

Application Note

Step Recovery Diodes



Step recovery diodes, or SRD's, are used as high order multipliers and will multiply as high as 20x when used as a comb generator. They depend on extremely fast recovery time, often referred to as "snap time" to generate pulses rich in harmonics. Proper filtering and pulse shaping produces the familiar output of sharp, fast rise time pulses.

By storing charge during the positive half of an input sinusoidal signal and then "extracting" that charge during the negative going half cycle, a current pulse with a rise time equivalent to the "snap time" of the diode is generated in the impulse circuit of the multiplier. Output filtering then selects the desired harmonics for the application at hand.

Unlike C-Swing multipliers which utilize the non-linearity of the capacitance voltage curve to generate harmonics, and are most useful as low order, high power multipliers, SRD's are most useful as high order, low power multipliers. Because they can be made with low capacitance and low parasitics, they are most useful at the higher frequency ranges and will work with outputs as high as Ku band.

Figure 1. Capacitance Vs. Output Frequency

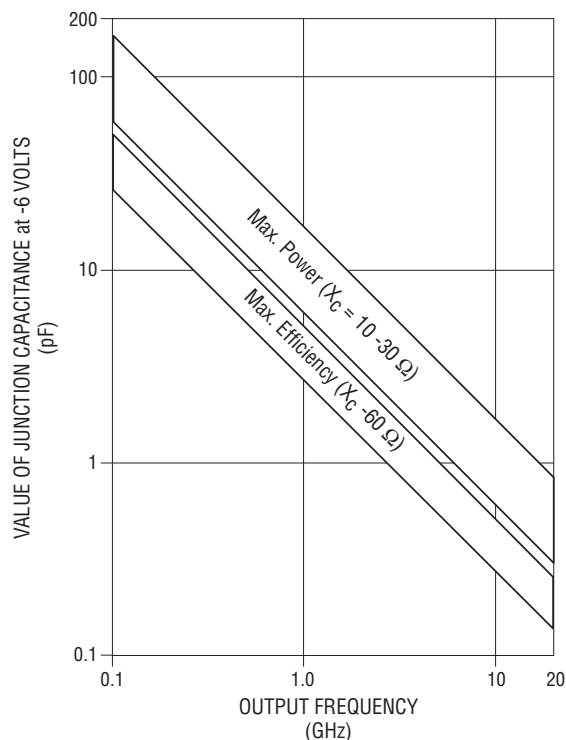
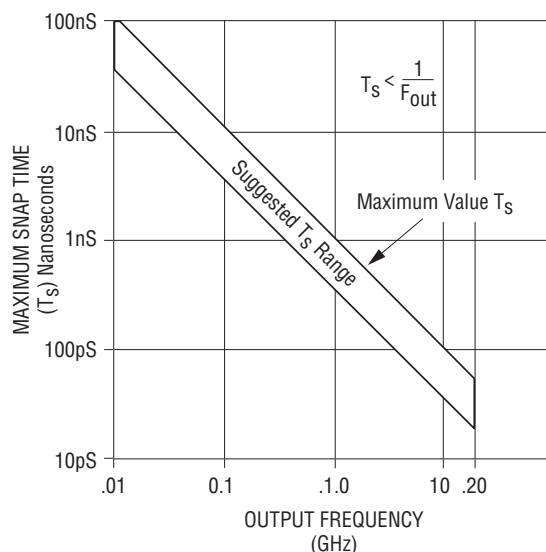


Figure 2. Capacitance Vs. Output Frequency



Selection of SRD's

In selecting a diode for comb generator operation, the following criteria should be determined:

- Input Frequency
- Output Frequency
- Bandwidth
- Efficiency

Once these values have been determined, the proper diode can be selected, as well as the proper value of the bias resistor.



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The major requirement for an efficient multiplier diode is that its lifetime is long enough that the reverse current can reach a peak before the diode “snaps” back to its high impedance state.

Figure 3. Ideal Lifetime

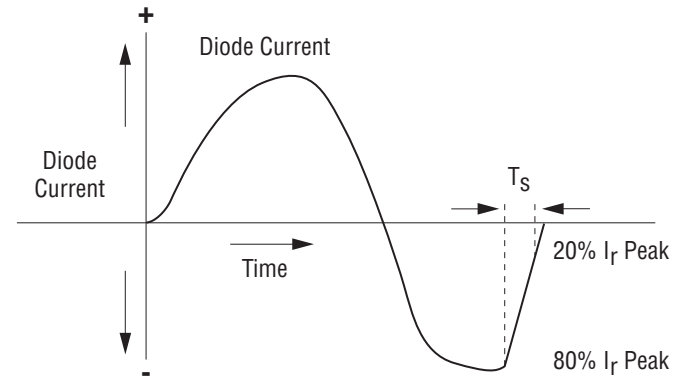
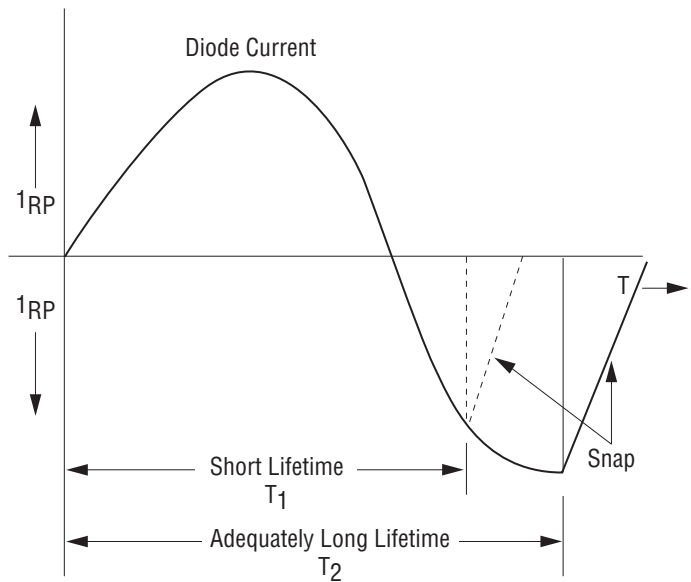


