AN ELECTRON-BOMBARDED SEMICONDUCTOR (EBS) MODULATOR AND SWITCH DRIVER

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ABSTRACT

High power PIN diodes hot switching control devices require large amplitude, fast risetime, forward bias current and reverse bias voltage pulse commands. Performance exceeding that available from present state-of-the-art binary state transistor drivers is highly desirable. This paper describes use of an Electron-Bombarded Semiconductor permitting faster and more reliable microwave high power switching.

INTRODUCTION

PIN diode control devices, capable of live or "hot" switching microwave power levels generally in excess of 50 watts (+47dBm), require careful attention to not only quiesent rf and dc voltage thermal effect[1], but also heating during transition from forward bias current to reverse bias voltage. As the PIN diodes are modulated between these states of low to high impedance they are temporarily under severe thermal stress. This occurs where the shunt mounted diode(s) are biased near 50 ohms resulting in rf power absorption.

Present and future systems applications often call for very high switching rates. Up to 1 MHz is common while 20 to 50 MHz is sometimes desirable. The result of high switching rates is reduced operating life.

High power switch drivers utilizing transistor circuitry often restrict 10-90% switching speeds to greater than 50 nanoseconds with driver delays of several hundred nanoseconds. This results from use of high voltage breakdown transistors and peripheral circuit time constants.

Figure 1 depicts a proven transistor single-pole-double-throw switch driver[2]. This driver, which is capable of supplying up to 4 amperes, is used to switch PIN diodes in the 300 to 600 volt breakdown range.

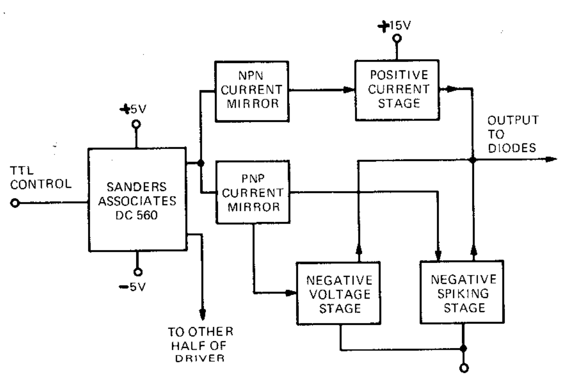

Figure 1. Fundamental Details of Transistor Driver

The quest for a faster driver has led to use of a readily available device called an EBS as a switch driver. This paper reports the preliminary results of the marriage of an EBS with a PIN diode switch for high power "hot" switching.

EBS PRINCIPLES

The Electron-Bombarded Semiconductor operates on the principle of current injection into a diode target from an electron beam emitting from the cathode[3]. A grid is available for on/off modulation. The EBS can be crudely compared to a cathode ray tube where the anode is a shallow PN junction semiconductor. The electron beam is accelerated to approximately 10 keV. When the high energy stream of electrons strikes the diode target, the beam current is amplified by approximately 1600 times due to carrier multiplication within the diode. This current is then directed to an external load.

The output current risetime for an EBS is determined by the risetime of the input signal and the RC time constant of the target and external loads. If the input pulse risetime is negligible, the 10 to 90 percent risetime of the EBS output is determined by:

$$t_r \text{ (10\%-90\%)} = 2.2R_L \, (C_{DIODE} + C_{EXT}) \quad (1)$$

where R_L is the external load resistance, C_{DIODE} is the capacitance of the semiconductor diode and C_{EXT} is the capacitance of any external load. The EBS is capable of producing output currents of 4 amperes into a 100 Ohm load. Typical risetime of this pulse is 2 nanoseconds.

The entire unit, less power supply, is approximately 50 cubic centimeters in volume. Electron Bombarded Semiconductors presently have widespread use as high power amplifiers and TWT modulators.

EBS MARRIAGE WITH A PIN DIODE SWITCH

A PIN diode switch of single pole-single-throw configuration was assembled and thoroughly tested in the low loss and isolation states. The switch consisted of a high power PIN Diode Chip with a .2 PF junction capacitance, 500 volt breakdown, and 1.5 microsecond minority carrier lifetime mounted in a microstrip configuration. The switch was designed for optimum performance in the 2 to 4 GHz range. Table 1 describes the measured steady state performance of the switch at 3 GHz.

VSWR	1.4:1
Insertion Loss	0.5dB
Isolation	21.5dB
RF Power Handling	250 Watts CW

Table I. Performance of SPST S-Band Switch

The switch was next ready for connection to the EBS device obtained from Watkins Johnson Company. WJ-3684-4 was selected as one likely to be successful in the proposed application.

