Differential Amplifier
for use with
Attenuated Probes

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December 17, 1964

PLP 43

Copy No. 36

University of Wisconsin
Thermonuclear
Plasma Studies

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Introduction:

When a floating double probe is used to measure the potential gradient in a pulsed plasma discharge, the high frequency response is limited by the plasma impedance and probe capacitance. With the usual type double probe, with grounded shields, the capacitance seen by the plasma between tips is $\sim$50 pf and the capacitance from each tip to ground is $\sim$100 pf. With a 10^5 ohm plasma, this limits the response time to $\sim$10 μsec. The probe capacitance can be considerably reduced in two ways: (1) The signal from each tip can be used to drive a cathode follower, the output of which drives the shield surrounding its lead. This reduces the capacitance by about a factor of ten. (2) An attenuator may be placed at the very end of the probe. If the attenuation factor is 100, the capacitance could, in principle, be reduced by a factor of 100; however, it was found necessary to add a distributed capacitance between the probe resistor and the shield so the probe capacitance was only reduced by about a factor of ten. Using the probe shown in Fig. 1 and the cathode follower amplifier circuit shown in Fig. 3, the capacitance between tips and the capacitance from each tip to ground were reduced to $\sim$1 pf. The resistive component of impedance between the tips is 2 megohms and from each tip to ground is 1 megohm. The response time is no longer limited by the probe capacitance but by the high frequency cutoff of the differential amplifier.

Amplifier Characteristics:

The amplifier itself has a capacitance of about 10 pf between inputs and 10 pf from each input to ground. At present there is a parallel 12K resistor from each input to ground. By removing these resistors, the input impedance of the amplifier is $\sim$ 5 megohms. The amplifier is linear over the range -25 to +25 volts, which corresponds to 2.5 KV when used with attenuated probes.

With 6 feet of RG 58 A/U between the output and the scope, no termination is necessary, and the response time is 0.2 μsec. The amplifier will drive a cable into the screen room, but in this case it is necessary to use a 50 Ω termination and the response time is slowed to 0.5 μsec.

There is some variation in gain for different amplifiers and probes. With an attenuated probe, the differential gain is $(1.0 \pm 0.2) \times 10^{-2}$ without termination and $(0.5 \pm 0.1) \times 10^{-2}$ with a 50 Ω termination. The common mode gain is $(1.2 \pm 0.2) \times 10^{-2}$. Each amplifier/probe combination should be calibrated on the bench before being put into use. The circuit for doing this is shown in Fig. 2.

Balancing Procedure:

Since the common mode potential is often an order of magnitude larger than the difference potential, the amplifiers must be carefully balanced to maximize the common mode rejection ratio. This is done as follows: Using the circuit of Fig. 2, a 100 volt common mode signal from the scope calibrator is applied at V_{cm}. It is not necessary to have a difference signal at ΔV. The scope sweep is triggered from the calibrator and the sweep speed is set at 0.5 msec/cm. The differential output is displayed on an 0.01 volt/cm. scale. The potentiometer and capacitor trimmer in the amplifier are then adjusted to minimize the signal output. The common mode rejection ratio should be about 100:1 when balanced. Each amplifier should be balanced on the bench with one particular probe and input polarity and the potentiometer locked by tightening the lock nut on its shaft.

Battery Life:

The biggest drawback of this amplifier is the frequency with which the filament battery must be replaced. A Burgess F4BP is used to supply the 6 volts @ 250 ma required by the filaments. In Fig. 4, the differential gain of the amplifier is plotted as a function of battery voltage for each of the three batteries in the amplifier. The time markers represent hours of intermittent use (4 hours on continuously per day). The lifetime is considerably longer for intermittent than for continuous use. The figure shows that the filament battery will be replaced many times before the others begin to weaken.

