EXPONENT
Empowering The Common Man

The Exponent Group of Journals For
Electronics

Volume: 4 - Number 1
Dec 2015 - Feb 2016

The Exponent Group of Journals for Electronics is an E-journal published Quarterly by **Booktionary Publishing House.**

Contents

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Editorial

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Dear Readers,

On behalf of editorial board, it gives me an immense pleasure to present this volume of the Journal of Electronics under Exponent Group of Journals. Through this journal, we are attempting to enhance new knowledge and technology amongst the youth, common man, academic and research community, professionals and industry practitioner. We are also focusing to introduce in each volume of this journal as a basic platform for various subjects in the electronics areas in order to realize new theories and developments for common man communities; thus bridging the gap between common man and technology, later research theories and industrial developments are also incorporated. Electronics Journal provides a platform for common man, researchers, industrialist and students to submit on-going research activities and developments in these areas. Overall the main objective is to impart quality education through these articles/papers.

In continuation with the theme of journal, we are publishing the papers which are not necessarily based on original research, but the subject of the papers are selected to match up with the goal of the journal, i.e. to enhance social awareness of latest technology in the field of Electronics and Tele-communication.
In this Volume of Electronics Journal we are presenting five papers.

First paper in this volume titled “Shrinking Radars” presents how the Radar setup which used to be huge one needing large infrastructure to accommodate is now reducing to smaller size. Just like all our devices are shrinking every year, so are the radars. However, there are huge radar systems still being built but they have their own purpose.

Our second paper titled “Introduction to Power Electronics” gives a description and overview of power electronic technologies including a description of the fundamental systems that are the building blocks of power electronic systems.

Next Paper titled “DIGITAL ELECTRONICS PART-VIII DIGITAL MEMORY DEVICES” is in continuation of series started earlier volumes . It discusses different types of memory devices which are used in Computers, microprocessor and microcontroller based system.

Next paper in this volume titled “OPERATIONAL AMPLIFIERS PART-II OP-AMP LINEAR APPLICATIONS” is continuation in series on “OPERATIONAL AMPLIFIERS”. It deals with linear applications of OP-AMPs such as Inverting and Non Inverting Amplifier . These amplifiers are used in number of analog systems.

Our last paper in this volume titled “An extremely simple FMCW Radar” deals with two types of radars, pulsed and continuous wave. A pulsed radar transmits a short pulse and listens to the echo for a few microseconds, whereas the continuous wave (CW) radar, as the name suggests, continuously transmits radio waves and receives the echo at the same time.

We hope all the papers/articles presented in this volume will be useful to the readers in the field of Electronics and also to a common person.

Shrinking Radars!

- Salil Tembe

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Whenever we hear the word "Radar", a picture comes to mind with a rotating line across a circular display with a few objects moving here and there. This is a general perception of radars that we have after watching a few Hollywood movies. Just like all our devices are shrinking every year, so are the radars. Well, there are huge radar systems still being built but they have their own purpose.

You may have come across the term "System on a Chip" (SoC) where RAM, storage and the processor are all built on one single silicon chip and that is how it is these days if you happen to open up your tablet computer or your cellphone. SoC has made it possible to shrink our devices by eliminating the need to use separate chip for RAM, separate chip for mass storage and a separate chip for processing the data. Even the graphics processor is now embedded into the same SoC integrated chip. One chip and it takes care of everything and that is why we have super slim and super powerful smartphones available these days giving more space to have a huge battery inside.

Nevertheless, our main focus is along the same lines but with regards to radars.

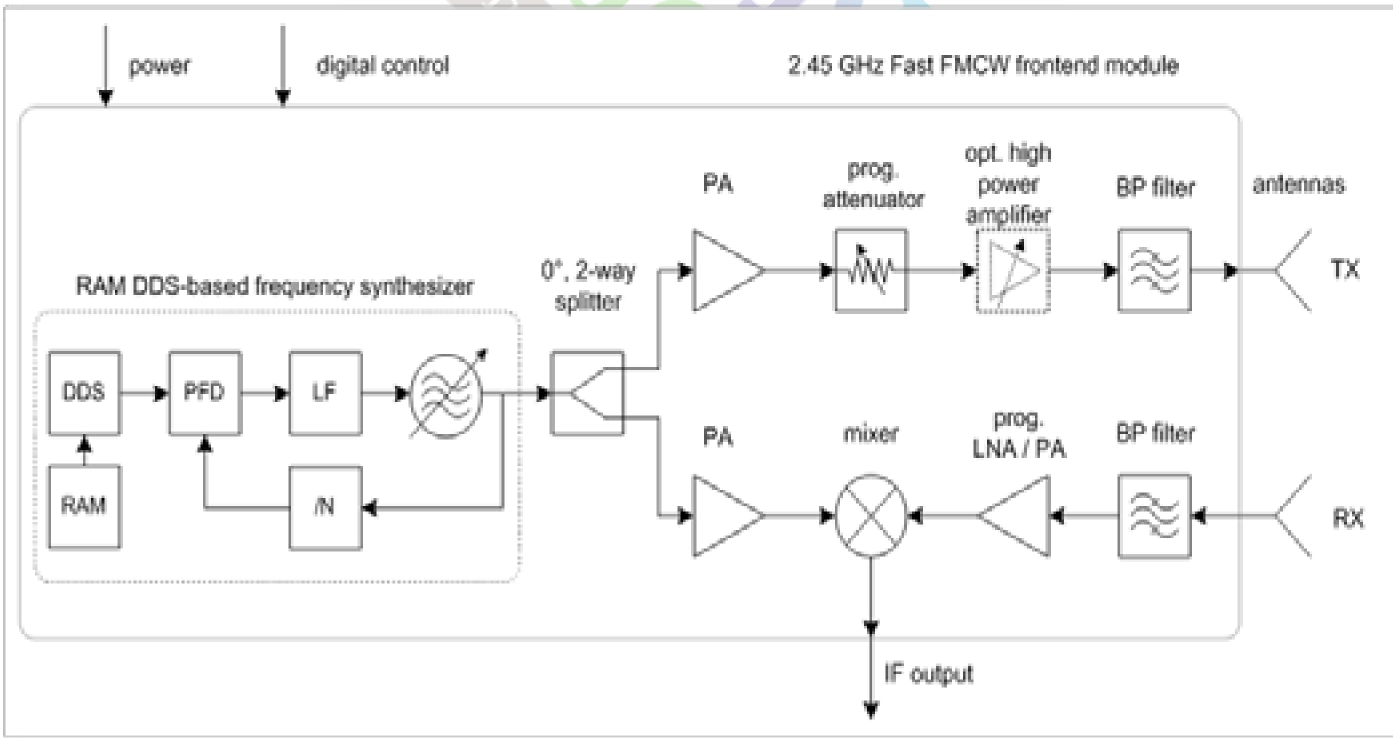

Figure 1 Radar front end module where most of the analog circuitry exists operating at very high frequencies

Over the last several decades, as electronics has progressed and started becoming digitized, so have the radars. Huge amounts of data processing which was done using analog circuits consisting of tens of transistors, filters, frequency converters and analog signal processors is now done entirely in the digital domain. With increasing processing power and shrinking size of computing equipment, it is possible to process the signals in real-time on single chip multi-core digital signal processors. But we need to understand what kind of signals are processed on the digital domain and we can only come to understand that upon looking at the basic block diagram of a radar.

Inevitable analog components

Figure 1 only shows the front end module, that is basically where the radar pulse is transmitted or received from. Depending on the radar application, the radar is designed to output frequencies ranging from as low as 100MHz to as high as 100GHz.

Abbreviations used in the block diagram:

- RAM : Random access memory
- PFD : Phase frequency detector
- DDS : Direct digital synthesizer (Use to generate any type of wave)
- LF : Low pass filter
- /N : divide by N
- Prog. Attenuator: Programmable attenuator
- BP : Band pass filter
- TX : Transmitter
- RX : Receiver
- LNA : Low noise amplifier
- PA : Power amplifier

As shown in the Figure 1, most of these components operate at the final frequency the radar is designed to transmit. Suppose it is designed to operate at 24GHz, it will be difficult to handle these signals digitally directly at that frequency. Instead, something called as up conversion is used.
Using the principle of frequency mixing, we can produce a higher frequency from a lower frequency. This is done with help of a mixer.

Up conversion to high frequency

The DDS generates a low frequency, say 100MHz signal which is then simply multiplied with the fixed high frequency carrier, say 24GHz. The result is 24GHz + 100MHz = 24.10GHz which is then finally transmitted. The power of the signal is still quite weak. If we want to look at targets located at 20kms away, we need to transmit a high power signal and that is done with the PA (Power amplifier).

