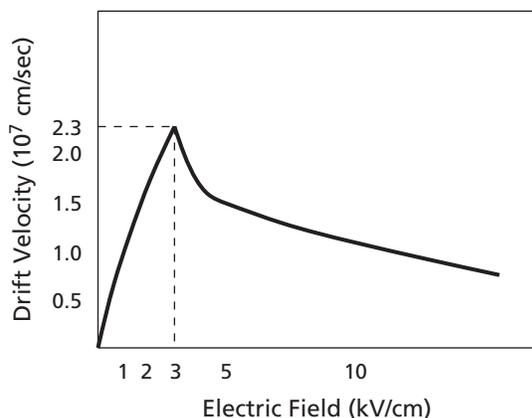


Gunn Diodes

Application Note

Gunn diodes are used as transferred electron oscillators (TEO) by using the negative resistance property of bulk Gallium Arsenide. The figure below shows the electron velocity in GaAs as a function of the applied electric field. Greater than about an electric field of 3.2 KV/cm, the electrons in N type GaAs move from a high-mobility, low-energy valley to another valley where the mobility is lower. Consequently, the net electron velocity is lower. This negative resistance is used for generation of microwave power.



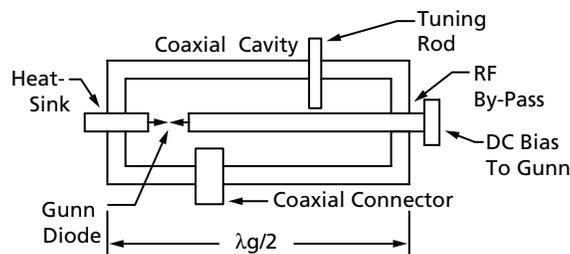
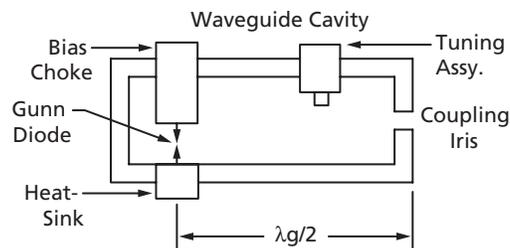
Dependence of Carrier Velocity on Electric Field In GaAs

Oscillator Design Considerations

Stable TEO oscillators are most easily designed by mounting a Gunn diode in a coaxial cavity or in a waveguide cavity as shown in the accompanying schematics. Microstrip oscillators also may be used. However, particular attention must be paid to heatsink the diode adequately.

Normally, TE modes are used for excitation in the waveguide cavities. The series equivalent circuit of a Gunn diode is a capacitance in series with a negative resistance. This capacitance may be resonated with the inductance of a shorted waveguide section of suitable length located behind the diode. The coupling to the external load may be controlled by an iris of appropriate dimensions. The distance between the diode and the iris is roughly $\lambda_g/2$ at the desired frequency.

The Gunn diode may be mounted on a post to provide adequate heatsinking. The coupling to the waveguide is through the post. The DC bias is conveniently applied through a dumbbell filter choke combination. For the coaxial cavity design, the diode is conveniently mounted at the end of the line to provide adequate heatsinking. The diode may be coupled to the load by an inductive loop located near the diode. Such a coupling also isolates the bias supply from the load. A sliding short on the inner conductor may be used to adjust the frequency.



Gunn Diodes Application Note

Bias Circuit Oscillations

Inherently, the Gunn diode has a negative resistance from DC and up. This negative resistance, together with the lead inductance and any stray capacitance, may lead to relaxation type of oscillations. In many cases, the oscillation amplitude is large enough to cause the diode to burn out. This type of failure may be minimized or even avoided by connecting a large capacitor(s) across the diode as close to the diode as possible. This capacitor combination must have a frequency response of at least a few tens of MHz.

Tuning

Mechanical-frequency tuning is accomplished by inserting a tuning rod (preferably made from a low-loss dielectric such as sapphire with a dielectric constant K of 9) into the cavity. The tuning rate is proportional to the rod diameter; however, too large a diameter may cause waveguide modes. The cut-off wavelength for a rod of diameter (D), is given by:

$$\lambda_{co} = 1.7 * D * \sqrt{K}$$

Electronic tuning is accomplished either by using a YIG sphere or by using a varactor in the oscillator. In the case of electronic tuning by varactors, the tuning bandwidth and the efficiency of the oscillator depend on the junction capacitance of the chip, the package capacitance (if any) and the Q of the diode (see MV 2000 and MV 3000 varactor series for selection).

