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# SQUARE LAW DETECTOR FOR THE 6 CM TUNNEL DIODE AMPLIFIER

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## Object

This report will describe procedures and equipment used to select a square law detector-video amplifier circuit to be used with a 6 cm tunnel diode radiometer system.

## Discussion

In a power measuring device, such as a radiometer, it is desirable to record the output signal directly as a function of input power (or change in input power, $\Delta P$). This need can only be met by a device commonly called a "square law detector", where

$$V_{out} = CP_{in}^{1/\alpha} .$$

For a square law device $\alpha = 1$; for a linear device $\alpha = 2$.

After consideration, it was decided to use the Aertech tunnel diode detector units. These units (similar to backward diode detectors) seemed to possess better figures of merit at 6 cm than conventional cat whisker type detectors. Two units were provided by Aertech. Aertech also built the tunnel diode amplifier. The sensitivity of the tunnel diode detectors with relatively low video impedance loads is about an order of magnitude greater than the conventional diodes. Since the tunnel diode is a low power device, a low level detector is mandatory. The equivalent noise temperature of the detector and video amplifier circuit are of interest because of the low output power level (-25, -30 dBm) of the amplifier. Measurements were made to insure that the noise from the detector-video amplifier circuit would not mask the signal. The rule of thumb used was

$$\frac{E_{dc}\left(\sqrt{\frac{2B_v}{B_{rf}}}\right)}{E_{ac}} \geq 10$$

where $E_{dc}$ is the detector output voltage at a given input power (in this case, input power was -25 dBm, the expected quiescent operating point)

$B_v$ is the video bandwidth

$B_{rf}$ is the radio frequency bandwidth

$E_{ac}$ is the RMS noise voltage from detector and video amplifier.

It is interesting to note that in each case the $E_{ac}$ was almost entirely a function of the video amplifier, indicating a need for improvement in low noise video amplifier design. However, since the Dicke switch rate is usually at a low frequency, it will be difficult to eliminate the semiconductor 1/f noise, probably the greatest contributor to video amplifier noise figure.

The video amplifier circuit is shown in Figure 2. Circuit values will vary depending on desired gain, bandwidth and detector load. The bandwidth used in the tunnel diode systems was 1000 Hz (about 1500 Hz noise bandwidth). Gain for the first video stage was adjusted to 100. RMS noise voltage referred to the input was nominally 1 $\mu$V. Different operational amplifiers were tried, but the model 1507 Burr-Brown units were best. All possessed about the same noise levels.

## Procedure

1) The equipment was set up as shown in Figure 1.
2) The power to the detector was adjusted to a nominal -30 dBm by means of the variable attenuator.
3) The power to the detector was varied in 1 dB steps over the expected dynamic range. The 1 DB attenuation steps were controlled by the Weinschel precision attenuation equipment.
4) DC output voltage from the detector was monitored with the John Fluke differential voltmeter.
5) Steps 3 and 4 were repeated for different values of $R_L$ (video load resistance).

## Summary

Two detectors were used in this test, both Aertech tunnel diode type. Serial number 1082 was a high impedance unit (400 Ω) and serial number 1083 was a low impedance (200 Ω) unit. Twenty-four curves were plotted, 12 for each diode. Only a representative number of curves are shown in this report. For diode number 1082, the best $R_L$ was 1000 Ω. Over a dynamic range of about 10 dB (from -32 to -22 dBm) the measured deviation from square law was less than 1 percent (see curve 1C). For diode number 1083, an $R_L$ of 200 Ω gave a deviation over the same range less than 1 percent. Curves for values of $R_L$ near the optimum values are shown. At approximately -22 dBm both detectors began saturating, so these units must only be used for low level detection purposes. The voltage sensitivity (K) for the diodes is as follows:

No. 1082 $R_L = 1000\ \Omega$ $K \cong 2000$ mv/mw

No. 1083 $R_L = 200\ \Omega$ $K \cong 700$ mv/mw.