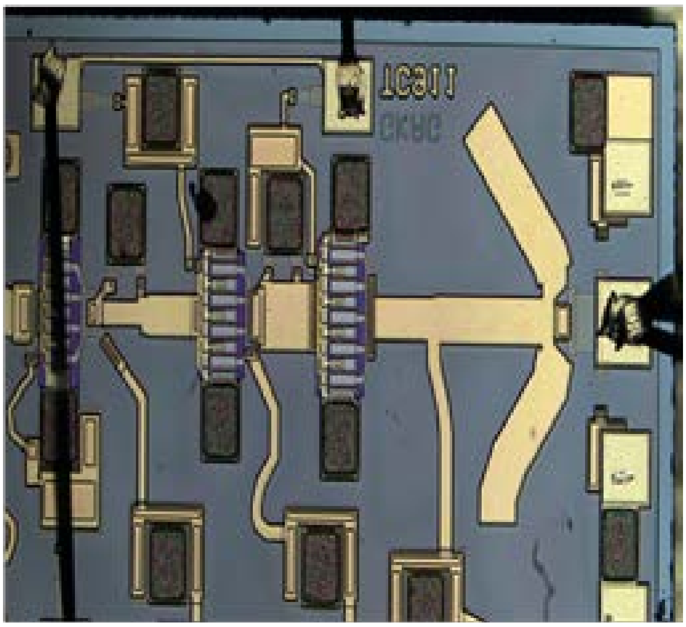

Figure 2 Final output filter of LNA under the microscope at 100x magnification. (SAMEER Atmospheric Radar Division, Mumbai)

When the transmitted signals hits the target and reflects back, it needs to be picked up by the receiver. The received signal is always very very weak and needs to be amplified. Again, this is something that needs to be done in analog domain because digital circuits cannot directly handle such high frequency signals yet. LNA and a bunch of filters make the signal ready for “mixing”. Mixing again converts the signal frequency down to something that can be handled by the digital receiver and this is labelled as “IF” (Intermediate frequency).

This is where digital signal processing plays a huge role. Once IF is converted to digital signals, complex digital signal processing algorithms can take over and extract the target’s size, speed, direction, distance and so on. All these algorithms required large transistor circuits in the past, but with signal processors that has been eliminated and replaced with processor circuit boards as small as your set top box sitting on your TV. Just to point out the fact, your TV set top box is well capable of processing radar signals and all you need to do is feed it with appropriate signal.

Such signal processing boxes are known as Digital receivers. This has brought down the size of radars tremendously. Again, size of the front end is what makes the radar quite bulky and that too can be shrunken further and designed to fit on a silicon chip!

Power = size!

Military radars and weather radars are something that are used to detect targets located at several kilometers away. To successfully detect those targets at such large distances, you need more power. More power equals, heavier amplifiers that may require its own cooling system which makes radars as huge as a truck.

But, if you are looking to detect objects just a few meters away, you can be well off using single chip radars which are making its way through into consumer markets.

Like I said, power is proportional to size, similarly, size is also inversely proportional to frequency.

The higher the frequency, lower the component size. At 66GHz, the filters, power amplifiers are so tiny, you need a microscope to look at them. Here is an image of just one of the sections inside a LNA in the receiver section and it is designed to operate at 35GHz.

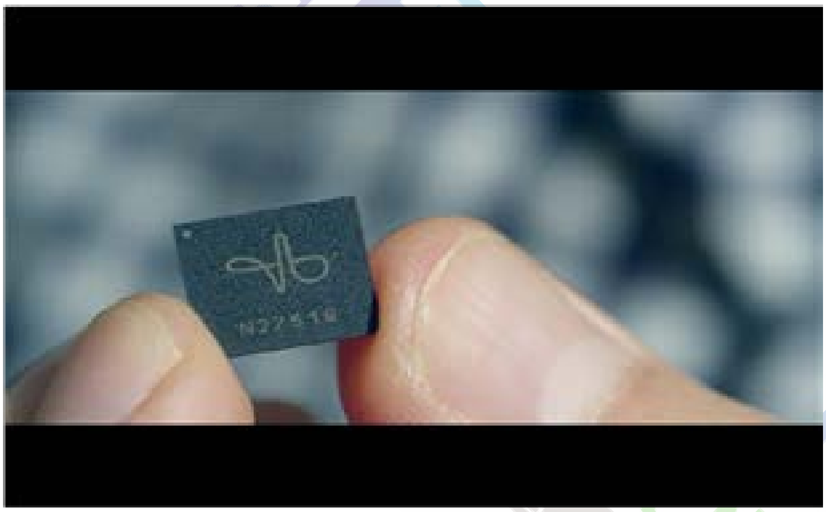

Figure 3 Project Soli radar on a chip - Google ATAP's Project Soli

Project Soli is just one of the many "Radar on a Chip" projects undertaken by several research organizations world over.

Just as we saw, there are analog amplifiers and mixers and then there is a digital receiver to process the signals. Digital receiver simply being a general applications process with lot of processing power that can be programmed like any other processor in the world, we are simply left to design an equivalent analog front end (similar to one shown in the Figure 1).

Project Soli integrates a signal processor and the analog front end together and the result is a "Radar on a chip" operating at a whopping 66GHz.

If you haven't seen the video, go ahead and click on the link: https://www.youtube.com/watch?v=0QNiZfSsPc0

Others in the game

Google is not the only one in the game of one chip radars. Company called Omniradar has been making single chip radars for a while and they have even specified certain applications where it can be used.

The following image [3] from Omniradar's website is enough to explain some of its applications!

