LOW NOISE 11 GC PARAMETRIC AMPLIFIER USING REFRIGERATED SILVER BONDED GERMANIUM DIODE

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The authors had previously reported that the silver bonded germanium diode was suitable for a parametric amplifier and we have succeeded in parametric amplification at 11GC using this type of diode, and obtained a noise figure of 3.5 dB at room temperature.[1), 2)]

Recently the authors have experimented with an 11GC parametric amplifier using a refrigerated silver bonded diode and obtained very low noise characteristics. The diode used in our experiments was a silver bonded diode of the type GSBI, and is made through the following process. After a silver whisker containing a small amount of gallium has been brought into point contact with an N-type germanium wafer, an electrical forming process is performed by applying the discharging current of a capacitor to it. The case holder of the diode is a glass sealed type as that of a 1N263. The main features of the diode are; the junction capacitance at zero bias is less than 0.3 pF, the breakdown voltage is 6V and the cutoff frequency at breakdown voltage is higher than 120GC.

The impedance characteristics of the diode were measured using the automatic impedance display unit as shown in Fig. 1, which was developed by Mr. Tsuchiya in our laboratory.[3)] The important part of this unit is the

1) S. Kita and F. Obata, Proc. IRE. Vol 48, p 1651, Sep. 1960.

2) S. Kita et al., Trans IRE, ED-8, p 105, March 1961.

3) S. Tsuchiya, Electronics, Vol 34, p 80, July 21, 1961.

waveguide coupler. It is called a phase directional coupler and consists of two rectangular waveguides that intersect at right angles with their broad wall in close contact. There is a coupling slit at the common wall. This slit can be rotated about its center at high speed by a synchronous motor. The reflected wave from the diode under test is detected by a crystal diode in a secondary waveguide. This detected voltage is linearly proportional to the magnitude and the phase of the reflected wave, and this voltage is amplified and applied to a cathode ray tube on whose surface a Smith chart is printed. The impedance of the diode being tested can be read from the position of the bright spot on the cathode ray tube. This method of impedance measurement is very easy compared to the conventional method, for instance, the slotted line method.

The impedance characteristics of the diode at room temperature and at 110°K, are shown in Fig. 2. The former is shown by a solid line, and the latter by a dotted line. At room temperature, the diode was matched at zero bias, and the impedance variation of the diode with bias voltage was measured at 11GC. The Q's of the diode at zero bias voltage and -5V were 8 and 17, respectively, at 11GC from the curves in Fig. 2. The diode was refrigerated using heat conduction in a copper rod which was immersed in liquid nitrogen. But the diode could not be refrigerated to a temperature below 110°K, as the heat conduction of the waveguide was large. The impedance locus approximately coincides with $R/Ro=0.85$ circle at 110°K. This means that the series resistance of the diode decreased to 85 per cent of its value at room temperature. The junction capacitance at zero bias also decreased to 75 per cent. And so the quality factor at zero bias increased by about 50 per cent from the value at room temperature. The temperature dependence of the series resistance (Rs), the junction capacitance at zero bias (Co), and the quality factor at zero bias (Qo) are shown in Fig. 3. By refrigeration, Rs and Co decreased and Qo increased from the value at room temperature. The authors believe that such characteristics are due mainly to the temperature dependence of the resistivity of germanium.

By refrigeration, the contact potential of the diode increases. Therefore, the amplitude of the applied pump voltage in the forward bias region of the diode can be large. That means the factor of capacitance change γ and the dynamic quality factor $\tilde{Q}$ of the diode become large as shown in Fig. 4. By refrigeration the $\tilde{Q}$ increased to 3.0 from 2.4.

The reverse current of a parametric diode is an important factor for low noise parametric amplification. The voltage-current characteristics of the silver bonded diode are shown in Fig. 5. The reverse current of the diode is about 1μA at -1V at room temperature. The current decreases about 0.01μA at 140°K and this value is comparable to the value of the diffused silicon diode.

An 11GC parametric amplifier was built using the silver bonded diode. The signal frequency was 11.6GC and the pump frequency was 23.2GC. The measured noise figures (degenerated type) as a function of the diode temperature are shown in Fig. 6. The noise figure was lowered to 1.5 dB when the diode was refrigerated to 140°K. The pump power necessary to maintain the gain at 12 dB was about 70 mW at room temperature and decreased to 30 mW at 140°K.