The most significant performance characteristic to be measured concerned the ability of the EBS to drive a dynamic load with large impedance change during switching.

EXPERIMENTAL RESULTS

The PIN diode switch bias was adjusted for forward conduction at 50 milliamperes. This test simulates the worst case condition-switching from isolation to loss - thus requiring depletion of stored charge. The EBS bias and test equipment for observing switching speed is indicated in Figure 2.

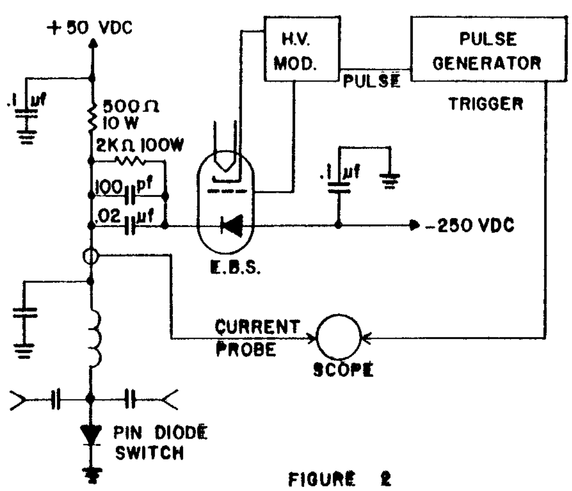

FIGURE 2

EBS-High Power Switch Marriage

Figure 3 upper trace shows a spike of $\simeq$ 600 watts, which allows the R.F. (lower trace) to achieve a $\simeq$ 10 nanosecond rise time from off to on.

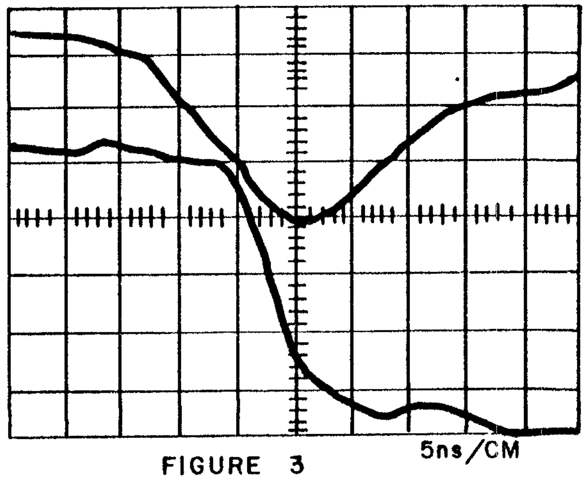

FIGURE 3

(a) Upper Trace-EBS Output
(b) Lower Trace-RF Switching Waveform

The switch was also actuated in the low loss to isolation condition with -40 VDC initially applied to the PIN diode. This is adequate reverse bias to hold off in excess of 250 watts. Switching the PIN diode with the EBS in the forward direction was accomplished in 8 nanoseconds with no driver delay. The reverse switching time for the same switch with a transistorized driver is 100 nanoseconds. The forward or "off" time is 30 nanoseconds.

CONCLUSIONS

The testing indicates that a high power PIN diode switch can be driven by an EBS of current source type. Switching time both from loss to isolation and isolation to loss states is 10 nanoseconds or less. Driver delay is minimal. The stress on the EBS itself is far less than its rated values as in common applications such as TWT modulators or amplifiers. Only 10KV, cathode voltage is required. The EBS appears to be impervious to the effects of the PIN diode dynamic load impedance. The heating effects which cause degradation during switching through the rf absorption impedance are greatly reduced. The EBS driver is less complex than a transistor driver. The reliability of high power switches with PIN diode chips of 300 volts to 1000 volts breakdown or greater should be improved with use of the EBS in lieu of a transistor driver.

FUTURE DEVELOPMENT

A multiple diode target EBS with electron beam steering is the logical step to further advance the product. This will allow for switching both on and off states without changing fixed bias. Also, if for example, four targets were available, a SPDT switch could be operated in a practical manner.

ACKNOWLEDGEMENT

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REFERENCES

1. J.F. White, "Semiconductor Control" pages 80 through 87, Artech House, Inc. 1977.

2. T.O. Perkins "Hot-Switching High-Power CW" Microwave Journal, May 1975.

3. D.J. Bates, A.Silzars, "Electron Bombarded Semiconductor (EBS) Devices", Microwave Journal, March 1972.