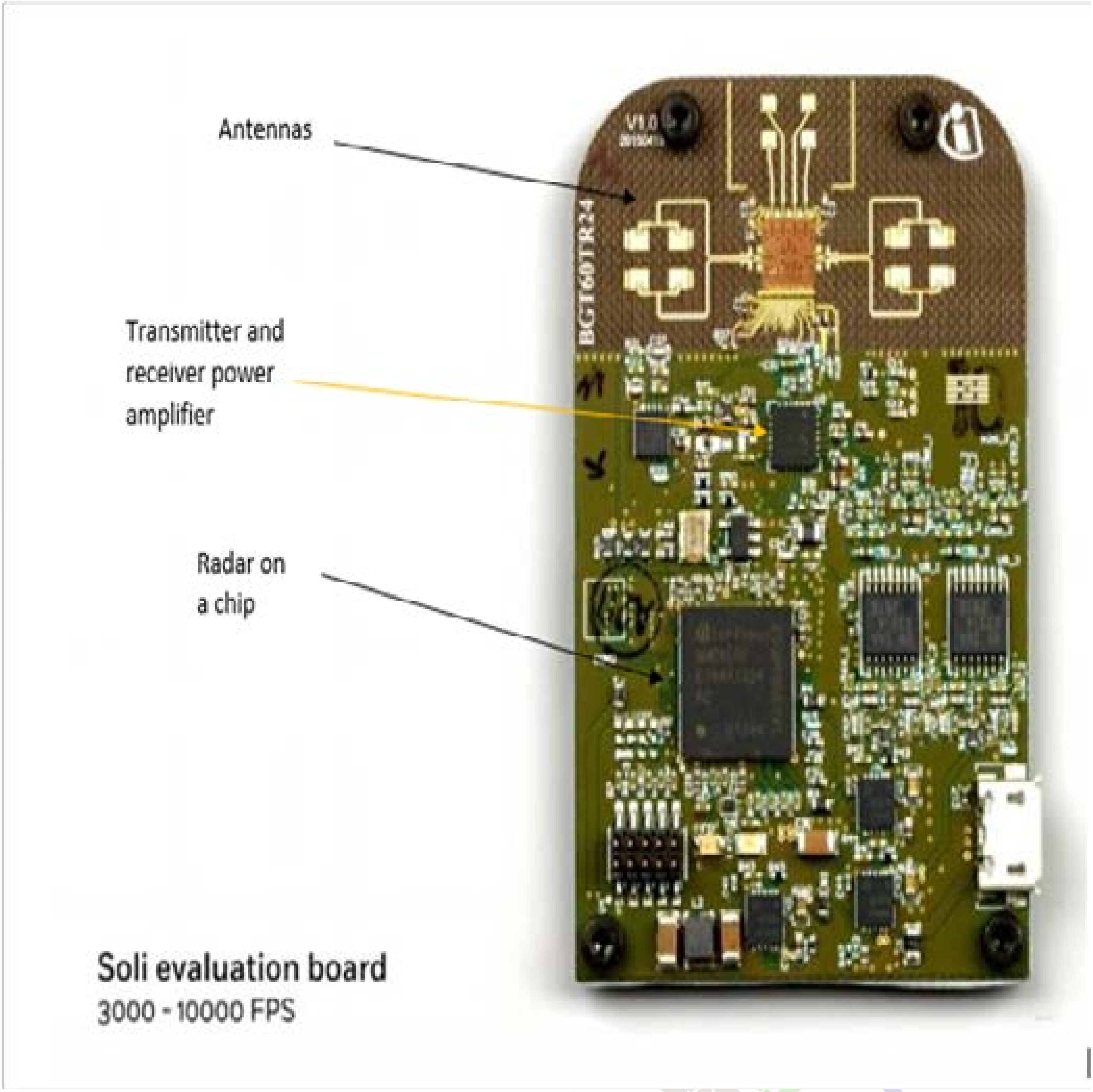

Figure 4 Project Soli's evaluation board

These tiny radars can come extremely handy in the future of Internet of Things where everything will be connected to a single network. It can be used for automatic turning on and off of lights in a room, detecting whether you are sleeping so that the computer can automatically turn off the lights and the TV in the room. YES! These radars can detect what you are doing because they are very sensitive. Although that is only possible if you have an appropriate algorithms running on the digital signal processor. Applications are tremendous!

ADAS – Advanced Driver Assistance System

ADAS has been on the rise in recent years. Some time ago, we had an article in the Exponent Group of Journals for Electronics (December 2014) which talked about how all the components inside any given vehicle are interconnected over the CAN bus.

Just another set of electronic components that have been getting installed in modern cars are “Radars”. Radars installed on the front, the back and on the sides to help the driver drive the vehicle [4] safely by maintaining proper distance with other vehicles on the road. It also comes handy while parking.

ADAS radars are quite tiny and they operate in the automotive band which is at 75GHz.

Figure 5 Applications of single chip radars

Conclusion

Watch out for tiny radars popping up in phones, gaming consoles, smart watches, modern vehicles, railways and much more. Radars are used everywhere and with modern signal processors and nanotechnology on the rise, they are going to shrink further!

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Introduction to Power Electronics

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Abstract

This article gives a description and overview of power electronictechnologies including a description of the fundamental systems that are thebuilding blocks of power electronic systems. Technologies that are described include: power semiconductor switching devices, converter circuits that processenergy from one DC level to another DC level, converters that produce variablefrequency from DC sources, principles of rectifying AC input voltage in uncontrolled
DC output voltage and their extension to controlled rectifiers, converters, AC to AC, AC TO DC, DC TO AC.
Key words- Introduction to power electronicsconverters, applications of power electronics.

1. Introduction

1. Power electronics (PE)

It is experienced tremendous growth after the introduction of thefirst solid-state power switch, the silicon controlled rectifier (SCR) in 1957. Today,almost all of the technologies that require control of power control utilize PE technology.

This chapter will give the reader an overview on the field of PE including: A description of the fundamentals of the power semiconductor switching devices.

Converter circuits that process energy from one DC level to another DC level.

Converters that produce variable frequency from DC sources.Principles of rectifying AC input voltage in uncontrolled DC output voltage andtheir extension to controlled rectifiers.

Converters that convert to AC from DC (inverters) or from AC with fixed orvariable output frequency.AC controllers.DC–DC–AC converters.Matrix converters or cycloconverters.

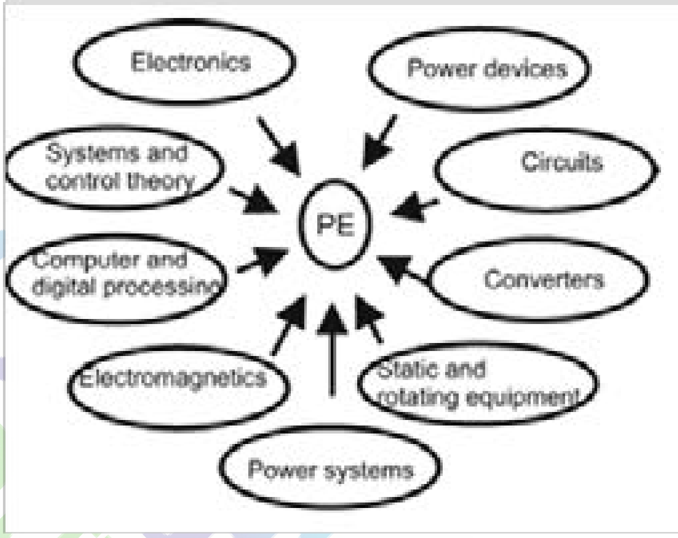

Fig 1. Power electronics & related topics.

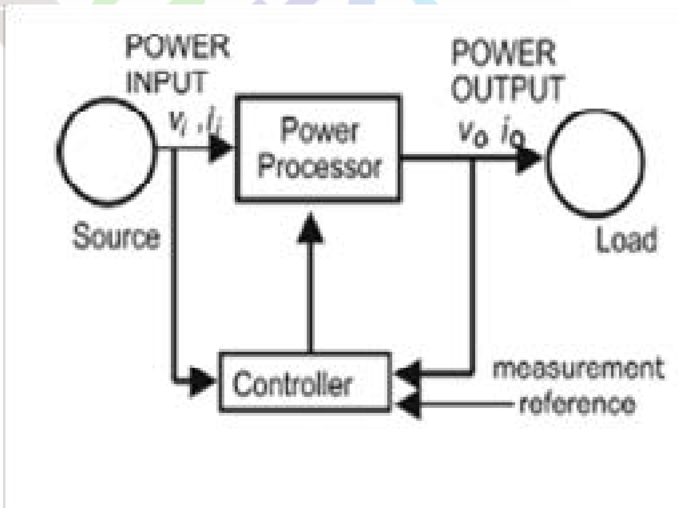

Fig 2. General Power electronics systems

2. General Power electronics systems

Power electronic circuits are used to control the power conversion from one ormore AC or DC sources to one or more AC or DC loads, and sometimes withbidirectional capabilities. In most power electronics systems, this conversion isaccomplished with two functional modules called the control stage and the powerstage. Fig2.shows the topology for a single source and single load converterapplication that includes a power processor (the power stage) and a controller (thecontrol stage). The converter, handles the power transfer from the input to output,or vice versa, and is constituted of power semiconductor devices acting asswitches, plus passive devices (inductor and capacitor). The controller is responsiblefor operating the switches according to specific algorithms monitoringphysical quantities (usually voltages and currents) measured at the system inputand or output.

3. Development

The development of devices and equipment able to individually or in combinationconvert efficiently electric energy from AC to DC, DC to DC, DC to AC,and AC to AC together with the changes that occurred in electrical power engineeringhas resulted in wide spread of PE in a large spectrum of applications.

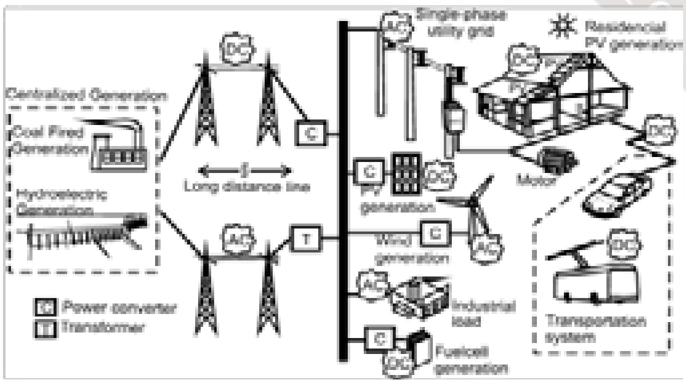

Fig 3. Power electronics and electrical energy generation transmission, storage, and distribution

2. Ultrasonic Power electronics and electrical energy generation transmission

Figure 3 shows how electrical energy generation is distributed for the end-user, showing transmission, distribution, storage, renewable energy sources and users.

In fact, nowadays PE is a key technology for all those sub-systems, and has spreadin many applications, examples including:

- Residential: heaters, home appliances, electronic lighting, equipment sources;
- Commercial: heaters, fans, elevators Uninterruptible Power Supply (UPS), AC and DC breakers, battery chargers;
- Industrial: pumps, blowers, robots, inductive heaters, welding, machine drive, portable sources;
- Transportation: electrical and hybrid vehicles, battery chargers, railroad electric system;
- Utility systems: high voltage direct current, generators, reactive compensators,
- interface for photovoltaic, wind, fuel cells systems, Flexible AC TransmissionSystem (FACTS) equipment;
- Aerospace: sources for spacecrafts, satellites, planes;
- Communication: sources, RF amplifiers, audio-amplifiers.

