOR "C1". THE + SIDE OF C1 IS THE "V+" SUPPLY AND THE – SIDE OF C1 IS THE "V–" SUPPLY, WHICH ARE – AND + IN THE SENSE THAT CIRCUIT GROUND IS HELD SOMEWHERE BETWEEN THOSE TWO VOLTAGES BY THE ACTION OF R14, R15, R16 AND R5.

SELECTOR SWITCH DECKS AND DESIGNATIONS



NOTES ON VTVM OPERATION

- THE VTVM HAS EITHER A SINGLE SWITCH SELECTABLE PROBE, OR TWO SEPARATE DEDICATED PROBES, NOT COUNTING THE "COMMON" TEST LEAD. FOR DC VOLTS ONLY, THE SINGLE PROBE'S SWITCH MUST BE SELECTED TO THE "DC" POSITION, OR THE DEDICATED "DC VOLTS" PROBE MUST BE USED. FOR MEASURING AC VOLTS OR OHMS, THE SINGLE PROBE'S SWITCH MUST BE SELECTED TO THE "AC/OHMS" POSITION, OR THE DEDICATED "AC VOLTS/OHMS" (SOMETIMES REFERRED TO AS THE "DIRECT" PROBE) MUST BE USED. THE ONLY ELECTRICAL DIFFERENCE BETWEEN THEM IS THAT THE AC/OHMS/DIRECT PROBE TIP IS DIRECTLY WIRED TO THE VTVM'S INPUT CIRCUITRY, WHILE THE DC PROBE TIP IS ISOLATED FROM THE VTVM'S INPUT CIRCUITRY BY A 1M RESISTOR. THIS RESISTOR IS A CRUCIAL COMPONENT OF THE DC VOLTS ATTENTUATOR CIRCUIT, BUT IS LOCATED IN THE PROBE TO HELP REDUCE CAPACITANCE ISSUES.

- BEFORE STARTING ANY VOLTAGE MEASUREMENT, FIRST VERIFY THAT THE METER'S POINTER IS AT THE 0 VOLT POINT ON THE SCALE (WITH THE PROBE NOT CONNECTED TO THE EXTERNAL CIRCUIT UNDER TEST). IF IT IS NOT AT 0V, THEN USE THE "ZERO ADJUST" CONTROL ON THE FRONT PANEL OF THE VTVM TO "ZERO" THE METER. UNLESS THE VTVM HAS BEEN ABLE TO WARM UP FOR AT LEAST 30 MINUTES, IT IS LIKELY TO BE UNSTABLE, WITH THE ZERO DRIFTING AND REQUIRING FREQUENT ADJUSTMENTS OF THE "ZERO ADJUST" CONTROL. DURING MEASUREMENTS, IF THE VOLTAGE READING LOOKS QUESTIONABLE, TEMPORARILY REMOVE THE TEST PROBE FROM THE CIRCUIT UNDER TEST, AND USE THE "ZERO ADJUST" CONTROL TO RE-ESTABLISH A ZERO READING PRIOR TO RECONNECTING THE PROBE TO THE CIRCUIT UNDER TEST.

- DC VOLTAGE MEASUREMENTS: THE INPUT IMPEDANCE ON ALL DC VOLTS IS 11M, SO THERE IS MINIMAL (NEGLIGIBLE IN MOST APPLICATIONS) LOADING OF THE CIRCUIT UNDER TEST. CONNECT THE "COMMON" TEST LEAD TO THE COMMON OR CIRCUIT GROUND OF THE CIRCUIT UNDER TEST, AND USE THE "DC VOLTS" PROBE TO TEST VARIOUS POINTS IN THE CIRCUIT UNDER TEST. FOR POSITIVE VOLTAGES, THE VTVM'S FUNCTION SWITCH SHOULD BE SET TO THE "DC+" POSITION, AND FOR NEGATIVE VOLTAGES, USE THE "DC–" POSITION. IF THE METER TRIES TO POINT DOWN SCALE, SWITCH TO THE FUNCTION SWITCH'S OTHER DC POSITION. IF THE APPROXIMATE MAGNITUDE OF THE VOLTAGE TO BE MEASURED IN NOT KNOWN, START WITH THE RANGE SWITCH AT ITS HIGHEST VOLTAGE SETTING, THEN SELECT TO AN APPROPRIATE LOWER RANGE AS REQUIRED TO GET A GOOD READING.

