Gunn and IMPATT Microwave Devices

The author shows how to safely test these diodes used in 10-GHz operation.

Over the past 20 years, microwave equipment has been changing over to solid-state devices at a very fast pace. Solid-state devices now dominate in the low- to medium-power ranges. I had been very comfortable with vacuum tube devices so it took some adjustment for me to switch from klystrons to diodes as microwave oscillators.

Vacuum tubes are forgiving—they give some indication before going self-destruct. Unfortunately, this is not the case with transistors and diodes, where it is often too late by the time you see the flash or smell the smoke.

This one fact I believe has kept many from experimenting with them. I have outlined some procedures in testing surplus solid-state devices in a non-destruct environment—particularly, Gunn and IMPATT (IMPact Avalanche Transit Time) diodes for use on our 10-GHz microwave bands. The procedures described here will give an insight into how these devices operate and how to handle them.

Klystron vs. Gunn

The klystron vacuum tube has been in use for quite a long time, and many pieces of test equipment still use the old reliable 723A/2K25-type tube. Three power supply voltages are required to operate the tube: B+ dc, B- dc, and filament. The power supply weight for this is at least 10 pounds, and not exactly portable. The power output of the average klystron was about 10 to 20 milliwatts. I have operated pieces of equipment producing 100-mW output, but they required boilers to carry away the heat produced in generating rf. The klystron system is bulky and non-portable (See Figure 1).

The obvious advantages to solid-state devices at microwave frequencies outweigh the high initial cost. A simple Gunn diode oscillator requires only a single low-voltage-dc supply. Let's examine what is required, just what constitutes a Gunn diode or IMPATT diode, and also what makes them different from each other, and how they operate to produce microwave energy.

Gunn diodes were named after J.B. Gunn of IBM, who in 1963 discovered a fluctuating current while testing a piece of Gallium Arsenide (GaAs). While it is held that he did not connect the microwave possibilities at the time, he did discover the effect first. Just prior to this, Ridley, Watkins, and Hilsam postulated the existence of negative resistance in semiconductors. They laid out the theory to a tee, but their attempts to prove it in the lab failed due to the purity of their specimen of GaAs. Another scientist, Kroemer, tied together the postulated theory and the fluctuating current observed in Gunn's experiments and declared they were one and the same: the theory and the proof of negative resistance. Gunn did not recognize the mi-
microwave oscillation because he was looking
for noise in semiconductor materials, not rf.
This Gunn diode should be called a silicon or
gallium arsenide resistor as in reality it
does not have a P-N junction as normal
diodes do. We all think of PNP and NPN
transistors, and I even take for granted the
diode. But all common diodes have a P-N
junction—at least, detectors, rectifiers and
multipliers.

Another factor making diodes suitable for
microwave frequencies is their very short
leads. This gives them a very low inductance
and capacitance to present to the microwave
circuits. Stray inductance and capacitance
can make microwave circuits very hard to
tame or not work at all. See Figure 2 for some
typical packages used in microwave diodes.
The screw terminal is the cathode in these
deVICES. Microwave Associates lists a capaci-
tance of .22 pF and an inductance of .16 nH
for this 118 case/package at 10 GHz.

Microwave Gunn diodes as well as other
types are quite small. The threaded side of the
diode is used for connection in the heat sink
for dissipation, and is given a good contact
with the surface with a small dab of heat sink
compound. The efficiency of these diodes is
low, less than about 20%, but considering the
ease with which they can be made to operate,
one can overlook that. The wafer-thin piece
of Gallium Arsenide is attached to one end of
the heat sink post (see Figure 2) and covered
by a .050-inch ceramic sleeve. The top of the
GaAs is attached with ribbon contacts and put
on top of the sleeve for fixing to the top cover
plate for the contact to the dc supply feed.

This post is the anode in the diodes that I
have. It can be reversed, but that is by special
order from the original supplier of the diodes.

Gunn Operation

This wafer-thin GaAs Gunn diode is mounted
in a suitable microwave cavity or waveguide
and coupled to a source of dc voltage, positive to the anode. When the
voltage is adjusted to some critical value,
microwave oscillation will take place and is
controlled by the dimensions of the wave-
guide and post connecting the diode. The resistance of the diode varies but is in the range of
1 to 10 Ohms in samples I have tried. Gunn
diodes are driven with a constant voltage sup-
ply. This allows them to have all the current
they want as long as the voltage is held to
some special value, usually under 12 volts.

