TRENDS IN ELECTRONICS

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ABSTRACT

This paper reviews briefly the trends in electronics from its inception and describes the ubiquitious applications of electronics in various fields of Defence Equipments and Systems.

Dawning of the Electronic Age

The Electronic age dawns with the opening of the present century.

In 1900-01, Richardson gave his law of "emission of electrons" from heated metal as a function of the temperature of the (emitter) metal. The heated metal has thus been the source of electrons for all types of thermionic or electron tubes.

The next step was (*a*) to overcome the effect of "space charge" around the metal by applying positive potential to an electrode (plate) placed nearby and to draw the electrons through the space and (*b*) to control their flow by electrode/electrodes placed in between emitter and plate at suitable potentials with respect to emitter.

Fleming's diode (with emitter or cathode and plate) having properties of detection and rectification came in November 1904. In 1907, Lee De Forest invented the triode (with cathode, control grid and plate) having properties of amplification and oscillation as well as detection *which revolutionised the whole system of electronic equipment.*

The invention of Screen-grid tube (with cathode, control grid, screen-grid and plate) by Hull followed in 1915-16. The pentode (with cathode, control grid, screen-grid, suppressor grid and plate) resulted from efforts to improve characteristics of triodes and screen-grid tubes.

About 1908, Armstrong established methods of reception by super-regenerative, heterodyne and super-heterodyne principles using triodes.

High-power (transmitting) triodes which required constant evacuation during the operation to obtain desired vacuum were developed.

Thus the foundation for transmitting and receiving equipment using thermionic tubes was laid by 1920.

Impact of Radio Telephone and Telegraph Links and Systems

The advent of S.W. radio telephone and telegraph systems about 1925 brought about many changes in trends of electronic development.

To start with, the design and construction of better types of receiving and transmitting triodes received considerable attention.

In receiving triodes either of glass or metal types, cathodes (filaments) were generally oxide-coated, and the grids and plates were of nickel. The idea of employing "getters" (of magnesium or barium or Zirconium) to obtain desired degree of vacuum in Vacuum triodes came about this time.

Transmitting triodes of plate dissipation upto 600-700 watts were made of glass envelope, with plates of molybdenum or tantalum, grids of molybdenum and cathodes of thoriated tungsten. For tubes of plate dissipation of the order of a few kilowatts, plates were in the form of copper cylinders which were part of envelope and cooled by circulating water or oil or by air blast; grids were of molybdenum, tungsten or tantalum and cathodes of tantalum. (The property of tantalum to absorb gas when raised to high temperatures was utilised).

The transmitter equipment upto 1925 consisted of triode self-oscillator (of large power at the transmitting frequency) and triode modulator and sub-modulator systems. Subsequent to 1925, to prevent "drift" and "scintillation" of (master) oscillator frequency which was now a fraction of the radiated frequency the transmitter consisted of a master oscillator followed by a buffer amplifier frequency multiplier and radio frequency power amplifiers, and the modulation system was applied either at low-power or high-power r.f. amplifier stage.

The receiving equipment evolved was of super-heterodyne and double Super-heterodyne types for telephone and telegraph systems respectively.

Impact of Radio Broadcasting

The impact of radio broadcasting produced a few important changes in trends of electronic developments.

From 1925 to 1934, modulation was applied at low-power r.f. amplified stage in broadcast transmitters all over. Since 1935, with increase in power of transmitters high efficiency modulation systems—High power class 'B', Doherty and Chireix systems have been developed.

"Negative Feed-back" principle (in which a portion of the output is fed back to input with 180° phase opposition) was invented by Black in 1934 and successfully applied to improve performances of amplifiers as well as transmitters.

Impact of Television

The advent of television produced certain outstanding changes in trends of electronics.

Cathode ray tubes which had originated several years ago now underwent considerable improvement so as to be suitable for picture tubes in television and display tubes in radar and allied works.

Modern method of scanning by electron beam (using interlaced scanning which finds wide application in electronics was evolved. The outstanding electronic contribution was the evolution of the "Mosaic screen" (an ingenious photo-electric device) which made the development of television camera possible.