Power electronics will continue to be an enabling technology to address ourfuture electricity needs. It is expected that new power devices for higher power,higher frequency, and lower losses will continue to be invented. Global energyconcerns will provoke a large interest in the increase of the conversion efficiencyand more application of PE in power quality, distributed generation, energyconservation, and smart grids. The integration of power and control circuitry intofunctional modules will result in systems solutions that are highly integrated intopackaged products that will be both more reliable and affordable.

3. Power Semiconductor Devices

Electronic switches capable of handling high voltage and current operations athigh frequency (HF) are the most important devices needed in the design of energyconversion systems that use PE. For the purposes of this discussion we will definethe concept of an ideal switch. An ideal power electronic switch can be represented as a three terminals device as shown in Fig. 4.

The input, the output, and acontrol terminal that imposes ON/OFF conditions on the switch. A switch isconsidered ‘‘ideal’’ when it is open, it has zero-current through it and can handleinfinite voltage. When the switch is closed it has zero-voltage across it and can carry infinite current. Also, an ideal switch changes condition instantly, whichmeans that it takes zero-time to switch from ON-to-OFF or OFF-to-ON. Additionalcharacteristics of an ideal switch include that it exhibits zero-power dissipation,carries bidirectional current, and can support bidirectional voltage. If weplot the switch current (i) with respect to its voltage (v) we define four quadrantsthat are often referred to as the v-i plane and are shown in Fig. 5. By definition,an ideal switch can operate in all four quadrants.

Practical or real switches do have their limitations in all of the characteristicsexplained in an ideal switch. For example, when a switch is on, it has some voltageacross it, known as the on-voltage and it carries a finite current. During the offstage, it may carry a small current known as the leakage current while supporting afinite voltage. The switching from ON-to-OFF and vice versa does not happeninstantaneously. Of course, all actual switching devices take times to switch andwe define these characteristics as the delay, rise, storage, and fall times. As aconsequence of the above two non-ideal cases, there is voltage and current acrossthe switch at all times, which will result in two types of losses. The first loss occursduring the on and off-states and is defined as the ‘‘conduction loss’’. The secondloss is defined as the ‘‘switching loss’’ which occurs just as the switch changesstate as either opening or closing. The switch losses result in raising the overall.

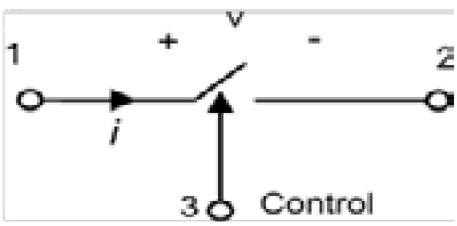

Fig 3.Ideal switch

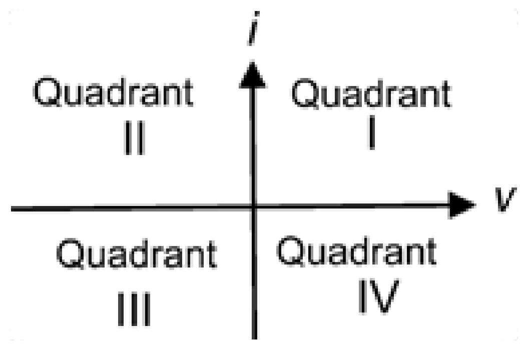

Fig 4.Four quadrant switch

4. Power converter topology& Major Application

DC to DC	Chopper	Constant to variable DC or variable to constant DC	
DC to AC	Inverter	DC to AC of desired voltage and frequency	
AC to DC	Rectifier	AC to unipolar (DC) current	
AC to AC	Cycloconverter, AC-PAC, Matrix converter	AC of desired frequency and/or magnitude from generally fine AC	

Fig 5. Converters

6. Conclusion

This was the introduction to power electronics & for different desired application. This is advanced field where entire power conversion & control takes place. This series of articles are utilized for the enhancing the knowledge of common man in the society ;so open source help of journals ,online Books &articles are usedt from the internet. Accordingly copyrights cannot be claimed since the references are cited in the articles.

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Digital Electronics Part-VIII Digital Memory Devices

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Abstract

Everyone of us use digital devices such as desk top computer, Lap top computer, mobiles, ipod, ipad,and so on but very few know base of these devices i.e. digital electronics. Through series of articles in this and subsequent volumes we shall present this very useful topic for common user.

This paper is therefore eighth paperin this series of digital electronics i.e. digital memory devices can be constructed using Flip Flops based on any of logic families and are further used memory in number of digital devices stated above . There are different types of memory devices such as RAM (Random Access Memory - further classified as Static RAM and Dynamic RAM) , ROM (Read Only Memory – further classified as Masked ROM, Programmable ROM, EPROM (Erasable and Programmable ROM), EEPROM (Electrically Erasable and Programmable ROM).

Introduction

A memory device in a computer is just like a human memory brain and is used to store data and instruction. Computer memory is the storage space in computer where data is to be processed and instructions required for processing are stored.

The memory is constituted from into large number of small parts called as cell. Each location or cell has a unique address which varies from zero to memory size minus one.

For example if computer has 64k bytes, then this memory unit has 64 * 1024 = 65536 memory location. The address of these locations varies from 0 to 65535.

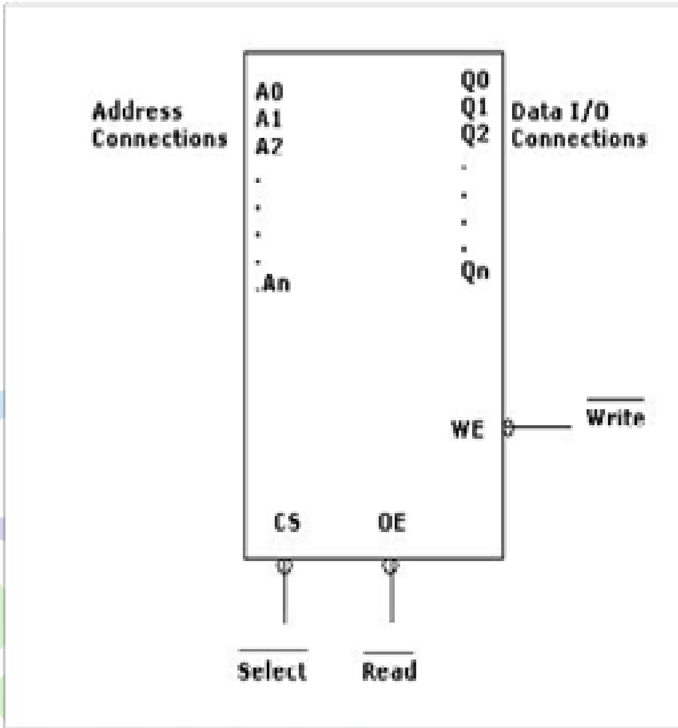

Fig.1. Typical Digital Memory

As shown in fig.1, any digital memory device consist of Address lines A0 to An, Data lines D0 to Dn and control signals such as Select, Read and Write.

Number of Address lines will decide how much data a memory device can hold e.g. if Number of Address lines are 10 , A0 to A9,then it can hold 210 = 1024 data units denoted as Kilo data units.

Number of Data lines decides number of bits in each data unit. e.g.if there 4 data lines it is known as nibble, 8 data lines as byte, 16 data lines as word, 32 data lines as double word. Generally most of the digital devices has 8 data lines i.e. bytes.

If a device has say 16 address lines and 8 data lines it will called as 64 Kbyte device.

1. Flip Flops and Memory Device:

Let us see how we can obtain a memory device from Flip flops. In earlier articles we have seen what is Flip flop, amongst various types of FFs, D-FF is used as single bit of memory. If we cascade 8 D-FFs together it forms a Byte. When we arrange many such arrays of D-FFs it forms into Memory Device. E.g. if we arrange 1024 such arrays of D-FFs it will form into memory device of 1 Kbyte.

2. Types of Memory :

With reference to a computer memory is primarily of two types:

- Internal Memory − cache memory and primary/ main memory
- External Memory − magnetic disk / optical disk etc
- Capacity in terms of storage increases.
- Cost per bit of storage decreases.
- Frequency of access of the memory by the CPU decreases.
- Access time by the CPU increases.

