STUDIES ON A CLASS OF NEGATIVE RESISTANCE AMPLIFIERS AND DETECTORS

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بسم الله الرحمن الرحيم

STUDIES ON A CLASS OF NEGATIVE
RESISTANCE AMPLIFIERS AND DETECTORS

Investigation of Tunnel Diode
Super regenerative Amplifier and Detector

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CHAPTER IV

S U M M A R Y

The aim of the present work is to investigate super regenerative amplification (S.R.A.) and detection using tunnel diode. The different modes investigated are :

1- The linear mode of the super regenerative amplifier was investigated using analytical approximation of the tunnel diode characteristics. The gain and the amplitude characteristics of the amplifier were calculated.

The case when the quench period is large (non linear mode of S.R.A.) was investigated taking in consideration the tunnel diode non linearity and applying the quasi-linear method for analysis.

2- The operation of the amplifier as a super-regenerative detector was studied in the linear and non linear mode. The detector out put and the gain factor were calculated using the method of calculations of ordinary detectors.

3- Experimental investigations of the super regenerative amplifier and detector were carried out using Ga As tunnel diode and a tank circuit whose resonant

frequency $\simeq$ 2 Mc/s. Experimental results confirms the occurence of both super regenerative amplification and detection in the linear and non linear modes, the shape of the oscillation burst was found to vary from mode to another. Moreover, the circuit was found to oscillate at certain values of the bias voltage, and the oscillator can be frequency locked to any small external signal close to the resonant frequency, i.e. synchronization occurs.

CHAPTER I

I N T R O D U C T I O N

I-1- General

Fundamentally[1], the tunnel diode is a two-terminals semiconductor device that displays an a-c (alternating current) negative resistance over a portion of its current-voltage curve. This phenomenon occurs if the tunnel diode is biased in the forward direction. It is this a-c negative-resistance property of the tunnel diode that is exploited in a number of circuit arrangements to provide amplification, oscillation, switching, and memory functions extensively used in electronics.

Devices displays a-c negative resistance are not new to the field of electronics. This characteristic is found also in thyratrons, tetrode vacuum tubes, four-layer diodes, and others. However, because the tunnel diode is such a simple device, and a potentially in-expensive item, much engineering research has been directed toward increasing the number of applications. As a result, types of equipment using tunnel diodes are becoming more numerous and are being offered on the commercial market.

The tunnel diode was invented in 1958 by a Japanese scientist, Leo Esaki. Thus the tunnel diode is often refered to as the Esaki diode. The external appearance and structure of the tunnel diode is identical to the normal rectifying junction diode Fig. (1). The difference between the two is in the amount of donor and acceptor impurities added to the semiconductor materials. The impurities added to the tunnel diode semiconductor materials are $\approx$ 1000 times greater than those used in semiconductor materials for the rectifying junction diode. Therefore, the p-n junction is formed from highly doped p and n semiconductor materials.

It is the heavy doping of the tunnel diode semiconductor materials which causes the phenomenon of a-c negative resistance that permits the use of the tunnel diode as an amplifier, oscillator, super-regenerative amplifier and regenerative amplifier and switch ... etc.

I-2- Tunnel Diode Functions

a- Amplification

The tunnel diode may be used as a current, voltage, or power amplifier.

For instance, a stronger signal current may be obtained from a tunnel diode than is delivered by the signal source. Various circuit arrangement provide for various amounts of signal amplification, depending on the power-handling capacity of the particular tunnel diode.

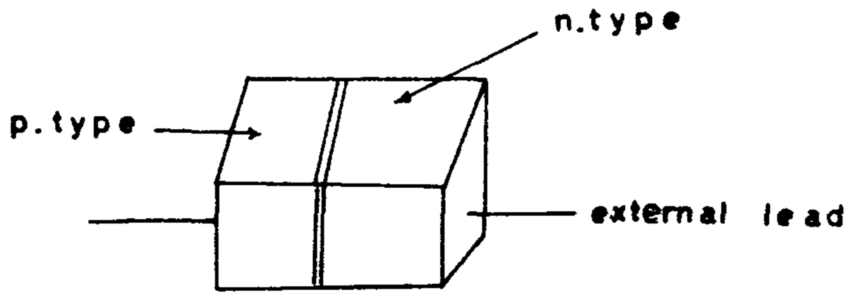

Fig. (1) Heavily doped n- and p-type semiconductor junction (single crystal)