Frequency Stability With Temperature

In general, the frequency stability of the oscillator depends on the material of the cavity, the reactance stability of the Gunn diode and the varactor (if any is used). Frequency stability may be improved by:

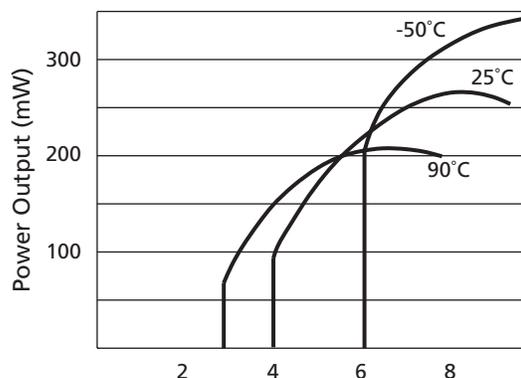
- Proper selection of the material of the cavity
- Mechanical temperature compensation or
- Proper selection of Gunn diodes

Power Stability With Temperature

The power stability depends on the operating bias voltage in relation to the turn-on voltage and the power peak voltage, the oscillator coupling to the load, the Gunn diode and proper heatsinking.

The accompanying figures show the variation of the turn-on voltage and the power peak voltage with temperature. The operating bias voltage must be chosen so that the turn-on voltage is below the operating bias over the operating temperature range. Similarly, the power peak voltage must be higher than the operating bias voltage over the operating temperature range.

Proper heat-inking is essential to obtain low turn-on voltage and high-power peak voltage.



Power Output vs. Bias Voltage and Temperature of a Typical MG1015 Gunn Diode

The tighter the coupling of the oscillator to the load, the greater the power variation.

Again, proper selection of Gunn diodes for a given application would minimize the power variation.

Gunn Diodes Application Note

Noise Performance of Gunn Diodes

In common with all oscillators, the Gunn diode oscillators have both AM and FM noise which vary with frequency from the carrier. The noise arises from random nucleation of domains. Far from the carrier — say greater than 30 MHz — the noise is essentially independent of frequency and depends on the device temperature and the loaded Q of the cavity. Closer to the carrier, both the AM and the FM noise vary inversely with frequency off the carrier. This 1/f behavior is characteristic of semiconductor surfaces.

Semiconductor surfaces also exhibit a random noise which is commonly known as “popcorn” noise in the 1/f flicker noise region. The “popcorn” noise appears as a burst of noise randomly. Some diodes exhibit this aperiodic noise quite often. In others, the frequency of appearance is rather low. The 1/f noise and the “popcorn” noise strongly depend on the surface preparation. MDT has developed a unique surface treatment technique which minimizes both the “popcorn” noise and the flicker noise.

External circuitry, including the cavity and the power supplies, influence the noise behavior. The power output and the frequency of the oscillator depend on the bias supply. Thus, the AM and the FM noise of the oscillator may be written as:

$$\text{Noise Power/Carrier Power (AM Noise)} = (\Delta P) + (dP/dV) * (\Delta V)$$

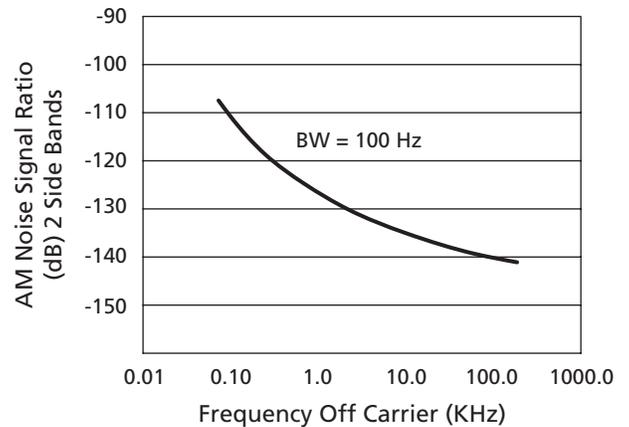
$$\text{Frequency Deviation (FM Noise), } f_{\text{RMS}} = (\Delta f) + (df/dV) * (\Delta V)$$

The first term is the noise power contribution due to the diode in the oscillator cavity. The second term is the contribution due to the power supply ripple (ΔV volts). The dependence of power output and frequency on bias voltage are dP/dV and df/dV , respectively. Since, in general, dP/dV and df/dV vary rapidly with bias past the power peak voltage, it is advisable to operate the device below the power peak voltage at all temperatures to minimize the noise.