- AC VOLTAGE MEASUREMENTS: OBSERVE THE CAUTIONS ON THIS DRAWING REGARDING AVOIDANCE OF SITUATIONS WHERE THE VTVM'S CIRCUIT "COMMON ", WHICH IS BY DEFAULT ELECTRICALLY CONNECTED TO THE VTVM'S CHASSIS & CASE, AND ALSO TO EARTH GROUND AND THE GROUND OF THE AC POWER LINE, CONFLICTS WITH VOLTAGE POTENTIALS OF THE CIRCUIT UNDER TEST. THIS SHOULD NOT BE A CONCERN IF THE VTVM IS ONLY PROBING INSIDE LOW VOLTAGE CIRCUITS IN EQUIPMENT WHERE ALL CIRCUITRY IS ISOLATED FROM THE AC POWER BY A TRANSFORMER. A GOOD WAY TO AVOID CONFLICTS IS TO USE AN ISOLATION TRANSFORMER FOR EITHER THE VTVM OR THE CIRCUIT UNDER TEST, AND IF IN DOUBT, USE AN ADAPTER PLUG ON THE VTVM'S AC POWER CORD, WHERE THE ADAPTER PLUG PREVENTS THE VTVM'S AC POWER PLUG "GROUND" PIN FROM CONNECTING THROUGH TO EARTH/AC MAINS GROUND. EXCEPT FOR THESE SPECIFIC SITUATIONS, IT IS RECOMMENDED THAT THE VTVM'S POWER CORD BE ALLOWED TO MAKE NORMAL CONNECTION TO EARTH/AC MAINS GROUND.

  IF MEASURING SINE WAVES, IT IS USUALLY APPROPRIATE TO READ FROM THE "AC RMS" SCALES, AND IF MEASURING NON-SINUSOIDAL WAVEFORMS, IT MAY BE MORE USEFUL TO READ FROM THE "AC PEAK-TO-PEAK" SCALES.

  IN ITS AC VOLTS FUNCTION, THE VTVM IS VERY SENSITIVE TO AC FIELDS, AND IS LIKELY TO PICK UP UNWANTED VOLTAGES FROM THE HUMAN BODY WHEN IT IS NEAR AC WIRING. NEVER TOUCH THE TIP OF THE PROBE WHEN ON THE LOWER AC RANGES, OR ERRONEOUS READS WILL BE LIKELY. THE "ZERO ADJUST" CONTROL SHOULD BE ADJUSTED WITH THE PROBE SHORTED TO THE "COMMON" TEST LEAD, AND COMPARING THE ZERO SETTING WITH THE ZERO READINGS OBTAINED WITH THE FUNCTION SWITCH BRIEFLY MOVED TO THE "DC–" AND "DC+" POSITIONS.

- RESISTANCE MEASUREMENTS: BEFORE TAKING THE MEASUREMENT, HAVE THE TEST LEADS ("AC/OHMS" AND "COMMON") DISCONNECTED FROM ANYTHING AND USE THE "OHMS ADJUST" CONTROL ON THE VTVM'S FRONT PANEL TO GET A METER READING OF FULL SCALE "INFINITY", THEN SHORT THE TWO TEST LEADS TOGETHER AND USE THE "ZERO ADJUST" CONTROL TO GET A READING OF FULL LEFT ZERO. REPEAT THESE TWO STEPS TO VERIFY INFINITY AND ZERO. THEN CONNECT THE "COMMON" TEST LEAD TO ONE SIDE OF THE RESISTOR OR RESISTANCE TO BE TESTED, AND CONNECT THE "AC/OHMS" PROBE TO THE OTHER SIDE OF THE RESISTOR. READ THE NUMBER ON THE OHMS SCALE THAT THE METER'S POINTER IS INDICATING, AND MULTIPLY THAT READING BY THE RESISTANCE OF THE SELECTED RANGE. FOR EXAMPLE, IF THE METER POINTER INDICATES A READING OF 13, AND THE RANGE SWITCH IS SELECTED TO THE Rx100 POSITION, THIS MEANS TO MULTIPLY 13 X 100Ω TO GET A RESISTANCE VALUE OF 1300Ω (1.3K). ALTHOUGH THE OHMS FUNCTION IS POWERED BY A BATTERY (UNLESS A BATTERY ELIMINATOR IS INSTALLED), THE BALANCED BRIDGE CIRCUIT OF THE VTVM STILL REQUIRES SEPARATE POWER, SO EVEN IN THE OHMS FUNCTION THE VTVM MUST BE PLUGGED INTO THE AC MAINS POWER AND TURNED "ON". IF A BATTERY RATHER THAN A BATTERY ELIMINATOR IS BEING USED, IT WILL BE CONTINUOUSLY DEPLETING AS LONG AS THE VTVM IS SELECTED TO "OHMS".