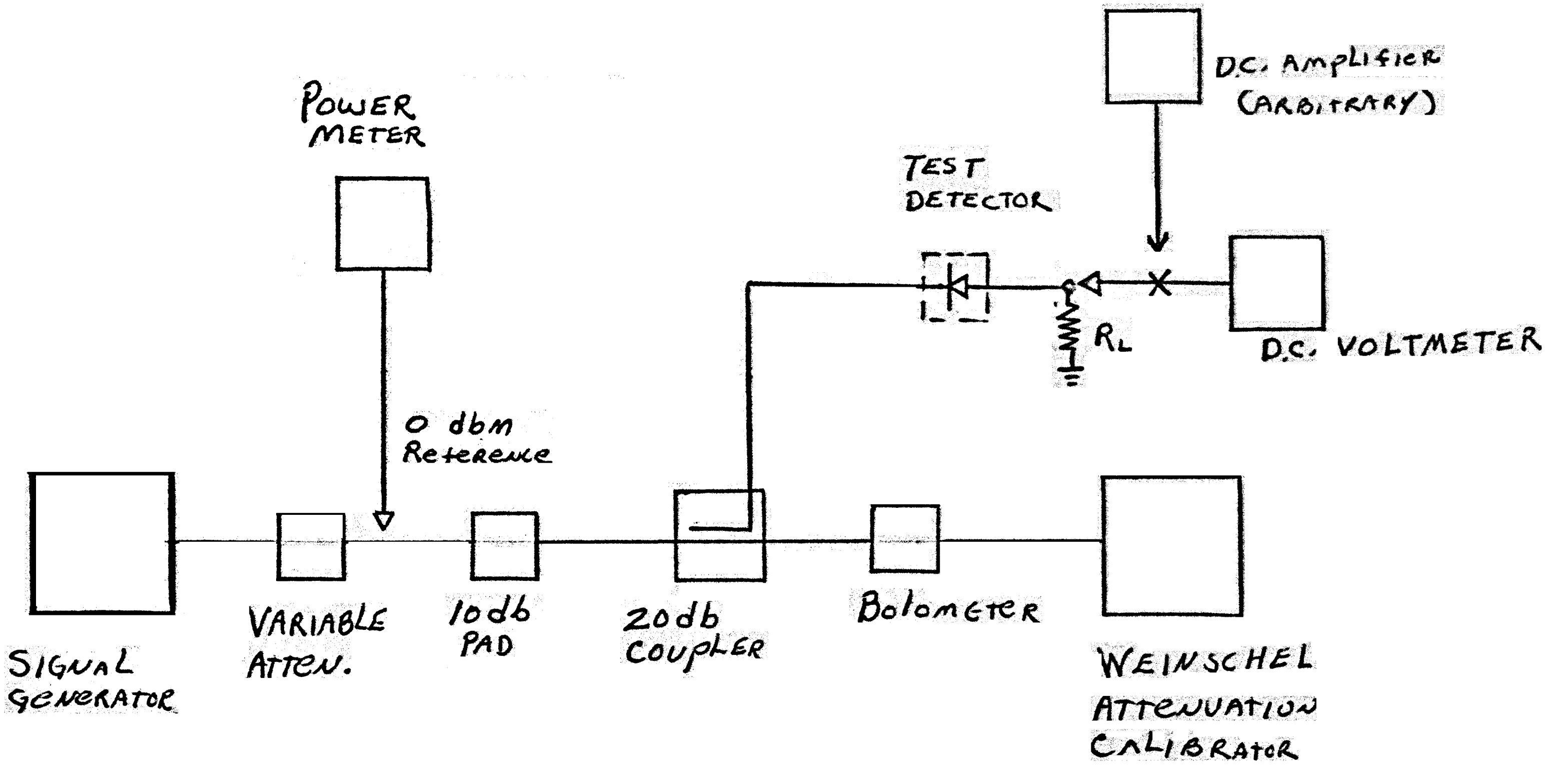
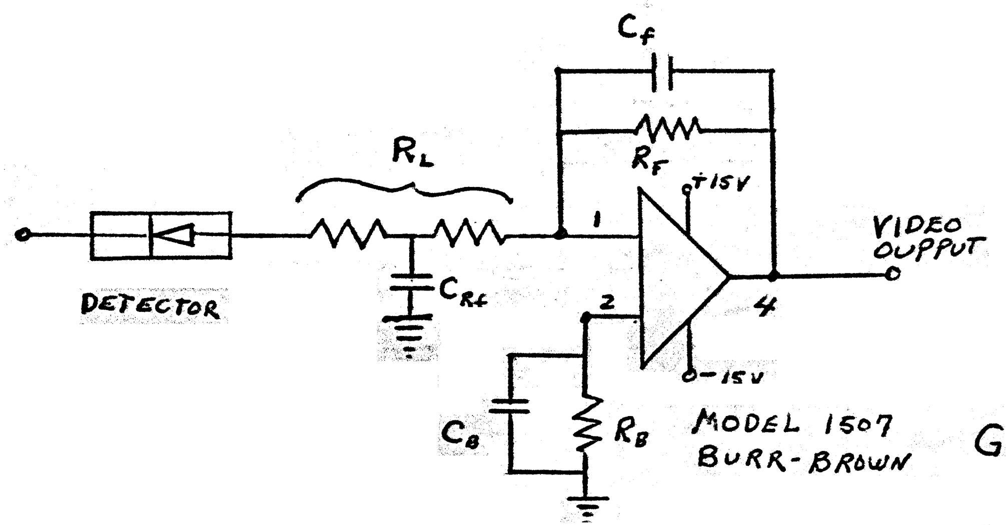


