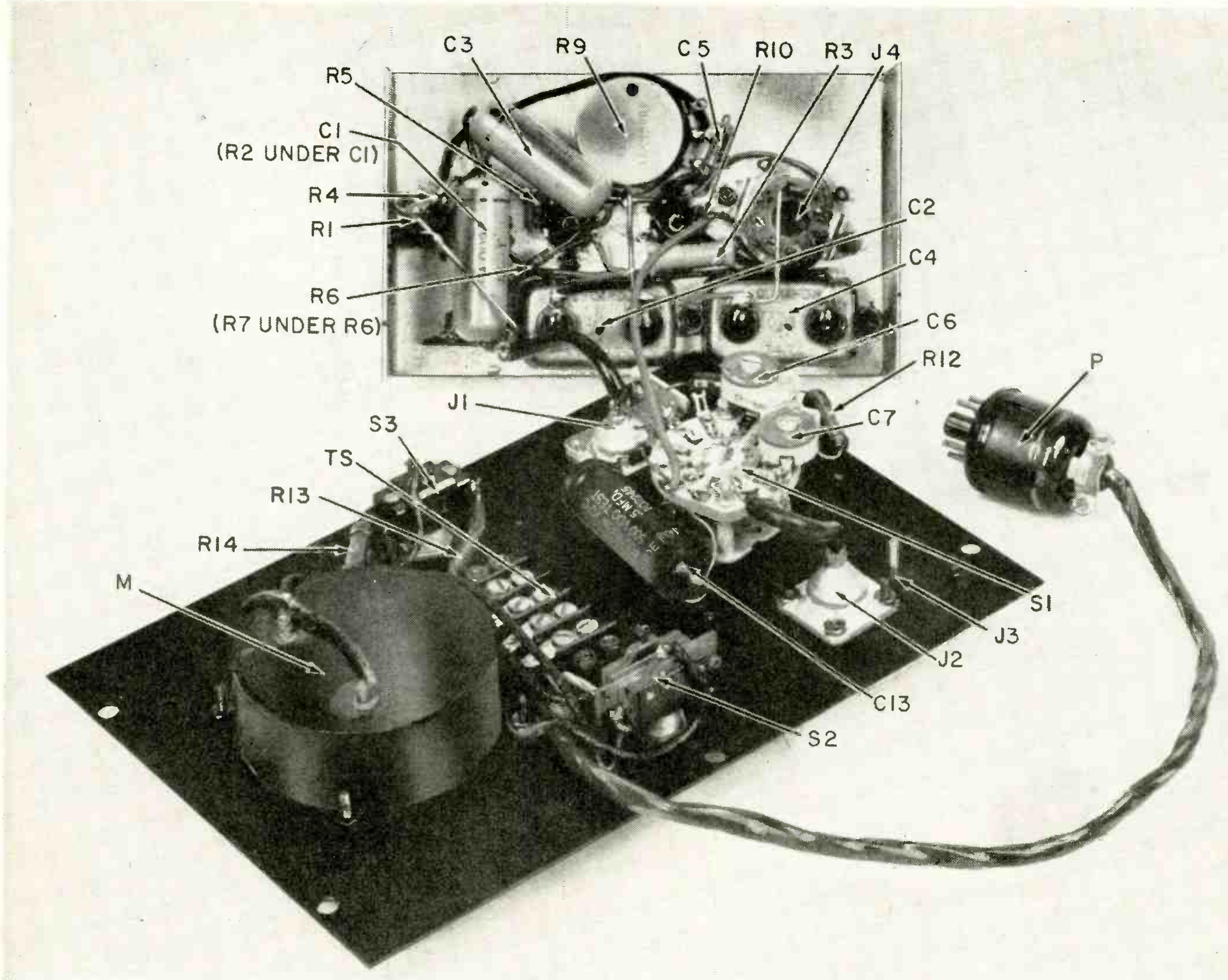
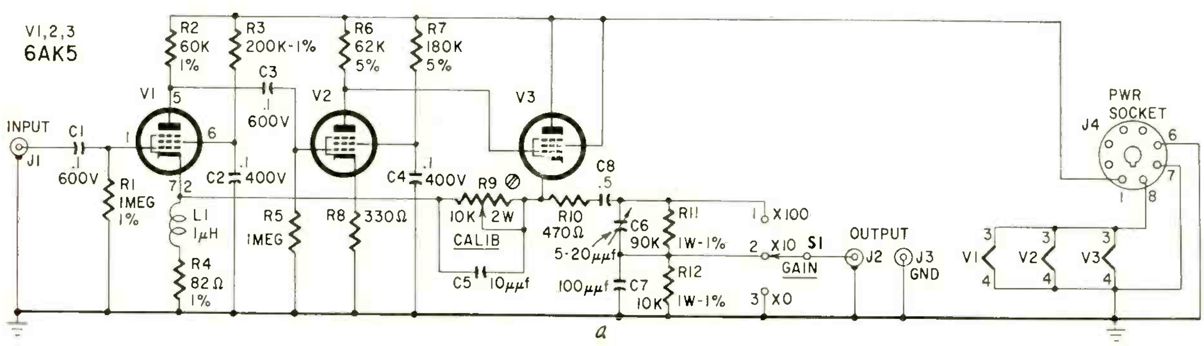


Disassembled unit shows construction details.