Better characteristics could be expected by an improvement of the refrigerating devices.

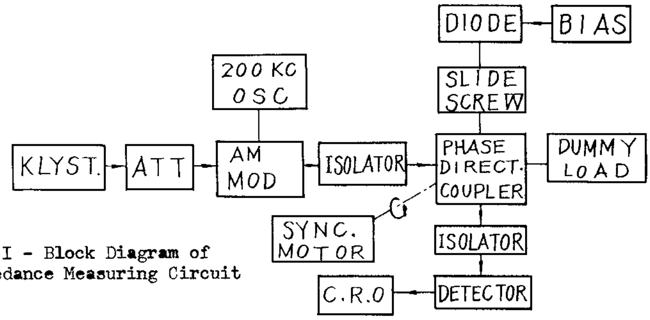

Fig. I - Block Diagram of Impedance Measuring Circuit

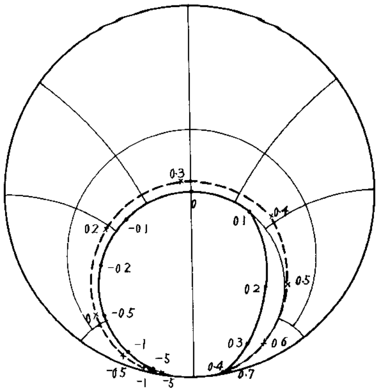

Fig. 2 - Impedance Variation of Silver Bonded Diode With Bias Voltage

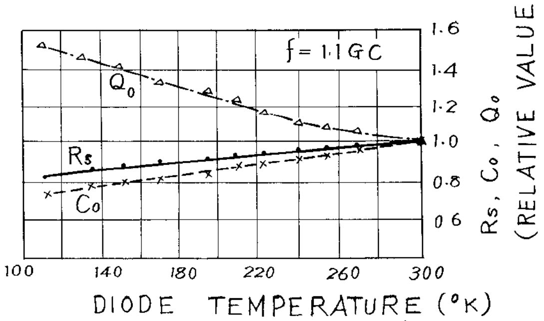

Fig. 3 - Variation of Diode Characteristics With Diode Temperature

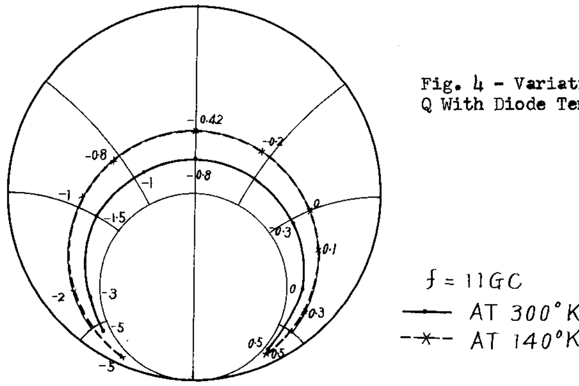

Fig. 4 - Variation of Q With Diode Temperature

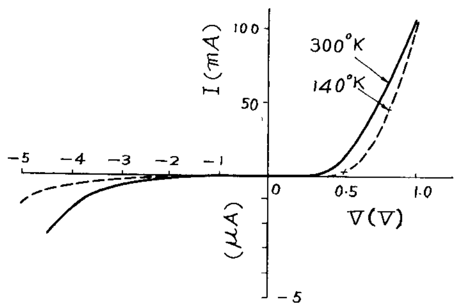

Fig. 5 - Voltage-Current Characteristics of Silver Bonded Diode

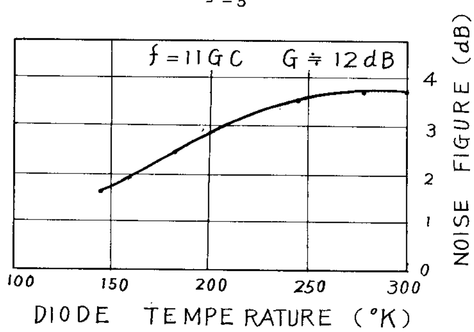

Fig. 6 - Variation of Noise Figure With Diode Temperature

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