VI-6 FREQUENCY MODULATION OF AVALANCHE TRANSIT TIME OSCILLATORS

J.W. Amoss and K.E. Gsteiger

Sperry Microwave Electronics Company

Electronic tuning of avalanche transit time oscillators has been treated explicitly by Gilden and Hines[1] and both theoretically and experimentally by others[2,3].

Since moderate output power from these devices is now being realized, the ease of electronic tunability suggests their use as transmitters in miniature solid state altimeters and low power communication systems. This paper presents experimental data taken to determine the frequency modulation characteristics of avalanche transit time oscillators.

The active element is a diffused silicon mesa diode, similar to the one described by Misawa[4]. The junction is formed by diffusing boron 2.4 microns deep in epitaxial silicon. The substrate is arsenic doped to a resistivity of .008 ohm cm and the epitaxial layer has a thickness of 7 microns with a nominal resistivity of 1 ohm cm. It is known that a high boron concentration in silicon leads to an excessive number of lattice defects, resulting in a high density of microplasmas. Therefore, a surface concentration lower than customary for the fabrication of varactor diodes was chosen. The uniformity of the junction was further improved by applying a multiple predeposition post-diffusion technique. The resulting impurity profile is represented in Figure 1. The junctions are of a nearly abrupt type with a sharp breakdown of 80 to 85 volts. Using conventional contacting and masking techniques, mesa diodes with a junction diameter of approximately 100 microns are formed and after dicing, individual diodes are mounted in a microwave pill package with a case capacitance of ~.25 $\mu\mu$f and a lead inductance of ~.3 nhy. The diodes exhibit typically a junction capacitance of .4 ~.5 $\mu\mu$f at breakdown.

The basic oscillator consists of the diode mounted in the re-entrant portion of a radial mode cavity. It is machined of copper to improve heat dissipation, has an internal volume of less than .02 in.^{3}, and employs loop coupling. Figure 2 shows a photograph of an oscillator with the external dimensions of a DO-5 power diode header. The cavity alone has a calculated resonant frequency of 17 GHz and an effective capacitance of about .15 $\mu\mu$f. Figure 3 shows oscillating frequency vs. diode junction capacitance. Maximum cw output power measured for oscillators operated at an ambient temperature of 25 C was 100 m watts at current levels of 40 ma. The microwave to dc efficiency was in this case more than 3%. In typical production lots, 75% of the diodes gave between 40 and 60 m watts of microwave power at current levels of 30 ma.

The oscillator was operated over an ambient temperature range from -70^{o}C to 100^{o}C with a frequency drift of 2.5×10^{-5} parts/^{o}C.

A modulating voltage applied in series with the dc bias was used to obtain frequency modulation. Figure 4 shows peak-to-peak frequency deviation of a typical oscillator as a function of applied rms voltage. These data were taken by observing the sideband nulls as the amplitude of the modulating signal was varied.

The plot of Figure 4 is linear to within measurement accuracy, which is approximately $\pm 2\%$. Figure 5 shows photographs of the spectrum for various modulation indices. The symmetry of these displays, the relative magnitude of the frequency components, and the output, observed through an envelope detector, indicate negligible amplitude modulation.

Using a battery to supply dc power and a microphone to achieve frequency modulation, an avalanche transit time oscillator has been used to transmit voice communication over a distance of 1/3 mile with approximately 5 m watts output power. Standard waveguide horns with a nominal gain of 17.5 ± 1.5 db were used as receiving and transmitting antennae. The receiver consisted of a conventional microwave receiver, slightly detuned to provide FM to AM conversion.

References

1. M. Gilden and M.E. Hines, "Electronic Tuning Effects in the Read Microwave Avalanche Diode", IEEE Transactions on Electron Devices, vol. ED-13, No. pp. 169-175, January 1966.
2. T. Misawa, "Negative Resistance in p-n Junctions Under Avalanche Breakdown Conditions, Parts I and II", IEEE Transactions on Electron Devices, vol. ED-13, No. 1, pp. 137-151, January 1966.
3. J.G. Jossenhans and T. Misawa, "Experimental Characterization of a Negative Resistance Avalanche Diode", IEEE Transactions on Electron Devices, vol. ED-13, No. 1, pp. 206-208, January 1966.
4. T. Misawa, "Microwave Si Avalanche Diodes with Nearly Abrupt Type Junction", paper presented at the 1966 International Electron Devices Meeting, Washington, D. C.