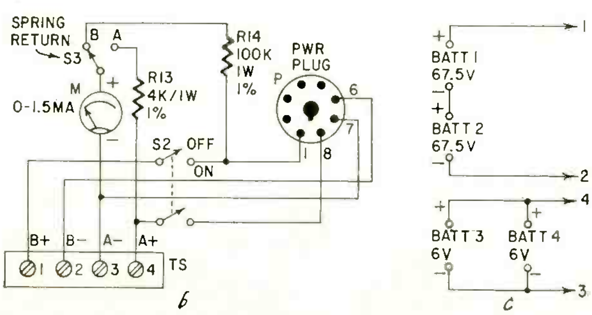
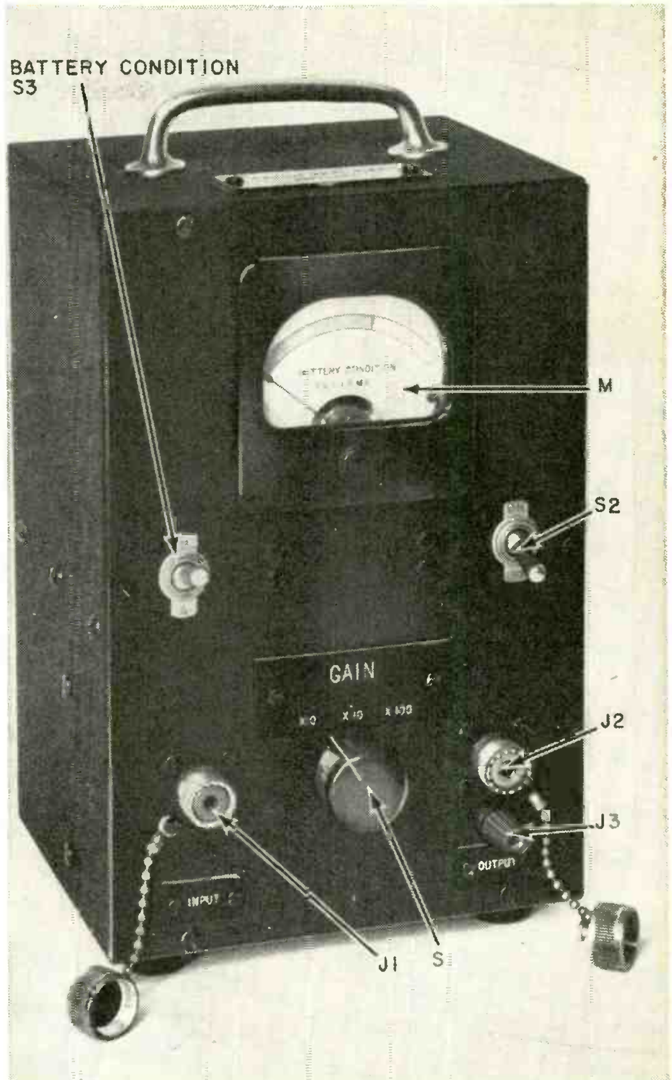


Fig. 1—a—Circuit of the 3-tube amplifier; b—metered battery power supply; c—battery arrangement. Batteries connect to corresponding terminals of TS.

measure MILLIVOLTS with a DECADE AMPLIFIER



Combined with scope or vtvm, an instrument with a 1% accuracy for making really low-level measurements.

By C. L. HENRY

R1—1 megohm, 1%
R2—60,000 ohms, 1%
R3—200,000 ohms, 1%
R4—82 ohms, 1%
R5—1 megohm, 10%
R6—62,000 ohms, 5%
R7—180,000 ohms, 5%
R8—330 ohms, 10%
R9—pot, 10,000 ohms, 2 watts
R10—470 ohms, 10%
R11—90,000 ohms, 1 watt, 1%
R12—10,000 ohms, 1 watt, 1%
R13—4,000 ohms, 1 watt, 1%
R14—100,000 ohms, 1 watt, 1%
All resistors ½ watt unless noted
C1, 3—0.1 μf, 600 volts, paper
C2, 4—0.1 μf, 400 volts, surplus oil filled
(use 0.1 μf, 600 volts, paper)
C5—10 μμf, ceramic
C6—5-20 μμf trimmer
C7—100 μμf, Mica
C8—0.5 μf, 600 volts, paper
BATT1, 2—67.5 volts (Eveready No. 467 or equivalent)
BATT3, 4—6 volts (Burgess F4H or equivalent)
J1, 2—coaxial connectors
J3—binding post
J4—octal socket
M—0-1.5 ma
P—octal plug
S1—single-pole 3-position ceramic rotary switch
S2—dpst toggle
S3—spdt, spring-return toggle
TS—4-terminal barrier type terminal strip
V1, 2, 3—6AK5
Sockets, 7-pin miniature (3)
Case, 9 x 6 x 5 inches (Budd CC-1095 or equivalent)