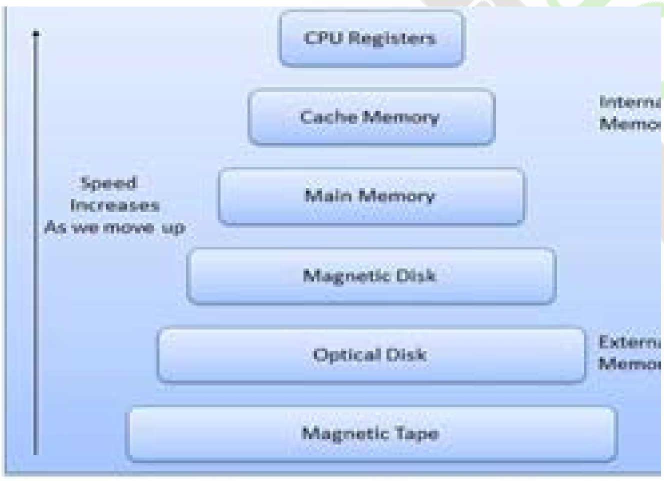

Fig.2 Characteristics of Memory Hierarchy are following when we go from top to bottom.

3. RAM

A Random Access Memory ,RAM constitutes the internal memory of the CPU for storing data, program and program result. It is read/write memory. It is called random access memory (RAM).

Since access time in RAM is independent of the address to the word that is, each storage location inside the memory is as easy to reach as other location & takes the same amount of time. We can reach into the memory at random & extremely fast but can also be quite expensive.

RAM is volatile, which means a data stored in it is lost when we switch off the computer or if there is a power failure. Hence, a backup uninterruptible power system (UPS) is often used with computers. RAM is small, both in terms of its physical size and in the amount of data it can hold.

RAM has two types :

- Static RAM (SRAM)
- Dynamic RAM (DRAM)

- **Static RAM (SRAM)**

Static means that the memory retains its contents as long as power remains applied. Data is lost when the power goes down due to volatile nature. SRAM chips use a matrix of 6-transistors and no capacitors. Transistors do not require power to prevent leakage, so SRAM need not have to be refreshed on a regular basis.

Because of the extra space in the matrix, SRAM uses more chips than DRAM for the same amount of storage space, thus making the manufacturing costs higher.

Static RAM is used as cache memory needs to be very fast and small.

- **Dynamic RAM (DRAM):**

DRAM, unlike SRAM, needs to be continually refreshed in order to maintain the data. This is done by placing the memory on a refresh circuit that rewrites the data several hundred times per second. DRAM is used for most system memory because it is cheap and small. All DRAMs are made up of memory cells. These cells are composed of one capacitor and one transistor.

RAM IC No.	Description
2114N-2L	2114 1Kx4 200ns Low Power RAM
CY7C130-30PC	CY7C130 1Kx8 30ns CMOS RAM
6116P-3	6116 2Kx8 150ns CMOS RAM
CY7C128-25PC	CY7C128 2Kx8 25ns CMOS RAM
23K640-I/P	23K640 64k SPI Bus Serial SRAM
6264P-12	6264 8Kx8 120ns CMOS RAM
CY7C185-15PC	CY7C185 8Kx8 15ns CMOS RAM
23K256-I/P	23K256 256k SPI Bus Serial SRAM
43256-10L	43256 32Kx8 100ns Low-Power CMOS RAM
62256	62256 32Kx8 CMOS RAM
62256ALP-10	62256 32Kx8 100ns Low-Power CMOS RAM
62256ALP-12	62256 32Kx8 120ns Low-Power CMOS RAM
628128	628128 128Kx8 CMOS RAM
628128LLP-70	628128 128Kx8 70ns Low-Power CMOS RAM
681000	681000 128Kx8 CMOS RAM
628512	628512 512Kx8 CMOS RAM
684000	684000 512Kx8 CMOS RAM

SMD RAM packages

Part No.	Description
HT6116-70S	2Kx8 70ns CMOS SRAM - SMD
HT6264-70S	8Kx8 70ns CMOS SRAM - SMD
62256-70S	32Kx8 70ns CMOS SRAM - SMD
CY62256L-70SNC	32Kx8 70ns CMOS SRAM - SMD
681000-7S	128Kx8 70ns CMOS SRAM - SMD
628512LLFP-70	512Kx8 70ns Low-Power CMOS RAM

Video RAM

Part No.	Description
4116	4116 16k Video RAM
4164	4164 64k Video RAM
41256	41256 256k Video RAM
514256	514256 256k Video RAM
511000P	511000P 1M Video RAM

Table 1. Different type of RAM ICs

4. ROM

ROM means Read Only Memory which can only read but cannot write on it. This type of memory is non-volatile. The information is stored permanently in such memories during manufacture.

A ROM, stores such set of instructions called as monitor program which is required to start computer when electricity is first turned on, this operation is referred to as bootstrap. ROM chip are not only used in the computer but also in other electronic items like washing machine and microwave oven.

Following are the various types of ROM –

- MROM (Masked ROM):

The very first ROMs were hard-wired devices that contained a pre-programmed set of data or instructions. These kind of ROMs are known as masked ROMs. It is inexpensive ROM.

- PROM(Programmable Read Only Memory):

PROM is read-only memory that can be modified or programmed only once by a user. The user buys a blank PROM and enters the desired contents using a PROM programmer. Inside the PROM chip there are small fuses which are burnt open during programming. It can be programmed only once and is not erasable.

- EPROM (Erasable and Programmable Read Only

Memory)

EPROM can be Erased by exposing it to ultra-violet light for a duration of upto 40 minutes. Usually, an EPROM eraser achieves this function. During programming an electrical charge is trapped in an insulated gate region. The charge is retained for more than ten years because the charge has no leakage path. For erasing this charge, ultra-violet light is passed through a quartz crystal window (lid). This exposure to ultra-violet light dissipates the charge.The users can reprogram this chip as per their requirement. During normal use the quartz lid is sealed with a sticker.

- EPROM sizes and types

EPROMs are available in several sizes both in physical packaging as well and storage capacity. While parts of the same type number from different manufacturers are compatible as long as they're only being read, there are differences in the programming process.

Most EPROMS could be identified by the programmer through "signature mode" by forcing 12 V on pin A9 and reading out two bytes of data. However, as this was not universal, programmer software also would allow manual setting of the manufacturer and device type of the chip to ensure proper programming.

Fig. 3 27C256 EPROM IC

EPROM Type	Size — bytes
1702, 1702A	256
2704	512
2708	1 KB
2716, 27C16, TMS2716, 2516	2 KB
2732, 27C32, 2532	4 KB
2764, 27C64, 2564	8 KB
27128, 27C128	16 KB
27256, 27C256	32 KB
27512, 27C512	64 KB
27C010, 27C100	128 KB
27C020	256 KB
27C040, 27C400	512 KB
27C080	1 MB
27C160	2 MB
27C320, 27C322	4 MB

Fig. 4 27C256 EPROM IC

- EEPROM (Electrically Erasable and Programmable Read Only Memory)

The EEPROM is programmed and erased electrically. It can be erased and reprogrammed about ten thousand times. Both erasing and programming take about 4 to 10 ms (millisecond). In EEPROM, any location can be selectively erased and programmed. EEPROMs can be erased one byte at a time, rather than erasing the entire chip. Hence, the process of re-programming is flexible but slow. Therefore it is more popular.

5. Serial Access Memory

Sequential access means the system must search the storage device from the beginning of the memory address until it finds the required piece of data. Memory device which supports such access is called a Sequential Access Memory or Serial Access Memory. Magnetic tape is an example of serial access memory.

6. Direct Access Memory

Direct access memory or Random Access Memory, refers to conditions in which a system can go directly to the information that the user wants. Memory device which supports such access is called a Direct Access Memory. Magnetic disks, optical disks are examples of direct access memory.

7. Cache Memory

Cache memory is a very high speed semiconductor memory which can speed up CPU. It acts as a buffer between the CPU and main memory. It is used to hold those parts of data and program which are most frequently used by CPU. The parts of data and programs, are transferred from disk to cache memory by operating system, from where CPU can access them.

Advantages

- Cache memory is faster than main memory.
- It consumes less access time as compared to main memory.
- It stores the program that can be executed within a short period of time.
- It stores data for temporary use.

Disadvantages

- Cache memory has limited capacity.
- It is very expensive.

Virtual memory is a technique that allows the execution of processes which are not completely available in memory. The main visible advantage of this scheme is that programs can be larger than physical memory. Virtual memory is the separation of user logical memory from physical memory.