Testing different Gunn devices, I slowly
raise the voltage from a supply made from a
LM-317 adjustable regulator mounted near the
device. As the voltage is increased, the
current is increasing in proportion to the
voltage until a critical point, when a slight
increase in voltage produces a slight decrease
in current. At this magic point (somewhat
different for various devices) this is the nega-
tive resistance region where microwave oscil-
lation is starting to take place.

This voltage is in the area of 4 to 6 volts for
most diodes; it varies quite a bit. The upper
voltage limit is not very high, and the maxi-
mum voltage on the highest device that I have
is about 18 volts. I might suggest preventing
destruction by not going above 9 to 10 volts
until you are sure of what you have. Keep the
voltage low, and the diode will be fine. Keep
growing only if you really need to know where
breakdown is located.

I have destroyed many devices in pursuit of this knowledge. One rule
I have discovered is that if the diode starts
oscillation on a low voltage, say 4 volts, its
maximum voltage will be around 10 to 12
volts; or those starting around 5.5 volts, the
max is 14 volts. Most Gunn diodes available
on the surplus market today have a top
voltage of 12-14 volts.

This point of negative resistance is just
inside the unstable region of the diode's curve.

As the voltage is increased past this starting
point of oscillation, current still increases but
not in such a direct manner as before oscilla-
tion. The output power of the Gunn device is
increasing until some further point when a
further increase will produce a decrease in rf
power output. If the voltage is increased fur-
ther, a point will be reached which will be very near the destruct voltage of the
device. Note that 1/2 to 1 volt beyond maxi-
mum rf, output will put you near that region.

My diodes put out power in the 100-250
mW range and operate with 8.5 to 10.5 volts,
drawing about 600 to 850 mA of current. A
good heat sink or large metal cavity is re-
squired for long-term operation and device
stability. I have violated this point on occa-
sion and lost several expensive diodes.

The cavity I have experimented with is the
SOLFAN mount, a cast metal cavity with the
diode mounted in the center of a large block
of metal. This cavity was intended to be run at
10 mW, with a 200-mW diode (+23-dBm output).
It gets quite hot after about a half
hour of operation. You can hold it in your
hand for a short time before it is uncomfort-
able. A better heat sink is needed for longer
operating periods. A cavity temperature of
100-120 degrees Fahrenheit is normal, and
for stability, maintaining a constant tempera-
ture will slow frequency drift and eliminate
the variables resulting from temperature
changes.

This cavity has to be modified slightly with
the addition of a solid rivet placed in the rf-dc-feed inside the cavity. I placed the rivet in the hole and tapped it lightly with a punch to seat it. It will not fall out of the cavity’s rf, but can be removed if you wish to replace the original 10-mW diode. To remove the rivet, pinch with small diagonal pliers and the rivet will pop free. A new 10/23 brass screw is drilled out and taped to accept the 3/48 threads of the high power Gunn diodes. (See Figure 4.)

Although I have not tried this, I have heard about placing two Gunn diodes in parallel to achieve a higher power output than can be obtained from one device. They may be mounted in a waveguide and spaced 1/2-guide wavelength apart. Remind yourself that an oscillator injected into another will cause them to lock to a common frequency as long as the mechanical tuning is within the same frequency; the other will follow for a few MHz or so.

**IMPATT Diodes**

The case styles used in Gunn diodes and IMPATT diodes are so small that the manufacturers do not put part numbers on the devices—you have to be very careful looking at each device on the surplus market. An IMPATT diode is operated in the constant current mode. That is, the voltage is increased to some specific point where avalanche current breakdown takes place. Some means has to be found to limit the current to a prescribed value. One very sure way to destroy an IMPATT device is to test it as a Gunn diode. The IMPATT diode doesn’t tolerate excessive current. See Figure 5 for IMPATT diode curves. The IMPATT diode is a real P-N junction, and this device is operated reverse-biased with a high voltage breakdown to produce a supply of electrons and holes. The diode is quite similar to a zener diode but is doped with impurities to have a controlling effect on the avalanche current so necessary for its operation. In this unstable mode, the voltage is made variable in the 80-90-V range, and the current is limited to about 30-50 mA. This can be set with a fixed resistor. The IMPATT diode has a critical voltage where microwave oscillation will take place somewhat like the Gunn description. The IMPATTTs that I have oscillate at about 82.5 volts dc with a power output of 100 mW at 10 GHz.