Advent of V. H. F. and U. H. F.

Barkhausen-Kurz (or Positive Grid) Oscillator (evolved in 1919 for V.H.F. & U.H.F.) was improved upon by Gill and later on by Marconi and Mathieu. A modified form of Barkhausen Oscillator which employed grid in the form of a simple "helix" and capable of generating frequencies upto 6000 Mc/s was invented by Clavier in France about 1930. Split anode magnetron (consisting of split anode, cathode and electro-magnet) was developed between 1921—28 by Hull, Haban and Yagi.

It was known as early as end of 1935 that range, bearing and elevation of an aircraft could be measured by the reflection of a pulsed-wave of 10 metres from the target. This gave birth to Radar. The "Home Chain Radar Stations" on wave-lengths 10 to 12 metres were opened along the eastern coast of England. In 1938-39, Butement experimenting on 1·5 radar metres for ship location recognised this as solution of the problem of detection of low-flying aircraft. Another home chain radar stations on 1·5 metres were then opened.

In 1940, several concerns in cooperation with Air Ministry and Department of Supply as well as various Universities in Great Britain developed and constructed radars on centimetre wave-lengths for anti-aircraft fire control, search light work and use on aircraft and ship.

Trends Subsequent to 1945

In the post-war period, the most outstanding contributions have been on "molecular and solid state electronics" leading to devices and equipment giving low noise, very high stability (a few parts in 10^{10}), small size, considerable robustness, low energy consumption and long life.

Only some of the important advancements in different fields of electronics are discussed below—

(a) Microwave Tubes on entirely new principles

As the tubes developed so far are unsuitable for use at decimetric and centimetric wave-lengths, special micro-wave tubes based on entirely new principles have been evolved for use at frequencies 1,000—90,000 Mc/s (30 cms-0·333 cms). Broadly, they are of three types as given below—

(1) *Tubes based on interaction of beam and cavity*

Klystron is the most important tube of this class. A klystron (two-cavity-type) consists of an electron gun, an input cavity (buncher), a drift space, an output cavity (catcher) and collector. In operation, the buncher gathers the electrons from the gun into small "bunches" spaced at intervals of time (determined by the frequency generated) which pass through the catcher at those times when they are able to give up their Kinetic energy to the r.f. field of the resonator.

A two-cavity Klystron operates as amplifier, frequency multiplier and oscillator. Three and multi-cavity Klystrons operate as high-power pulsed oscillators in micro-wave range. A reflex Klystron is used as low-power oscillator in centimetre range.

(2) *Tubes based on interaction of beam and circuit (slow wave structure)*

Travelling wave tube is the most important tube of this class. A travelling wave tube consists of a cathode, a focussing eletrode, input guide, slow-wave structure (helix), output guide, collector and magnetic field coils. In operation the wave gathers the electrons into bunches which excite oscillations in the out put compartment of the tube. The electromagnetic wave travelling along the

Both the cavity maser and the travelling wave maser have (minimum) noise figures of the order of 0·1 db.

(3) *Parametric Amplifiers*

In a conventional amplifier, d.c. power is converted into power at signal frequency, whereas in the parametric amplifier power comes from the pump (variable reactance element) which may either be a ferrite, or junction diode or an electron beam.

The principle of parametric amplification is as follows—

"If in an oscillatory circuit, either the capacitance or the inductance is varied periodically at an appropriate frequency with appropriate phase, electrical oscillations can be maintained in the circuit".

Two oscillatory circuits 1 and 2 (of frequencies W_1 and W_2) are coupled by varying capacitance (i.e. variable reactance element) 'C' say. The pumping frequency $W_3 = W_1 + W_2$. If pump amplitude is large enough, oscillation will occur at both W_1 and W_2; *for smaller pump amplitudes*, circuit 1 (W_1) acts as an amplifier over a finite band of frequencies.

The arrangement when $W_3 = W_1 - W_2$ becomes important at *micro-wave frequencies*. The (minimum) noise figure varies from 0·8 to 9·4 db depending upon variable reactance element used.