Figure 4 Snap Time (T_s) Definition



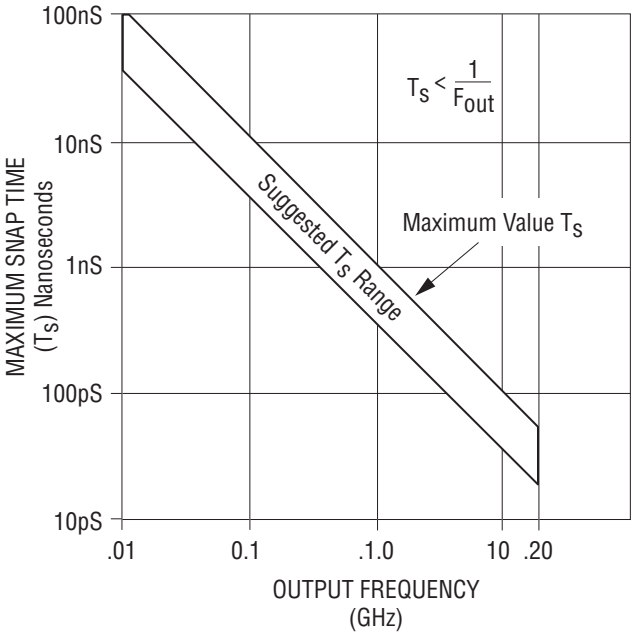
Input Frequency

The minimum required lifetime for a given input frequency can be calculated by: $T_L \times F_{IN} = 10$ Min. However, a value of 20-30 is considered best in most applications with the exception of bandwidths of 10% or greater, where a value closer to 10 will minimize difficulties of input matching.

Output Frequency

Transition time, or snap time as we have been using, is the key determinant for optimizing output of a multiplier circuit, i.e.:

$$T_s < \frac{1}{F_{out}}$$



Maximum and suggested values of snaptime (T_s) for SRD varactors vs. multiplier output frequency in GHz.

Output frequency also controls the choice of junction capacitance. A multiplier will work best if the output reactance is approximately 50 ohms at the self bias point established by the bias resistor. (Usually very close to the specified capacitance at -6 volts.)

$$C_j = \frac{1}{2 \pi f X_C}$$

Normally a reactance value between 30 and 60 Ohms is adequate for most multiplier applications, however since power handling is dependent on junction area, the larger the junction the better, so a reactance of 30 to 40 Ohms should be the goal.

Output Power

The output power required will determine the breakdown voltage needed and the thermal resistance of the diode. The breakdown voltage must be high enough so that the peak RF voltage plus the bias voltage will not cause the diode to avalanche. If this occurs, the diode will become quite noisy and could burn out. The required breakdown voltage can be estimated by:

$$Bv = k \sqrt{\frac{2 P_o}{(F_{in} \times C_t - 6)}}$$

where the constant

- k = 0.8 for multiplication < 4
- = 1.1 for multiplication = 4
- = 1.5 for multiplication > 4

The thermal resistance must be low enough to keep the junction temperature below 150°C during operation (all power not converted to harmonics may be assumed to be dissipated in the diode)

$$\theta_{jo} = \frac{150^\circ\text{C} - T_A}{(\text{power in}) - (\text{power out})}$$

where T_A is the ambient temperature.

Bandwidth

Step recovery diodes are inherently narrow band due to the “spike” response nature of the input impedance. For applications requiring bandwidths of 5-10% or greater, a low order multiplier utilizing a C-Swing type diode is recommended. If a broadband comb generator is required, the input and output filters should be kept as simple as possible.

Efficiency

The principle contributor to decreased efficiency in multiplier circuits used to be the cutoff frequency of the diode. Today, however, most modern SRD and multiplier designs have cutoffs in the 200 - 300 GHz range which is more than adequate for most multipliers up to Ku band. Efficiency for most multiplier circuits can be approximated by the expression:

$$\text{Efficiency} \approx \frac{1}{n} \text{ where } n > 3$$

For doublers, efficiency as high as 65% can be achieved. For triplers, efficiency as high as 50% can be achieved.

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