This separation allows an extremely large virtual memory to be provided for programmers when only a smaller physical memory is available. Following are the situations, when entire program is not required to be loaded fully in main memory.

- User written error handling routines are used only when an error occurred in the data or computation.
- Certain options and features of a program may be used rarely.
- Many tables are assigned a fixed amount of address space even though only a small amount of the table is actually used.
- The ability to execute a program that is only partially in memory would counter many benefits.
- Less number of I/O would be needed to load or swap each user program into memory.
- A program would no longer be constrained by the amount of physical memory that is available.
- Each user program could take less physical memory, more programs could be run the same time, with a corresponding increase in CPU utilization and throughput.

8. Auxiliary Memory

Auxiliary memory is much larger in size than main memory but is slower. It normally stores system programs, instruction and data files. It is also known as secondary memory. It can also be used as an overflow/virtual memory in case the main memory capacity has been exceeded. Secondary memories cannot be accessed directly by a processor. First the data/information of auxiliary memory is transferred to the main memory and then that information can be accessed by the CPU.

Characteristics of Auxiliary Memory are following −

- **Non-volatile memory** − Data is not lost when power is cut off.
- **Reusable** − The data stays in the secondary storage on permanent basis until it is not overwritten or deleted by the user.
- **Reliable** − Data in secondary storage is safe because of high physical stability of secondary storage device.
- **Convenience** − With the help of a computer software, authorised people can locate and access the data quickly.
- **Capacity** − Secondary storage can store large volumes of data in sets of multiple disks.
- **Cost** − It is much lesser expensive to store data on a tape or disk than primary memory.

9. Conclusion

This article thus represents different types of digital memory devices . All this information will be useful to understand concept of digital memories and for our further articles in the series of digital electronics.

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Operation Amplifiers Part - II Op-Amp Linear Applications

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Abstract

In Electronics circuits, Amplifiers play very important role of increasing magnitude of a small signal typically from microvolts to millivolts and millivolts to Volts so that it can be applied to a load . Simple example of amplifier is audio amplifier which is used in Radio, Tape recorders,CD players where an audio signal either picked up by an antenna or stored in magnetic tape or in Compact Disc(CD) is a small electrical signal is amplified by means of an amplifier in stages and applied to a speaker having low resistance. Initially these amplifiers were designed using discrete components using Bipolar junction transistor BJT or Field Effect Transistor FET, resistors, diodes and capacitors. In last volume after presenting basics of OP-AMPs, this article presents linear applications of OP-AMPs such as Inverting and Non Inverting and Difference Amplifier based on the information obtained from open source.

Introduction

As we aware that OP AMPis a direct coupled high gain amplifier with two inputs Inverting and Non-Inverting input and single output. Thus when any AC input is to be amplified without any phase of inversion we use it as Non-inverting amplifier and when any AC input is to be amplified with phase inversion we use it as Inverting amplifier. Further if we wish amplify the difference of two inputs we use it as Differential Amplifier. All these three configurations can be in Open loop or close loop where a feedback is added to control its overall gain.

1. OPEN LOOP Configurations

The open loop configuration means no connection (direct or through another network), between input and output terminals. The OPAMP in an open loop configuration works as high gain amplifier. There are three open loop configuration.

- Differential Amplifier
- Inverting Amplifier
- Non Inverting Amplifier

- **Differential Amplifier:**

Fig 1 shows the OPAMP in Differential Amplifier configuration. The two signal are applied to inverting and non inverting terminal namely Vs1 and Vs2. Rs1 and Rs2 represent the source resistance of these voltage sources which are normally very small as compared to the input resistance Ri of OPAMP which is in Mohms(Ri = 2Mohms for 741) . The OPMP amplifies the difference between two input signals and therefore known as Difference amplifier.As OPAMP can amplify both AC and DC signals the Vs1 and Vs2 can be AC or DC.

The Output voltage Vo = A(Vs1-Vs2)
Where A is open loop voltage gain of OPAMP.

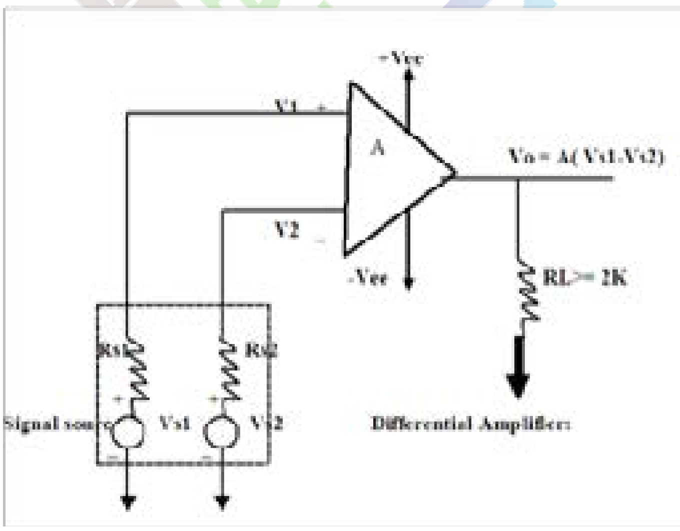

Fig. 1. Open Loop Differential Amplifier

- **Inverting Amplifier:**

In Inverting amplifier only inverting input is applied and non inverting input is grounded.

As v1 =0 V and V2 =Vin

$$Vo = -AVin$$

Where A is open loop voltage gain of OPAMP.

The -ve sign indicates phase inversion for AC signal while change of polarity for DC signal. Since the gain A is very high it used only for very low signal amplification. For higher input the output would saturate to +/- Vcc.

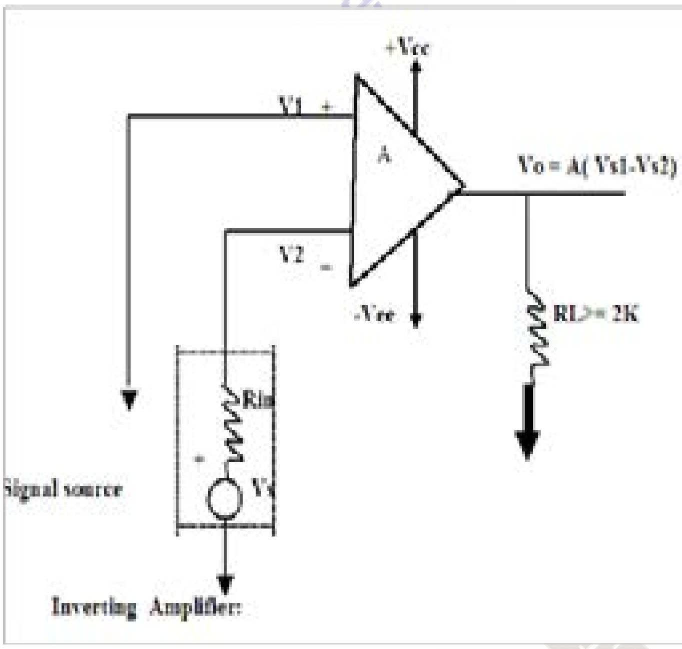

Fig 2 Inverting Amplifier

- **Non Inverting Amplifier**

In NON Inverting amplifier only non inverting input is applied and inverting input is grounded. As V2 = 0 V and V1 =Vin

$$Vo = AVin$$

Where A is open loop voltage gain of OPAMP

There is no phase inversion for AC signal while no change of polarity for DC signal. Since the gain A is very high it used only for very low signal amplification. For higher input the output would saturate to +/- Vcc. Due this reason in all the practical circuits OPAMP with negative feedback is used.

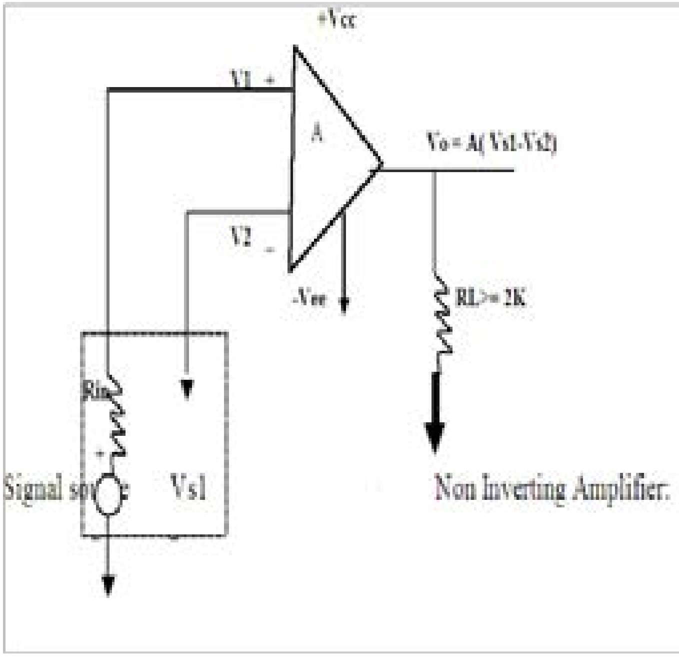

Fig 3 Open loop Non Inverting Amplifier

2. OPAMP with Negative Feedback

Since OPAMP in open loop config has very high gain , a very small input (noise) is also able to drive the output to saturation. To avoid this a negative feedback is used either in voltage series or voltage shunt.