SERVICE technicians, laboratory workers, experimenters and amateurs would often like to measure voltages smaller than 0.1. However, millivolt vtvm's are costly and very few shops have them.

We often get around the lack of a millivoltmeter by using an oscilloscope. But in many circuits, even a low-capacitance probe loads the tiny signal and there isn't enough left to give a readable trace. For example, when troubleshooting the front end of a TV receiver, the signal is often too small to produce a scope trace.

The perfect solution to these problems is the amplifier described in this article. It has a gain of 100 from 10 cycles to 500 kc within 1%, and 5 cycles to 1 mc within 2%. Connect a vtvm to the amplifier's output and the meter's 0- to 1-volt scale now reads 0- to 10-mv. When connected to the input of a scope with a 50-mv-per-inch deflection sensitivity, the scope's total sensitivity is boosted to 500 μv per inch.

The amplifier circuit is uncomplicated and straightforward. (See Fig. 1). Three 6AK5's are used, powered by a self-contained battery or an ac supply. The amplifier is a feedback type. V1 is the controlled stage, V2 gives most of the amplification, and V3 controls the first stage. This is done with a wide-band feedback network from V3's cathode to V1's cathode resistor. The output thereby varies the bias on the input stage and tends to cancel any overall gain variations. Feedback potentiometer R9 adjusts the total gain to exactly 100.

The amplifier's rise time is 0.3 μsec, and the tilt on a 0.1-second pulse is 2%. Like all feedback amplifiers, frequency response cuts off very sharply at the higher frequencies. The cutoff frequency of this amplifier is 1.5 mc. Input impedance is 1 megohm shunted by 10 μμf, and output impedance is 1,000 ohms shunted by 20 μμf on the ×100 position. A simple step attenuator at the output gives a ×10 position, which is sometimes useful. A ×0 position is also included. It is used to check the zero adjustment on the vtvm used with the amplifier. This ×0 position shorts the amplifier's output jack.

When building the amplifier, I decided noise output should be as low as possible so I use deposited-carbon resistors for R1, R2, R3 and R4. Most noise in this type of battery-operated circuit can be traced to current flow in a standard carbon resistor. The amplifier's noise output with its input shorted is 300 μv. This is equivalent to an input noise of 3 μv. Such a noise level is so low that measurements in the 30- to 1,000-μv range can be easily made.

Capacitors C5 and C7 are trimmers in my unit. However, the listed values were established as optimum and fixed units as shown in the parts list can be used.

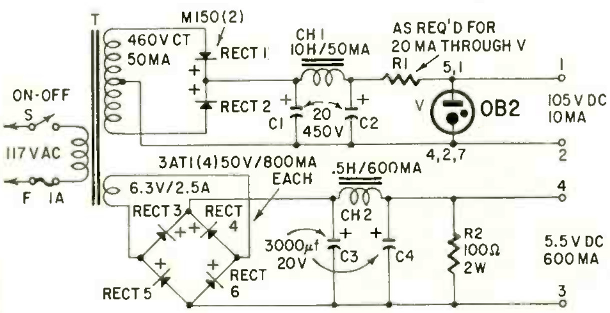
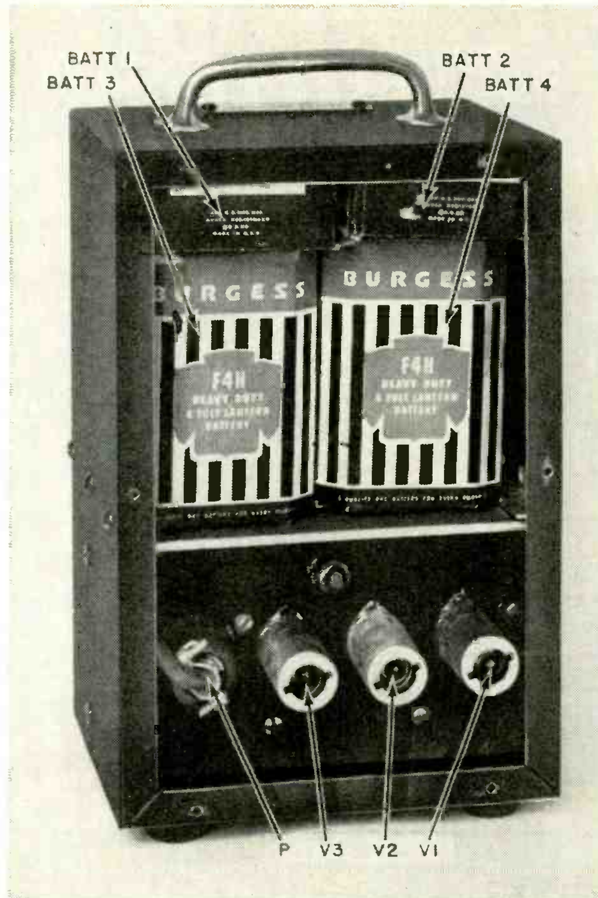


