General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

SEMIANNUAL STATUS REPORT

National Aeronautics and Space Administration Grant NGR 22-009-337

covering the period

November 16, 1968 - February 15, 1969

Submitted by: Paul Penfield, Jr.

March 20, 1969

MASSACHUSETTS INSTITUTE OF TECHNOLOGY Research Laboratory of Electronics Cambridge, Massachusetts 02139

N69-26419 ACCESSION NUM (THRU)

, . 1

3

SUMMARY OF RESEARCH

During the period 16 November 1968 through 14 February 1969, advances have been made on both experimental and theoretical understanding of avalanche diodes.

Theoretical calculations of static negative resistance in avalanche diodes were done during the previous six months. During the past three months, emphasis has been more on the transient case. A computer program has been written and refined, to simulate the behavior of such a diode as a function of time. It is possible to excite the diode with an arbitrary current waveform and view not only the resulting voltage but also electron and hole profiles and electric-field profiles. A collection of the resulting profiles shows how the transient behaves, and studies have been made on a variety of diodes and currents. It is also possible to consider the diode as excited through a circuit, and work has begun on writing the appropriate programs to simulate this.

We expect that these programs can be used to justify a lumped-circuit model for the diode. This model can then be used to design practical circuits such as oscillators.

An example of the use of these programs is shown in Fig. 1. Each line represents a profile of electron-current density at a specific time (the time in psec and the corresponding voltage are printed at the left). Each symbol represents a range of electron-current values; thus, higher numbers represent higher values of electron current, and letters still higher values. The diode is a p-i-n diode with base width 10μ , excited with a constant current of $2 \times 10^6 \text{ A/m}^2$.

A series of runs for various driving currents (all constant) shows that the amount of voltage breakback produced by the transient depends upon the current. For stronger currents the breakback is much higher, and for currents not much larger than the current for Fig. 1, the breakback is so large that the computation cannot be trusted, and a more elaborate program will be necessary.

Experimentally, an IMPATT avalanche-diode oscillator has shown noise and power improvement at the fundamental as the higher (second

1

AVALANCHE TRANSTENT

JNO= 1.000F 00, JPO= 1.000E 00, E0= 2.000E 07, 40 STEPS. DONGED= .000E 00, DX= .250 MICR MS, DT= 2.50 PS.

INDE	X:		-		ĴΜ	L	ES:	S	TH/	٩N	1	00	0	AM	PS.	/SI	ΩU,	ARE		MET	rer	۲.	ļ	ØTł	1E F	3 5	S YN	B.	ØLS	5:
S	YNE	101:	0	1	?	3	4	5	б	7	8	9	A	В	С	D	Ε	F	G	Η	1	Ĵ,	Κ	L	М	N	Ø	P	Q	R
PMR	۵F	10:	3	3	3	3	3	4	4	4	4	ų	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8

TIME		X=0 10.0 MI	CR CNS
(PS)	VOLTACE		
00	200.000	ger der der der ant hat die der der der der der im jak der der bei die der an sin set der der der der der der de der der der	ha 94
25	204.868	an a	
50	209.736	an die die der mit ein die die die die die die die die die se per ein pie die die die die die die die die die d	-
75	214.605	an de be ne ne ne ne be de de de se ve ne ne ne ne he rij he ta de	-
100	219.473	an die	
125	224.341	an a	
150	229.209	وي هذه الله الله الله الله الله الله الله	
175	234.077	ويو وي	-
200	238.946	de Bu fin de de se se bie du la de de de se se se se se de	-
225	243.814	وي و	
250	248.682	الما الله وله وله الله عنه وله عنه من عن وله عنه وله عنه الله عن الله الله عن الله عنه عنه عنه عنه عن عن عن عن	
275	253.550	ويت هو وي	
300	258.418	On de go de fur fur de de de de de de se de be de de de de de las de	
325	263.287		-
350	268.155	ر است و ا است و است	
375	273.022	وه و به هم هم هم هم هم هم هم هم هم من الله عن هم هم هم وه هم وه هم وه هم وه هم و	
400	277.890	کو قار اور کار دو کرد ورد ورد ورد ورد ورد ورد ورد ورد ورد و	· •••
425	282.756	110000	* * *
450	287.620	33322221111000	
4 75	292.475	6655554444333222111000	* me
500	297.293	999888777766655554443332211100	-
525	301.93%	DCCCCBEBAAA99988877766555443322110	
550	305.582	HCGGFFFEEEEDDDCCBBBAA999887766554332 10	• •
575	303.463	KKJJJJIIIIHHHGGGFFFEEDDDCCBBAA988776543	1
600	282.048	LLLLKKKKKKKKJJJJJIIIIIHHGGGFFEEDDCBBA9875	;-
62.5	239.331	LLKKKKKKKKKKKKJJJJJJJJJJIIIIHHHGGFFEDCBS)-
650	188.700	KKKKKKJJJJJJJJJJJJJJIIIIIIIHHHHGGGFEECB	
675	148.376	JJJJJJJJJJJJIIIIIIIHHHHHGGGFFEEDDCBBA986	5-
700	130.129	JJIIIIIIKHHHHGGGFFEEDDCBBA9876543210	-
725	128.820	HHHHGGGFFEEDDCBBA98765432 10	-
750	133.512	EDDCBBA9876543210	- 38-9
775	138.561	65432 10	-
800	143.466		-
825	148.337		-
850	153.205		-
875	158.074		-
900	162.942	84 (Sea 67) (Sea Sea Sea Sea Sea Sea Sea Sea Sea Sea	**
925	167.810		-
950	172.679		-
975	177.547		- *
1000	182.415		**

Fig. 1. Computer simulation of avalanche transients.

and third) harmonics were tuned. The variation in noise performance appears to be the important result, and a quantitive measure has shown that the tuning produced a 6-8 dB noise figure change when the oscillator was used as the local oscillator for a balanced mixer.

Incremental measurements of the avalanche impedance of the diode junction have been made as a function of the avalanche current in the range of frequencies from 4 GHz to 12 GHz. The negative real part still exists at 4 GHz, but is of little consequence, since the bulk series resistance of the diode overwhelms it. Considering both the real and imaginary parts of the impedance, there appears to be an optimum frequency at which to use the device as an oscillator. From these measurements, a small-signal model has been formed leading to a large-signal model of frequency-independent elements which we hope will predict the observed behavior regarding harmonic terminations.

3