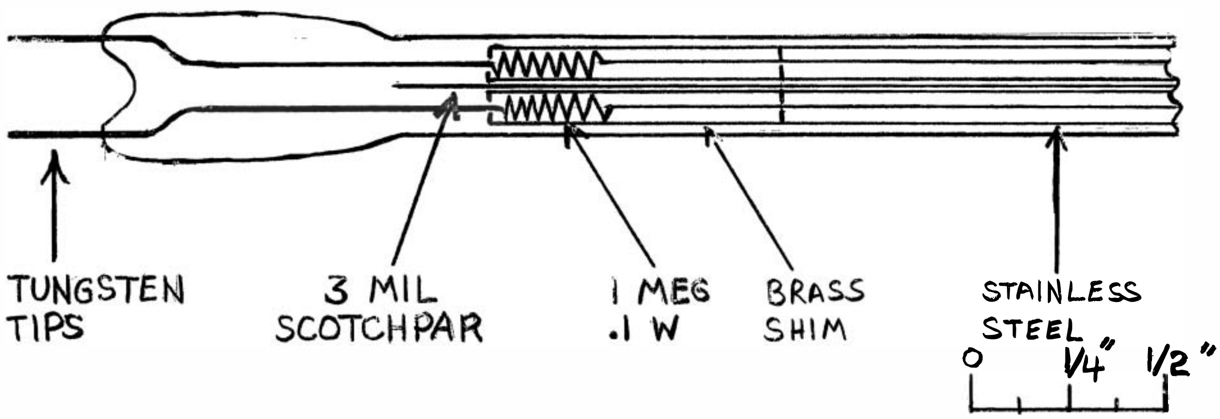


FIG 1 ATTENUATED PROBE

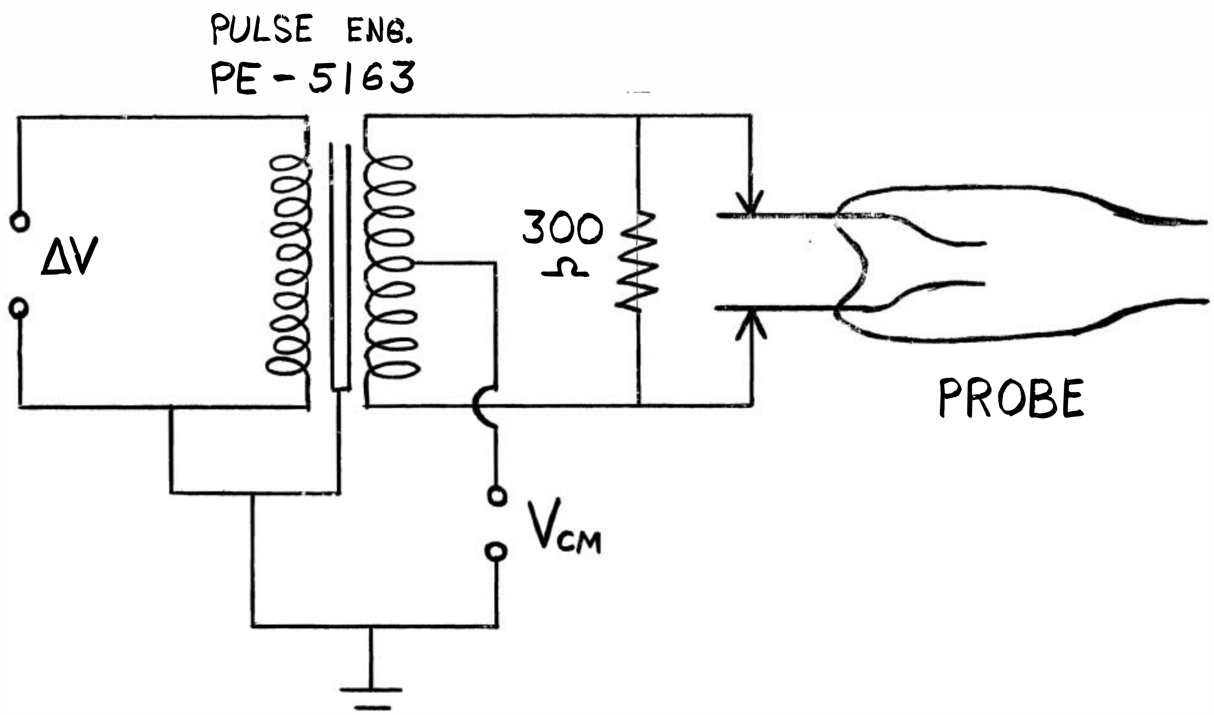