FIG. 1

TEST SET-UP



$$G = \frac{R_F}{R_L}$$

$$R_B = \frac{R_f R_L}{R_f + R_L} \cong R_L, \quad G \geq 10$$

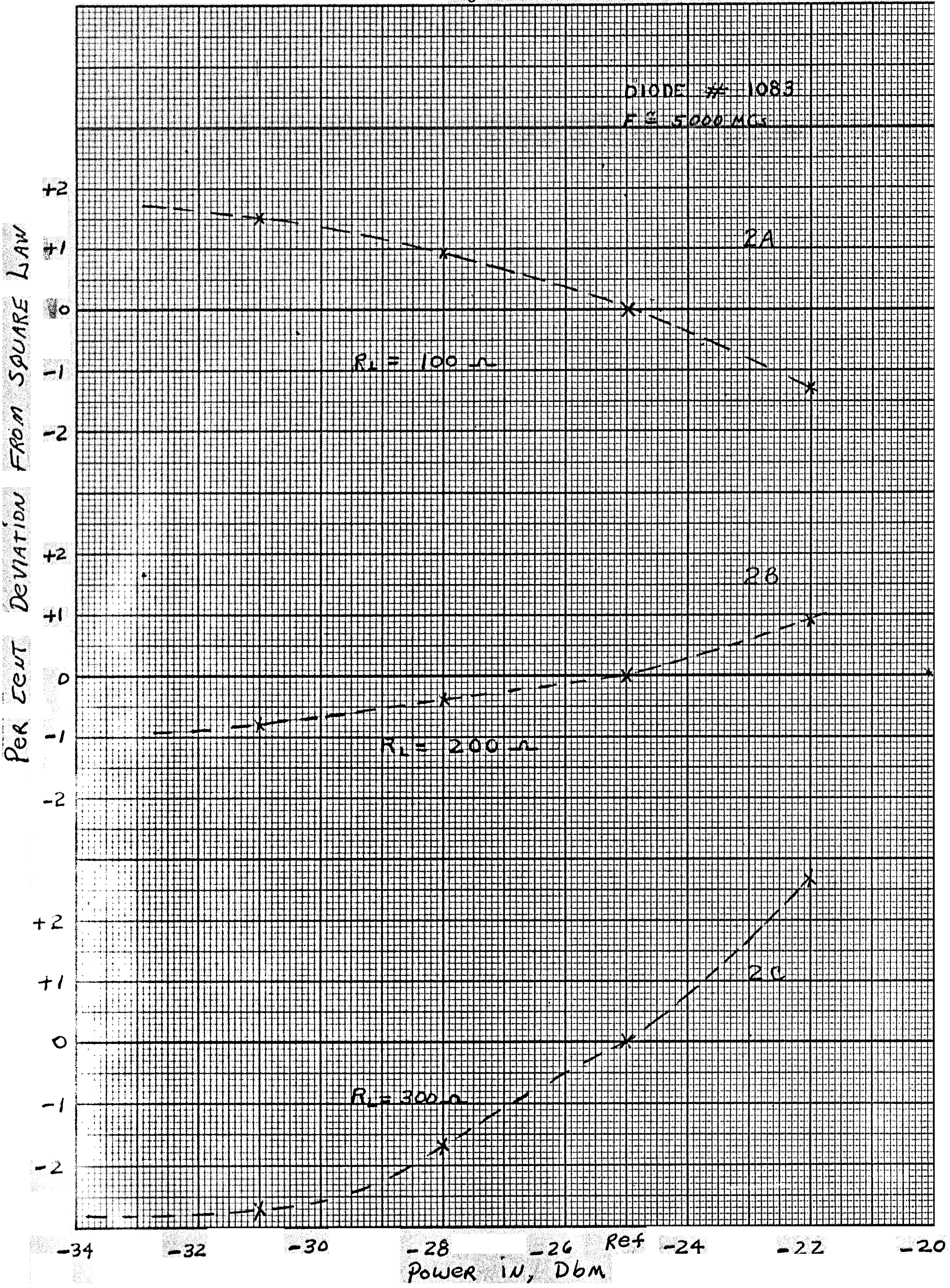
$$C_f = \frac{1}{2\pi f_c R_f}$$

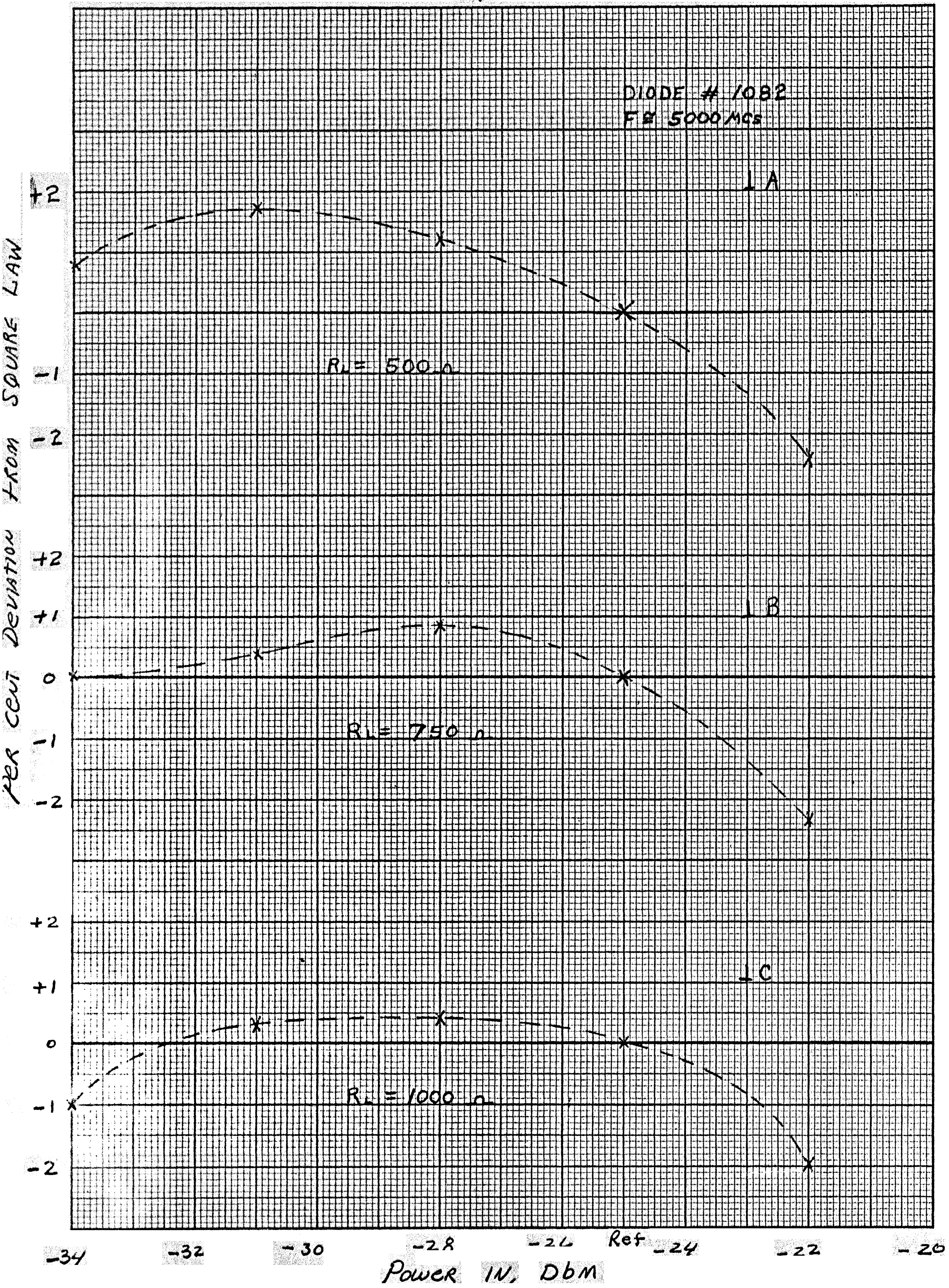
$$C_B \cong C_f$$

$C_{Rf}$, R.F. by PASS.

FIG. 2

VIDEO AMPlifier CIRCUIT


DIODE # 1083
F ≅ 5000 MCs
2A
R_L = 100 Ω
2B
R_L = 200 Ω
2C
R_L = 300 Ω
PER CENT DEVIATION FROM SQUARE LAW
+2
+1
0
-1
-2
+2
+1
0
-1
-2
+2
+1
0
-1
-2
-34
-32
-30
-28
-26
Ref
-24
-22
-20
POWER IN, DBM


DIODE # 1082
F ≅ 5000 Mcs
A
B
C
$R_L = 500\ \Omega$
$R_L = 750\ \Omega$
$R_L = 1000\ \Omega$
PER CENT DEVIATION FROM SQUARE LAW
+2
-1
-2
+2
+1
0
-1
-2
+2
+1
0
-1
-2
-34
-32
-30
-28
-26
Ref
-24
-22
-20
POWER IN, DbM

## Equipment Used

1) Signal generator, Hewlett Packard, Model 684C
2) Attenuation calibrator, Weinschel, Model BA-5
3) Bolometer, Narda, Model N-603
4) Attenuator, variable, Narda, Model 793-FM
5) Directional coupler, Narda, Model 3044-20
6) Differential voltmeter, John Fluke, Model 803B
7) Amplifier, DC, Hewlett Packard, Model 2461A
8) Power meter, Hewlett Packard, Model 431B
9) Attenuator, fixed 10 dB, Weinschel