- **Non Inverting amplifier (Voltage Series feedback Amplifier)**

Fig 1 shows a Voltage Series feedback Amplifier. An OPAMP has open loop voltage gain A, the feedback circ Non Inverting amplifier with feedback , because the input signal is applied to non inverting input.

Open loop voltage gain = A = Vo/ Vid

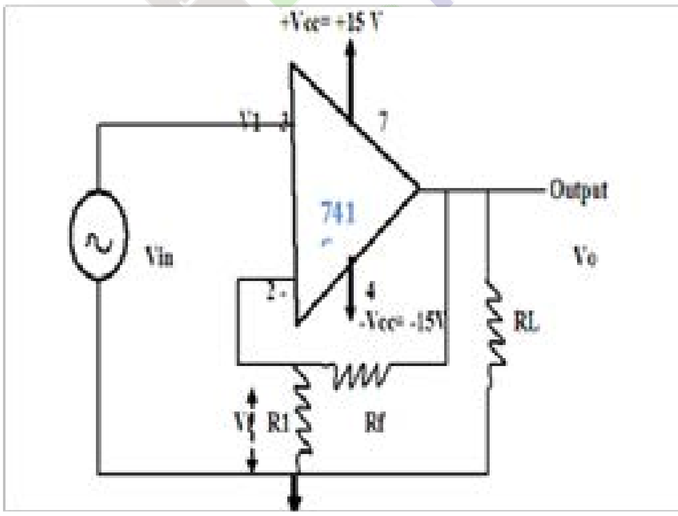

Fig. 4 Non Inverting Amplifier

Closed loop voltage gain(gain with feedback) = Af = Vo/Vin
Gain of the feed back circuit = B = Vf/Vo

- **Negative feedback:**

Vin = input voltage
Vf = Feedback voltage
Vid = difference input voltage

The OPAMP always amplifies difference input voltage, which is difference of Vin and Vf. In other words, the feedback voltage always opposes the input voltage(or out of phase by 180 0 with respect to the input voltage); Hence the feedback is said to be negative. Due to negative feedback voltage gain input resistance and output resistance and the bandwidth is affected.

- **Closed loop Voltage Gain:**

Further the feedback factor
B = Vf/Vo = R1/(R1 + Rf)
OR Af = 1/B ideally.

Af = A/(1 + AB)
where B = R1/ (R1+ Rf) called as feed back factor or gain of feed back circuit.

This equation can be explained by the following diagram.

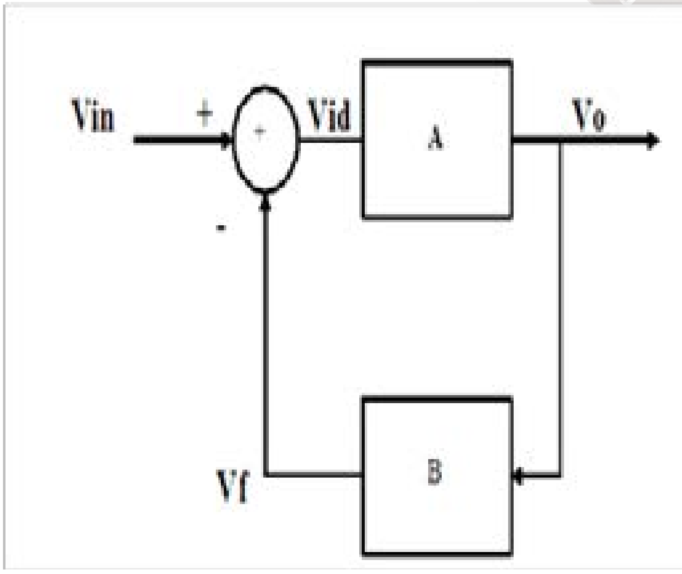

Fig. 5 Block diagram of NON inverting AMP with feedback

Consider the difference input Vid ,
Vid = Vo/A
Since A is very large, Vid = (V1-V2) == 0 or V1 = V2

In this case V1 = Vin
and V2 = Vf = R1 Vo / (R1 + Rf)

as V1 = V2 , Vf = Vin = R1 Vo / (R1 + Rf)
The gain with feedback for NI AMP:
Af = Vo/Vin = 1 + (Rf/R1)

- **Input Resistance: Non Inverting amplifier**

Input resistance of amplifier with feedback. The input resistance Rif with feedback:
Rif = Ri (1 +AB)

This means the negative feedback increases the input resistance Ri by (1+ AB) times.
Output Resistance of Non Inverting amplifier (Rof) :
Output Resistance with feed back is defined as resistance seen between output and ground . Rof can be obtained by Thevenins theorem for dependent sources. We cosider Vi =0, and apply external voltage Vo, then find output current Io.

Rof = Vo/Io.
Rof = Ro/ (1 + AB)
Thus the negative feedback reduces the output resistance by (1 + AB) times.

- **Bandwidth with Feedback (Non Inverting amplifier):**

The bandwidth of an amplifier is defined as the band9range) of frequencies for which the gain remains constant. Manufacturer specify either gain bandwidth product or graph of open loop gain versus frequency. Fig 6 shows the graph for IC 741.

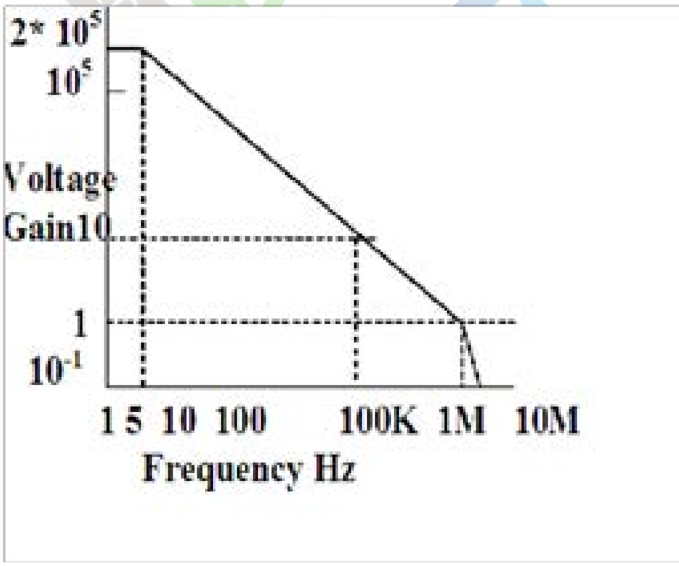

Fig. 6 Frequency response of OPAMP in NI config.

The open loop gain is 200,000 at bandwidth of 5 Hz. Thus gain bandwidth product =200000 * 5 = 1 MHz. This means we can increase the bandwidth by employing negative feedback by reducing the gain proportionately.

The value of 5 Hz is called as break frequency, the freq at which the gain A is 3 dB down from its value at 0 Hz.

This also means when the gain would reduce to 1 (UNITY GAIN) the bandwidth increases to 2 MHz.
The product UNITY GAIN BANDWIDTH

UGB = A * fo

Where A is open loop gain, fo is break freq.
For OPAMP with single break freq,

UGB = Af * fF

Therefore

A * fo = Af * fF

OR fF = A * fo / Af

However, for noninverting Amp

Af = A/ (1+ AB)

Thus fF = A * fo / (A/ (1+ AB))

= fo (1+ AB)

fF = fo (1+ AB)

Thus the above equation shows that the negative feedback in non inverting amp the Band width increases by (1+ AB).