FIG 2 BALANCING CIRCUIT

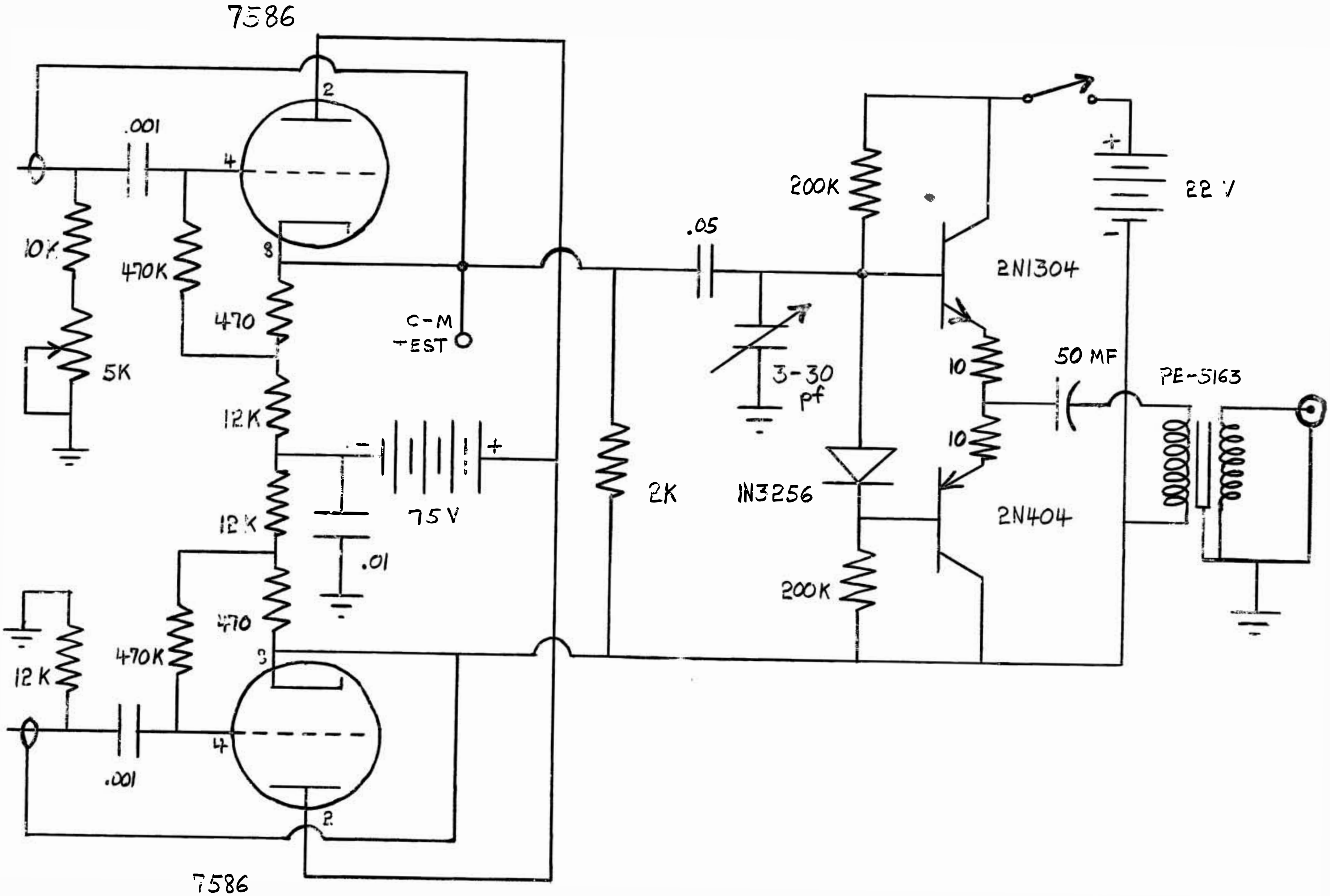