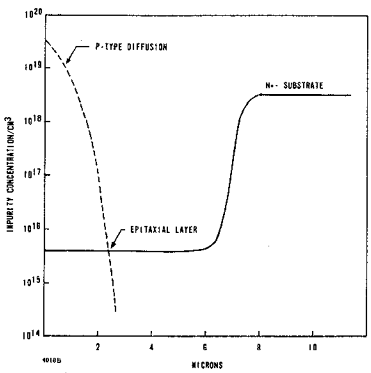


FIG. 1 - Impurity Profile of Oscillator Diode

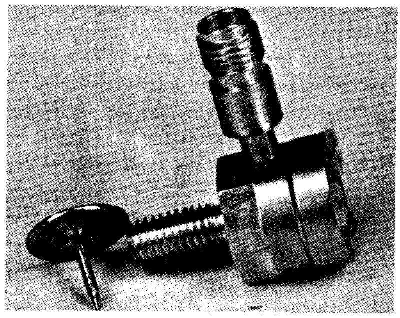


FIG. 2 - Microwave Oscillator with DO-5 Outline

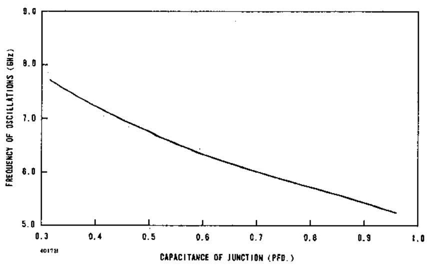


FIG. 3 - Frequency of Oscillation as a Function of Junction Capacitance at Breakdown

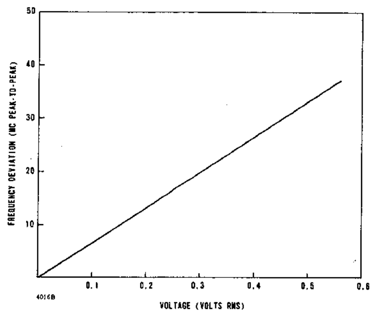
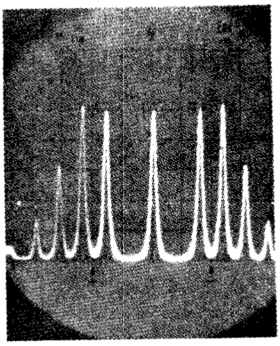
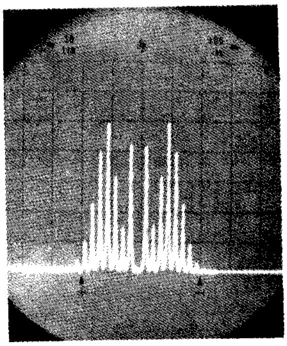


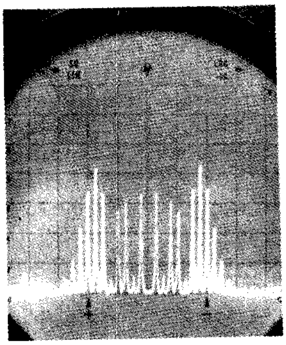
FIG. 4 - Frequency Deviation VS Applied Voltage (RMS) for a Typical Diode; Io : 30 MA



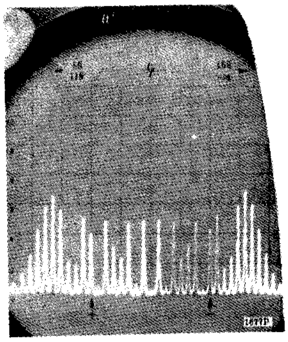
a) m = 3.8, Horizontal Sweep = 1 MC/cm



b) m = 5.5, Horizontal Sweep = 3 MC/cm



c) m = 8.7, Horizontal Sweep = 3 MC/cm



d) m = 14.9, Horizontal Sweep = 3 MC/cm

FIG. 5 - Photographs of Spectrum Analyzer Displays for various Modulation Indices fm : 600 KC