(c) **Transistors and Semi-Conductors**

The invention of the transistor (a semi-conductor device) in 1948 by Bardeen and Brattain marked the beginning of new era in Electronics. The original device was considerably developed, soon after by Shockley who gave a new theory of conduction in semi-conductors of the germanium type.

Junction transistor, photo transistor, junction diodes and photo diodes were discovered, followed by an array of new semi-conducting devices.

Transistors and semi-conductors being of extremely small size, considerable robustness, low energy consumption, and extremely long life possess outstanding advantages for majority of applications.

In October, 1958, Esaki discovered a new phenomenon in junction diodes which had been prepared *in a special way*. These diodes, called "tunnel diodes" (or Esaki diodes) exhibit remarkable properties which have unusual significance in the field of electronics. Tunnel diodes, unlike transistors and conventional diodes have no frequency limitations, require 1/100 of the power of a transistor, have their switching time (when used for computers and pulse communications) as short as 10^{-12} of a second, are unaffected even when exposed to nuclear radiation and with temperature extremes. In addition, they take such tiny space that an entire electronic exchange employing them could be fitted into a coat closet.

Applications to Defence Equipments and Systems

Prior to 1945, the application of electronics to Defence equipment was *mainly* in (*a*) H. F. and V.H.F. Communication sets, employing tubes and techniques developed upto 1945, (*b*) V.H.F. and Microwave Radar sets employing older types of V.H.F. tubes and Magnetrons as well as crystal receivers, and (*c*) V. T. Fuzes employing older types of tubes and usual circuit elements.

Subsequent to 1945, electronics have been applied or are being applied to far greater fields for the defence needs. Some of the important fields in which applications have been made are given below—

(1) *V.H.F. and Microwave Communications*—The equipments at terminals and repeaters for V.H.F. communications employ mostly travelling wave tubes and sometimes both travelling wave tubes and klystrons. Low noise travelling wave tubes of special design have been used as low noise amplifiers on the receiving side. The equipments at terminals and repeaters for micro-wave communications employ mostly magnetrons, klystrons and also travelling wave tubes. Low noise parametric amplifiers have been introduced on receiving side in tropospheric scatter-wave systems. Attempts have been made to transistorise V.H.F. equipment by using difused base germanium transistors, semi-conductor diodes and tunnel diodes.

The system of very great interest to defence is the "microwave tropospheric scatter-wave link" which gives communication over distance from 200 to 300 miles without repeater.

Recently a broad-band tropospheric scatter-wave system has been developed by I.T.T. Ltd. This can transmit from 120 to 600 telephone channels or a television channel upto at least 200 miles in 680—900 Mc/s band.

(2) *Micro Wave Radars*

With the development of electronic tubes and devices like (1) Klystrons Travelling Wave Tubes, Magnetrons, etc. suitable for decimetric, centimetric and millimetric ranges giving larger and larger power outputs, (2) stable low-noise micro-wave amplifiers and receivers, (3) efficient MTI and IFF systems, (4) transistors and semi-conductor devices, (5) printed circuitry, micro-miniaturisation and micro-strips, it has been possible to design and develop modern post-war centi-metric and millimetric radar systems of various specifications for various purposes.

Some of the *typical* radars developed abroad have their peak powers and frequencies given below. Approximate detection ranges are given with each.

1. *Early Warning Radar*—Peak power 5 MW, 3000 Mc/s (10 cm). (Detection range 1000—1200 miles).
2. *Search Radar*—Peak power—2 MW, 3000 Mc/s (10 cms). (Detection range 200-300 miles).
3. *Fire-control Radar*—Peak power 150 KW, 3 cms. (Detection range 25-30 miles).
4. *Air Field and Harbour Surveillance Radar*—Peak power 15 KW, 8·6 mm Wave-length.

   (Range about a few miles—high resolution).
5. *Air-Surveillance Radar*—Peak power 800 KW, 3000-3040 Mc/s (10 cms band).