The IMPATT diode is termed an Avalanche Effect device. What is going on is that the holes and electrons are involved in Impact and Ionization within the P-N junction and produces a negative resistance at some critical voltage with controlled current supplies. IMPATT operation happens when the voltage of the ringing waveform through the diode adds with the dc bias and causes the junction to go into the avalanche mode. If the device is biased properly, the junction will produce output on half of the duty cycle. In this case, the IMPATT diode is biased just above the point of avalanche, and when rf swings positive the avalanche current (which builds up slowly) reaches its peak when the rf voltage is zero. This repeated operation produces a current pulse traveling toward the anode. This type of operation is very noisy and is not suitable for local oscillator use in a receiver. It does produce quite an output, and the high voltage required for operation makes them somewhat less desirable than the Gunn diodes for portable operation.

**IMPATT Amplifiers**

IMPATT diodes are used in amplifiers, and the commercial applications are numerous. The IMPATTTs are operated (CLASS C) but from where I sit, their construction appears to be little less than black magic. What they do is run the IMPATT diode and couple low-level rf into a circulator which couples the energy to the port that the IMPATT is at. The low level rf and the output of the IMPATT (adjusted very near the input frequency) become locked to the input source and combine, producing a reproduction of the input signal at a higher power level (Figure 6).

We have been toying with the idea of using a RACON IMPATT source and filter in a 10-GHz beacon so that many stations could use it at their convenience to tune and test systems. By having the IMPATT source at someone’s home, the problem of high voltage power is minimized. I was very fortunate to be able to pick up several of these RACON sources new, and plan to use one for our San Diego Microwave Group’s beacon. See Figure 7 for details on the IMPATT cavity and filter used. This low-cost source is available from RACON. This device is made to operate at 10.525 GHz (pn 10000-104-02) with a wide band filter 8.2 to 12.4 GHz (pn 10000-109-01). The last price list I have from RACON lists the IMPATT source and filter at $60. (RACON, 8490 Perimeter Rd., S. Seattle WA 98108.)

Projects in the future include a simple home-made transmitter receiver out of items easy to obtain (the hardest of these to find is 1”-round Teflon® stock.) It has become very easy to generate rf at appreciable power, but it was somewhat difficult to achieve good receiver sensitivity—at least prior to current design.

Other projects in the very near future are some test equipment and i-f preamplifiers using low-cost devices. All projects have been the direct result of many hours of experimenting and field trials with each one making our equipment easier to use or improved in operation.

I can make available high-power Gunn diodes, case style 118 with silver brass rivets, operating at 10 GHz with measured power output better than 50 mW to approximately 100 mW, for $5 each, postpaid in the continental U.S. Some select higher power devices are available for 6, 10, and 18 GHz. Power output varies from one cavity design to another. I would be happy to answer any questions regarding this or other related projects, but please enclose an SASE for prompt reply.

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I am looking for a receiver for the 225-400 MHz AM Military aeronautical band. I know that there are several continuous coverage scanners available, but they are $350 up—do you have something cheaper?

**Doug Graham**
4929 Elm
Arcadia TX 77517

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**GTS Manual Mini Modem Model MM-101 (manufactured by Elec and Eltec Co., Hong Kong), Heathkit Oscilloscope Calibrator Model IG-4505, Leader rf signal generator Model LSG-11, Garrard Turntable Model Lab 95B, Johnson Messenger CB Model 323, Apple Ile Pro System Duo-Disk Imageprinter PrinterMonitor II, and ICOM IC-735 Transceiver.**

**Mike Adams—Haney Vo-Tech**
Center
3016 Hwy 77
Panama City FL 32405

I need service info for the following items and will purchase or pay for the copying costs: Unicorn Electronics power supply Model PS-11R, Tandy 64K Color Computer II, Model 26-3127, EMP/MI"m 26-941D, or 989 antenna tuner: five 7688 tubes; ten #12 6-V lamps for Bogen PA Amps; one switch each for the Panasonic rf 2800 receiver #RSR 98W or equivalent; one printer and disk drive for the Tandy Color Computer II Model 26-3127; and one Z-80/CMP and Modem Board for the Apple Ile Pro System.

**Bill Parker W4YKW**
3154 Ravenwood Dr.
Falls Church VA 22044

Wanted: External Frequency Display YC-7B for the Yaesu F77B.

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