- THE VTVM MAY BE USED TO MEASURE DECIBELS: [NEARLY VERBATIM FROM THE HEATHKIT MANUAL] BECAUSE THE HUMAN EAR DOES NOT RESPOND TO VOLUME OF SOUND IN PROPROTION TO SIGNAL STRENGTH, A [NEW] UNIT OF MEASUREMENT CALLED THE "BEL" WAS ADOPTED [SO NAMED BY THE BELL TELEPHONE LABORATORY IN HONOR OF TELECOMMUNICATIONS PIONEER ALEXANDER GRAHAM BELL]. THE BEL IS MORE NEARLY EQUIVALENT TO HUMAN RATIOS. NORMALLY THE READING IS GIVEN IN 1/10 OF A BEL (DECIBEL, OR "dB"). VARIOUS SIGNAL LEVELS ARE ADOPTED BY VARIOUS MANUFACTURERS AS [THE] STANDARD OF ZERO DECIBEL. THE VTVM "dB" SCALE USES A STANDARD OF 1 MILLIWATT INTO A 600Ω LOAD AS ZERO DECIBELS. THIS CORRESPONDS TO 0.774 VOLTS AC ON THE 1.5V SCALE. FROM THIS FIGURE, THE VARIOUS AC RANGES OF THE VTVM MAY BE CONVERTED TO dB, WITH ADEQUATE ACCURACY, BY THE FOLLOWIONG CHART:

AC VOLTS SCALE	DECIBEL SCALE
0~1.5VOLTS	READ dB DIRECTLY (FROM THE dB SCALE ON THE METER FACE)
0~5 VOLTS	ADD 10 dB TO THE READING
0~15 VOLTS	ADD 20 dB TO THE READING
0~50 VOLTS	ADD 30 dB TO THE READING
0~150 VOLTS	ADD 40 dB TO THE READING
0~500 VOLTS	ADD 50 dB TO THE READING
0~1500 VOLTS	ADD 60 dB TO THE READING

  AS THE DECIBEL IS A POWER RATIO OR VOLTAGE RATIO, IT MAY BE USED AS SUCH WITHOUT SPECIFYING THE REFERENCE LEVEL. THUS FOR INSTANCE, A FIDELITY CURVE MAY BE RUN ON AN AMPLIFIER BY FEEDING IN A SIGNAL OF A VARIABLE FREQUENCY, BUT CONSTANT AMPLITUDE, AT A REFERENCE FREQUENCY, e.g. 400 Hz, ADJUST THE INPUT TO GIVE A CONVENIENT INDICATION (e.g. ZERO dB) ON THE VTVM CONNECTED TO THE AMPLIFIER'S OUTPUT. AS THE INPUT FREQUENCY IS VARIED, THE OUTPUT VARIATION MAY BE NOTED DIRECTLY IN dB ABOVE AND BELOW THE SPECIFIED REFERENCE LEVEL.

- ACCURACY: [NEARLY VERBATIM FROM THE HEATHKIT MANUAL] THE ACCURACY OF THE METER MOVEMENT IS WITHIN 2% OF FULL SCALE, WHICH MEANS THAT ON THE 1500V RANGE (FOR EXAMPLE) THE ACCURACY OF THE METER MOVEMENT WILL BE WITHIN 30 VOLTS AT ANY POINT ON THE SCALE. ON DC VOLTS, THE ACCURACY OF THE MULTIPIERS (THE PRIMARY ATTENTUATOR RESISTANCES) IS 1% AND MAY BE ADDITIVE, RESULTING IN AN ACCURACY WITHIN 3% OF FULL SCALE. ON AC VOLTS, THE ACCURACY OF THE RECTIFIER CIRCUIT CONTRIBUTES VARIATIONS WHICH WILL RESULT IN AN ACCURACY OF WITHIN 5% OF FULL SCALE. KEEP IN MIND THAT ON THE LOWEST AC VOLTAGE RANGE, 1.5V, EXTREME SENSITIVITY WILL INTRODUCE ADDITIONAL VARIATION THROUGH STRAY PICKUP OF AC FIELDS. THEREFORE, ON THE 1.5VAC RANGE, IT IS POSSIBLE THAT THE ACCURACY MAY BE ON THE ORDER OF 15% OF FULL SCALE. THE ACCURACY OF THE OHMS FUNCTION DEPENDS ON THE METER MOVEMENT'S ACCURACY, THE OHMS MULTIPLIER (RESISTORS R25~R31), THE INTERNAL RESISTANCE OF THE BATTERY, AND THE STABILITY OF THE BATTERY VOLTAGE [THIS LAST IS NOT APPLICABLE IF A BATTERY ELIMINATOR IS USED]. IN THE Rx1 RANGE, THE INTERNAL RESISTANCE OF THE BATTERY AND THE BATTERY VOLTAGE BOTH VARY AS A RESULT OF THE FAIRLY LARGE CURRENT DRAWN BY THE RESISTANCE UNDER TEST. FOR GREATEST ACCURACY, TESTS ON LOW RESISTANCE VALUES SHOULD BE MADE AS QUICKLY AS POSSIBLE [SINCE THE BATTERY VOLTAGE MAY SAG QUICKLY DUE TO THE LOAD CURRENT]. ON THE HIGHER OHMS RANGES, THE ACCURACY DEPENDS PRIMARILY ON THE MULTIPLIERS WHICH ARE 1% TOLERANCE, AND ON THE METER MOVEMENT'S ACCURACY WHICH IS 2% . BECAUSE THE OHMS SCALE IS NON-LINEAR, THE RESULTING ACCURACY IS NOT READILY EXPRESSED IN A PERCENTAGE FIGURE, BUT GREATEST ACCURACY IS OBTAINED IN MID-SCALE READINGS, SO ADJUST THE RESISTANCE RANGE ACCORDINGLY.