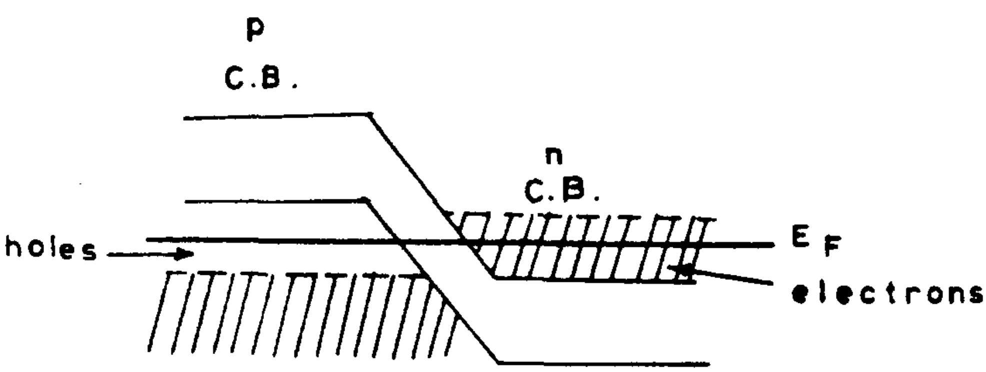

Fig.(2) Energy levels of tunnel diode.

b- <u>Oscillation</u>

The tunnel diode may be used to convert direct current energy into alternating-current, i.e. it may be used as an oscillator. When functioning in this manner, the tunnel diode absorps energy from a d-c source, in conjunction with a suitable timing tank circuit arrangement, and generates an a-c signal.

c- <u>Modulation and Demodulation</u>

The tunnel diode used in various circuit arrangements can provide amplitude modulation (variation in amplitude of an R-F signal) or frequency modulation (variation in frequency of an R.F. signal) demodulation (detection) of amplitude-modulated signals or frequency-modulated signals could be demodulated using tunnel diodes. These circuits are well-suited for miniature transmitters intended for short-range applications.

d- <u>Miscellaneous</u>

The tunnel diode may also be used to modify the shape of signal waveforms. Waveform shaping is vital in various types of radar teletypewriter, computer, and television circuits.

I-3- Advantages of Tunnel Diodes

a- Semiconductor devices and tunnel diodes, have common advantages over electron-tubes, these are :-

(i) Greater power efficiency because no heater element is involved.

(ii) No, worm-up time required.

(iii) Longlife expectancy because of their physical ruggedness, each will withstand centrifugal force, gravity, and impact tests that would completely shatter an electron-tube.

(iv) Operation at low voltages that permit the use of smaller circuit components.

(v) Extremely small in size compared to even miniature electron-tubes.

This permits ease of construction in microminiature modules especially desirable for use in portable equipment, aircraft, missiles, drones (unmanned aircraft), and satellites.

b- The tunnel diode has the following advantages over semiconductor:

(i) Much higher switching speeds. Present tunnel diodes can switch in one nano second (10^{-9} second), the tunneling action that occurs in a tunnel diode takes place theoretically at nearly the speed of light. Switching speed is of particular use in logic circuits and high-speed computers.

Because of this fact, the tunnel diodes were extensively applied in this field. The transistor is limited in switching speed because of the long transit time of current charge carriers through its base.

(ii) The tunnel diode can operate through wide temperature ranges without appreciable changes in its tunneling characteristics. This property is due to the very heavy doping of the semiconductor material. Extremes of heat from absolute zero to 400°C (for gallium arsenide tunnel diodes) do not generate enough electron-hole pairs and excess electrons to increase markedly in percentage the original number of these carriers contributed by the doping materials. In the transistor, however, light doping is used and an operating temperature of 100°C materially affects its characteristics

(iii) The tunnel diode can with-stand relatively much larger doses of nuclear radiation compared to the transistor before its characteristics are changed, which is attributed to the heavy doping of semi-conductor material.