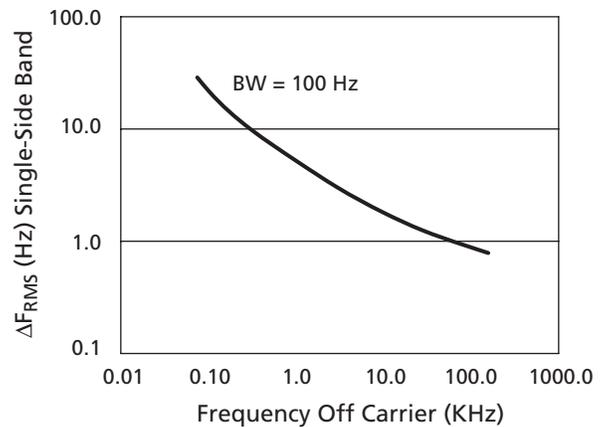
In summary, both AM and FM noise of Gunn diode oscillators depend on:

- Proper selection of Gunn diodes
- Loaded Q of the oscillator
- Power supply ripple
- Operating bias voltage

The figures below show typical AM and FM noise spectra of X band Gunn diodes.



AM Noise Spectrum of a 10 GHz Gunn Oscillator, Loaded Q = 4,000



FM Noise Spectrum of a 10 GHz Gunn Oscillator, Loaded Q = 4,000

Gunn Diodes Application Note

Application Notes

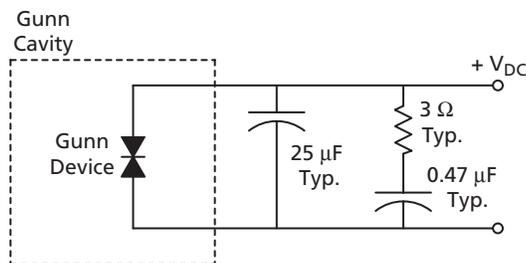
1. Frequency of operation for the Gunn diode must be specified with the order.
2. Minimum specified power is measured in a critically coupled high Q cavity.
3. Threaded stud or the prong opposite the weld flange is the cathode.
4. All Gunn diodes are burnt-in for a minimum period of 16 hours at a case temperature of $85 \pm 5^\circ\text{C}$ and at a minimum bias voltage of $1.1 * V_{OP}$.
5. Jan TX and Jan TXV equivalent screened diodes are available on request.
6. Adequate heatsinking must be provided for the diode to operate properly. A reasonable test is to measure the threshold current and compare it with the data supplied with the diode. Agreement within 5% would be an indication that heatsinking is adequate. (See the section on “Bias Circuit Oscillations and Mounting Precautions” below.)

Bias Circuit Oscillations

The Gunn diode has a negative resistance from DC through microwave frequencies. Consequently, it is prone to oscillate at low frequencies with the lead inductance from bias circuit connections.

The voltage due to bias circuit oscillations may be large enough to burn the device out if adequate precautions are not observed. It is prudent practice to suppress the bias circuit oscillations with a circuit similar to the one shown below.

Gunn Diode Mounting



Precautions

The Gunn diode is a power-generating device with a relatively low efficiency — about 2–5%. Consequently, considerable power is dissipated. Although MDT Gunn diodes are designed with long-term reliability in mind (with an MTTF in excess of 10^6 hours at an active region temperature of 260°C) with rugged construction by design, an adequate heatsinking is still essential to keep the active region temperature within the prescribed limit.

The heatsink material must have a high thermal conductivity. Materials like OFHC copper ($k = 3.9 \text{ W}/^\circ\text{C}/\text{cm}$) are suitable. If the package is threaded, then a sharply tapered heatsink may be used with the diode screwed into the heatsink with a torque of not more than 6 in-oz (4.5 cm-newtons) to prevent damage to the threads.

A vise-like holder should prove adequate for a diode with a prong. Or, the diode may be soldered in the heatsink. If the diode is soldered into the heatsink, then the case temperature must not be allowed to exceed 225°C in a non-operating condition.

Ordering Information

Orders for products may be placed directly with the factory or with our authorized representatives. Please indicate part number and package outline. For example, if you wish to place an order for a 250 mW Gunn diode to operate at 10 GHz, the part designation should be:

MG1007-15, $f_{OP} = 10 \text{ GHz}$