  NOTE: WHEN COMPARING THIS VTVM TO ANOTHER METER, CONSIDER THAT THE ACCURACY OF THE OTHER INSTRUMENT MAY DEVIATE IN THE OPPOSITE DIRECTION [FROM THAT OF THE VTVM]. THEREFORE, WHEN COMPARING TWO INSTRUMENTS OF 5% ACCURACY [EACH], THE TOTAL DIFFERENCE MAY BE 10%. CRITICAL COMPARISONS SHOULD ONLY BE MADE AGAINST CERTIFIED LABORATORY STANDARDS.

- ELECTROSTATIC CHARGE: THE FACE OF THE METER MOVEMENT IS MADE OF POLYSTYRENE PLASTIC, AND IT HAS BEEN TREATED AT THE FACTORY TO RESIST THE ACCUMULATION OF STATIC ELECTRICITY. HOWEVER, SHOULD A STATIC CHARGE ACCUMULATE THROUGH REPEATED POLISHING OR CLEANING OF THE METER FACE, THE POINTER WILL DEFLECT IN AN ERRATIC MANNER, REGARDLESS OF WHETHER THE INSTRUMENT IS TURNED ON OR OFF. THIS CONDITION CAN BE CORRECTLY QUICKLY. ONE METHOD IS TO USE ANY OF THE COMMERCIALLY AVAILABLE "ZERO STATIC" TOOLS, INCLUDING THOSE INTENDED TO CANCEL STATIC CHARGES ON VINYL LP RECORDS. ANOTHER METHOD IS TO APPLY A SMALL QUANTITY OF LIQUID DISHWASHING DETERGENT TO A CLEAN, SOFT CLOTH AND WIPE THE FACE OF THE METER. THE ACCUMULATED STATIC CHARGE WILL IMMEDIATELY DISAPPEAR. IT IS NOT NECESSARY TO REMOVE THE FACE OF THE METER MOVEMENT FOR THIS CORRECTION.

- UNLIKE MOST MODERN SOLID-STATE ANALOG, AND DIGITAL, MULTIMETERS, THIS VTVM DOES NOT INCORPORATE ANY PROTECTIVE CIRCUITRY OR COMPONENTS. ALWAYS BE MINDFUL OF GOOD PRACTICES SUCH AS STARTING A MEASUREMENT FROM HIGHER RANGES (FOR VOLTAGES), SWITCHING DOWN WHEN THE READINGS INDICATE THAT IT IS SAFE TO DO SO.

REPLACING VACUUM TUBES

THE 12AU7 TWIN TRIODE TUBE (V2) IS BECOMING SOMEWHAT LESS AVAILABLE AS EITHER NOS (NEW OLD STOCK) OR AS UOS (USED OLD STOCK), AT LEAST AT REASONABLE PRICES. ALTHOUGH NOT VERIFIED BY THE AUTHOR OF THIS DOCUMENT, PURPORTEDLY THE 12AU7 CAN BE REPLACED IN THIS VTVM BY THE FOLLOWING TUBE MODELS WITHOUT CONCERN FOR FUNCTIONALITY:

12AT7
12AV7
12AZ7

AT THE TIME OF THIS DOCUMENT'S CREATION, THE 6AL5 TWIN DIODE TUBE (V1) IS STILL FAIRLY PLENTIFUL AS NOS AND UOS AT REASONABLE PRICES. NOTE THAT SOME SOURCES CLAIM THAT THE 6AL5 CAN SIMPLY BE REPLACED WITH A COUPLE OF SOLID-STATE DIODES, e.g; 1N4005, 1N4006, 1N4007, HOWEVER THERE IS MUCH ADVICE AROUND THAT DOING THIS WILL COMPROMISE THE ACCURACY OF THE AC VOLTAGE READINGS ON THE VTVM DUE TO REVERSED NON-LINEAR RESPONSES BETWEEN THE TUBE AND THE SOLID-STATE DEVICES.

REVISION A 1-12-2023

HEATHKIT IM-18 VTVM
(ALSO FOR SIMILAR MODELS)
SCHEMATIC DIAGRAM