   (Range 100 miles or more).
6. *Marine Navigational Radar*—Peak power upto 50 KW, 9320-9500 Mc/s (3 cms band).

   (Range 10-15 miles).

One of the most outstanding achievements of post-war radar development is DOPPLER RADAR. The purpose of this is the detection of mobile targets like men and vehicles in severe ground clutter conditions. The radial speed of targets to be detected may vary between 1 and 20 metres/sec. The detection range is about 300 metres for walking men and 2500 to 3000 metres for vehicles.

An ominirange DIGITAL RADAR has been developed in USA, which can detect inter-continental ballistic missile at a range of 3000 miles.

(3) *V.T. Fuzes*

This electronic device consisting of an oscillator of V.H.F. (or centimetric) waves together with the auxiliary devices (like A.F. amplifier, switching circuit, etc.) is housed inside an anti-aircraft shell. Each shell therefore contains several sub-miniature metal (thermionic) tubes and other components as well as power supply and an antenna. Thermionic tubes and other components inside the device are able to stand the colossal impact of firing. Within 15—20 metres of the aircraft, the device explodes the shell automatically (by means of waves reflected from the target) showering the aircraft with fragments. Thus the efficacy of anti-aircraft fire when the guns are controlled by radar and the shells are equipped with these radio fuzes increases immeasurably.

Attempts have been made to transistorise the oscillator, A.F. amplifier and switching circuits in the fuze.

(4) *Computers*

Considerable advancement has been made since 1945 on the design and construction of computers for Defence needs.

The computers are of two types, —(*a*) Analogue Computers and (*b*) Digital computers.

(*a*) *Analogue Computers* (which form the essential parts of many defence systems like Radars, Guided Missiles systems, etc.) are designed to solve specific types of differential equations arising in aero-dynamical, mechanical, hydro-dynamical, acoustical and other systems by setting up electrical analogues. Analogue computers require a large number of high-gain d.c. amplifier for integrators, differentiators and adders. Many types of function generators are also required for solution of non-linear equations. D.C. Vacuum—tube ampl fiers employing feedback of various types have been used in analogue computers for functions as integrators, differentiators and adders and requires to be stabilised against drift and circuit instability. The accuracy of an analogue computer is directly dependent upon the quality of the amplifiers in its basic circuits.

A voltage feedback transistor integrator has also been built. A temperature stabilised integrator can also be built using transistors.

(*d*) *Digital Computers* can give greater accuracy and mumerical solutions and can generate non-linear functions required for solution of certain important types of equations.

The essential components of a digital computer are (1) Control unit; (2) Storage unit and (3) Arithmetic unit. In addition, input devices such as tapes, timing or synchronising devices, output devices such as typewriting or coded tapes and power supply arrangements are incorporated.

The equipment requires a large number of pulse amplifiers and flip-flop stages consisting of either vacuum tubes or transistors and semi-conductor diodes. Ferrites (Semi-conductor devices) are being used now in computer "memories" as well as logical switching circuits. Ferrite cores of extremely small dimensions are arranged in the form of a matrix, and such matrix planes stacked one above the other can give a "compact memory" with access time of 1 micro-second.

Medicine

There have been many applications of electronics in medicine. Some of them are given as follows—

It has been found that if a hypertension patient is placed in the field of a generator radiating energy at 50 Mc/s in pulses of duration ten-millionth of a second, his blood pressure and temperature decreases considerably and drowsiness is produced.

It has also been found that subjecting the human nervous system to the action of weak square pulses having frequency from one to forty pulses per second produces sleep with no harmful side effects.

A miniature electronic probe for detailed investigation of human stomach and intestines has been evolved. The patient swallows the probe (containing a transmitter) like a pill. The radio probe passes down the aesophagus into the stomach and from there into the intestines signalling the values of such important medical characteristics as pressure, acidity, etc. The signals radiated by this unusual transmitter are received by radio receiver and recorded on the tape of an oscillograph. The recorded curves help the physician to diagnose the ailment. The radio probe is a real wonder of engineering as all its components are housed in a plastic case only 24 mm long.