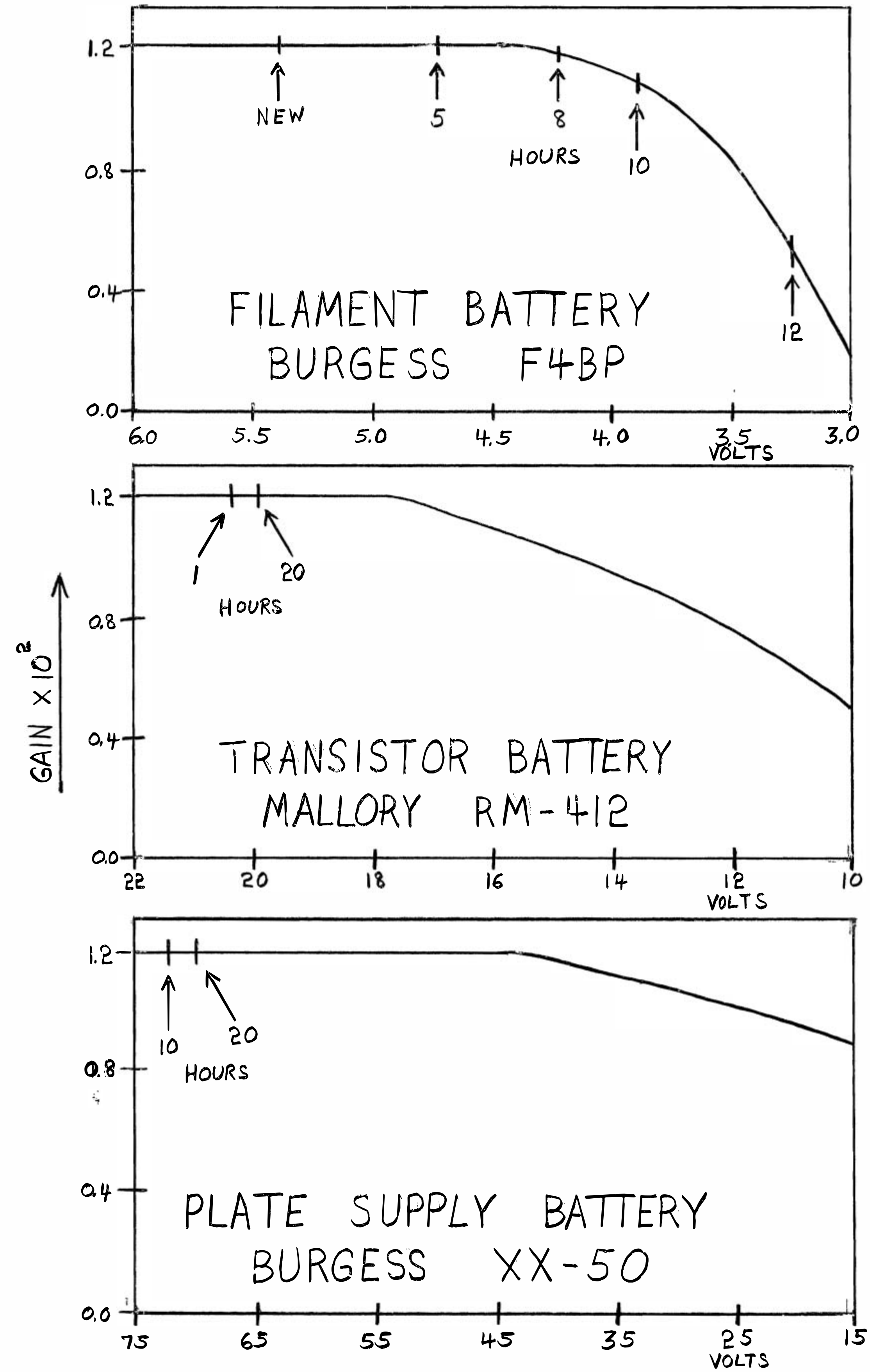


FIG 3 DIFFERENTIAL AMPLIFIER



BATTERY DECAY CURVES

FIG 4