Fig. 2—Ac supply designed for use with the decade amplifier.

With the back removed, batteries and tubes are exposed.



R1—resistance required for 20 ma through V with load disconnected
R2—100 ohms, 2 watts, carbon
C1, 2—20 μf, 450 volts, electrolytic
C3, 4—3000 μf, 20 volts, electrolytic
CH1—10 henries, 50 ma
CH2—0.5 henry, 600 ma
F—fuse, 1 amp
RECT1, 2—M150 (Sarkes-Tarzian)
RECT3, 4, 5, 6—3AT1 (International Rectifier)
S—spst toggle
T—power transformer: primary 117 volts; secondary: 460 volts ct, 50 ma; 6.3 volts, 2.5 amps (Stancor PC-8418 or equivalent)
V—OB2
Chassis to suit
Miscellaneous hardware

The amplifier input overloads at 0.25 volt, which is equivalent to a 25-volt output. A power socket is included for applications where an external power supply might be desirable. I recommend using an ac supply (Fig. 2) only where the amplifier is operated continuously for long periods of time. In ordinary measurement work, one set of batteries will last several months and the hum problems of an ac supply are avoided.

(For your protection it would be wise to use a jack from the power supply and a plug on the chassis. This avoids the possibility of getting a jolt from a hot plug or accidentally shorting a battery. *—Editor)*

The meter on the instrument's face shows the battery condition and is not connected to the amplifier. It is simply calibrated on a good–bad basis. First I found the point at which a further decrease in battery voltage affects the amplifier's calibration. From this point down, the scale is painted red. S3 is a spring-loaded toggle which normally connects the meter to B-battery. When S3 is held in its other position, it is connected to the A-battery.

How to use it

Applications for the amplifier are too numerous to mention fully. Possibly the first that comes to mind is voltage measurements. With a conventional vtvm monitoring the amplifier output, voltages from 1 mv to 0.1 volt can be measured accurately. The amplifier lets your vtvm function as a millivoltmeter and it is limited only by the frequency response of the vtvm or the amplifier, whichever is less. However, if you have a millivoltmeter, adding the amplifier lets you measure voltages from 10 μv to 1 mv. But remember, amplifier noise is equivalent to a 3-μv input.

When used with a scope, the amplifier has several advantages. It is useful for measuring signals that are normally too small to produce an adequate indication on the scope and for amplifying the output of a crystal probe. Another application worth noting is the use of the amplifier with a low-capacitance probe. Probes with a 1-μμf input capacitance and an attenuation of ×100 can be connected to the amplifier's input. The output is fed to a scope and the unknown signal is viewed at its normal value, with practically no circuit loading. This is very important in critical circuits, since even a slight loading distorts the true waveform. Since the amplifier's gain is very stable and accurate, the unit can be used to measure the attenuation of pads and networks.

Construction is simple and, after using it in my shop for about two years I find more uses for this decade amplifier every day. Built as a general-purpose amplifier for the shop, it will more than repay your effort. END

BENCH TESTED

Connect to a vtvm and you have a meter that will read 0—10 mv on what used to be a 0—1-volt range. Hook the decade amplifier to a scope (50-mv-per-inch deflection sensitivity) and get 500-μv-per-inch deflection sensitivity.

This decade amplifier was tested by a member of the staff of RADIO-ELECTRONICS. His report states that the unit operates as described by the author. The amplifier was tested by feeding it signals at various frequencies. Their amplitudes were measured at the amplifier's input and output, both with a scope and a vtvm. Only minor slips off exact ×10 and ×100 multiplication were noted; both these were within the tolerances of the test equipment used. Frequency response seems slightly different from that stated by the author—instead of 5 cycles to 1 mc within 2% it is 7 cycles to 1.4 mc. Noise level is also somewhat better than stated—the author says 300 μv, the tests show 275 μv.