3. Inverting amplifier (Voltage Shunt feedback amplifier):

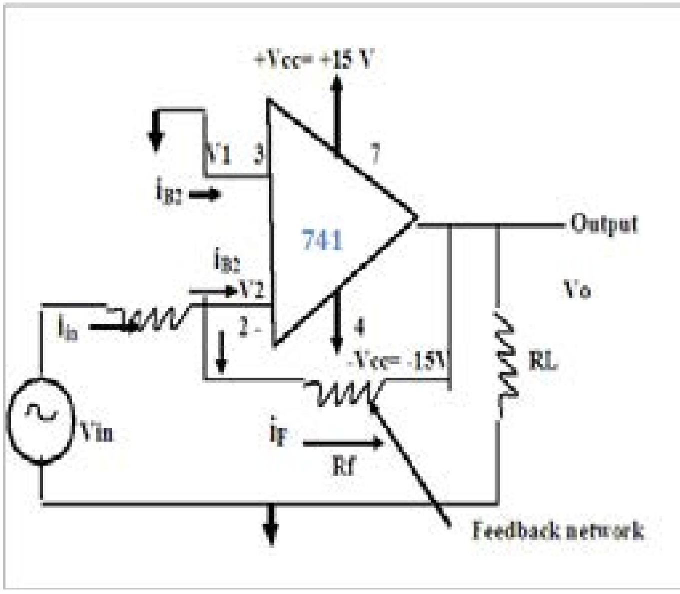

Fig.4 Inverting amplifier with feedback

Fig. 4 shows the Voltage shunt feedback Amplifier or Inverting amplifier with feedback. The input is applied to inverting input and the amplified and the inverted output signal is also applied to inverting input via the feedback resistance Rf. This results in a negative feedback because any increase in the output signal results in a feedback signal into inverting input ,causing decrease in output.

The NI input is grounded and feedback circuit is single resistor Rf.

- **Closed Loop Voltage Gain:**

The Closed loop voltage gain Af

Af = Vo/Vin

= - ARf/ (R1 + Rf + AR1)

Af=-ARf/ (R1 + Rf + AR1)

Exact

As A is very large, AR1 >> R1+ Rf .

Af = - Rf/ R1

Ideal

The – ve sign shows phase inversion of input for ac signals and polarity inversion for dc signals. From above equation we can see that the gain can be changed by varying Rf.

Dividing the exact equation for Af, by (R1+Rf)

$$Af = \frac{-ARf/(R1+Rf)}{(R1 + Rf + AR1)/(R1+Rf)}$$

Or

$$Af = \frac{-AK}{(1+AB)}$$

where K= Rf/(R1+Rf) called as voltage attenuation factor,

B = R1/ (R1+ Rf) called as feed back factor or gain of feed back circuit.

Comparing this equation with equation of non inverting amplifier with feedback , Af = A/ (1+ AB), we can observe that –ve sign in above equation represents phase inversion and the input signal is attenuated by K times in this case.

This can be explained by the following diagram fig.5

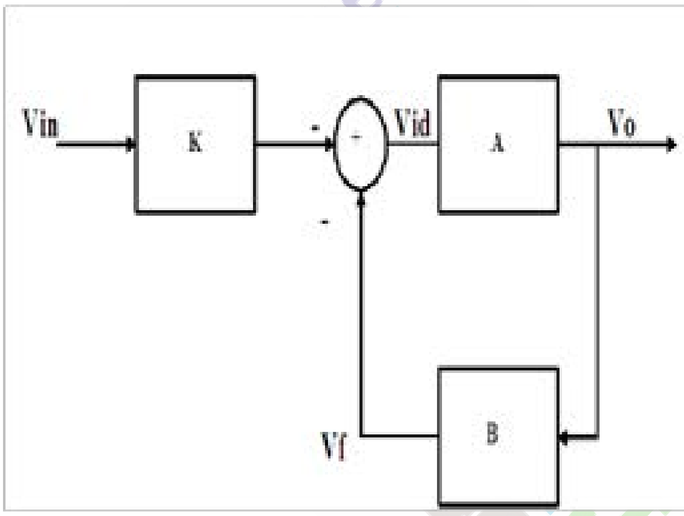

Fig.5 Block diagram of inverting AMP with feedback using a voltage summing junction as a model for current summing.

- **The Concept of Virtual Ground (Short):**

As referred with circuit of INV amp of Fig 4, the Non inverting terminal is at ground, the input signal is applied to INV terminal via R1. The difference input Vid = Vo/ A, since A is very large Vid == 0 volts. But Vid = V1- V2 , here V1 the NI input is = 0 volts (as it is at ground), Vid = -V2 = 0 volts.

Thus the INV terminal V2 is also at ZERO potential. On the other hand the OPAMP has very high input resistance Ri, thus no current flows between the INV and NI terminal . This called as Virtual ground. i.e. the V1 and V2 are at same potential without actual short between the two.

- **Input Resistance with Feedback (Rif):**

To find the Input Resistance with Feedback, we have to millarize the feedback resistor Rf, that is to split Rf into two millar component.

The Input resistance with feed back Rif is

Rif = Ri + (Rf/(1+A)) ll (Ri) Exact

Since Ri and A are very large Rif/(1+A)|(Ri) = 0 ohms Hence

RiF = Ri (ideal)

- **Output Resistance with feedback(RoF):**

The Output Resistance with feedback(RoF) is the resistance measured at the output terminal of the feedback amplifier.

Thus Rof = Ro/(1+AB)

Where Ro Output Resistance of OPAMP,
A = open loop Gain,
B = Gain of feedback circuit.

- **Bandwidth with Feed back (INV AMP):**

For a given OPAMP a gain bandwidth product is always constant. Futher the gain of the amplifier with feedback is always less than that of open loop. Thus the Bandwidth with feedback must be larger than that of open loop.

fF = fo (1+AB)
where fo is break frequency (bandwidth) for open loop of OPAMP = unity gain Bandwidth/ Open loop voltage gain= UGB/A (for OPAMP with single break frequency like 741)

Thus fF = UGB (1+ AB)/ A

fF = (UGB)(K)/Af

where K= Rf/(R1+ Rf) ; and Af = AK/ (1+AB)

Thus to find closed loop bandwidth of INV amp fF, can be found if fo is known for the OPAMP . To calculate the bandwidth practically we can plot Gain with feedback versus frequency . it is obvious that the for same closed loop gain Af, the closed loop bandwidth for INV Amp is lower than NI AMP by a factor of K(<1).

e.g. for Af =1, fF = UGB for NI AMP
and fF = UGB/2 for INV AMP since Rf= R1 for Af =1

for K==1 , the value of fF will be nearly same for NI AMP and INV AMP.

4. Comparison of NI AMP and INV AMP:

PARAMETER	NI AMP	INV AMP
VOLTAGE GAIN	Af = A(R1 + Rf) / (R1 + Rf + AR1) : Exact = A/(1+AB) = 1 +(RF/R1) ;ideal	Af = -A Rf / (R1 + Rf + AR1) Exact = AK/(1+AB); K= RF/(R1+RF) = -RF/R1; ideal
GAIN OF FEEDBACK CIRCUIT	B= R1/(R1+RF)	B= R1/(R1+RF)
INPUT RESISTANCE	RiF= Ri(1+AB)	RiF= Ri+(RF/(1+A))
OUTPUT RESISTANCE BANDWIDTH	RoF = Ro/(1+AB) f_F= fo/(1+AB) f_F = UGB/Af	RoF = Ro/(1+AB) f_F= fo/(1+AB) f_F = UGB(K)/Af

5. Conclusion:

Thus OPAMP has multiple applications amongst which we have seen some of main linear applications mainly the amplifiers with close loop feedback having advantages over their open loop counterpart. The close loop feedback amplifier has many practical applications as they have better stability, higher input resistance, lower output resistance, higher bandwidth.

6. Reference:

- Operational Amplifiers by Ramakant Gaikwad.
- Electronic circuits and Devices by Allen Mottershead.

An extremely simple FMCW Radar

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To those who do not know, there are two types of radars, pulsed and continuous wave. A pulsed radar transmits a short pulse and listens to the echo for a few microseconds, whereas the continuous wave (CW) radar, as the name suggests, continuously transmits radio waves and receives the echo at the same time.

The FMCW radar on the other hand stands for Frequency Modulated Continuous wave radar. The word "Frequency modulated" means that we are changing the frequency of the radio waves before transmitting. The change in frequency is some time varying mathematical function.

Big words, right! Nothing to be scared of though, because the principle of operation is extremely simple. So simple that I could construct this radar in within hour and had it working flawlessly.

The Y axis on the graph is the frequency and the X axis represents time. The graph simply tells us that the frequency is increasing with time and falls back after the cycle completes and starts over. To elaborate it more in technical terms, the frequency is following a periodic ramp function.

The red line is the transmitted frequency modulated radio wave, whereas the green line is the received signal. The received signal is slightly delayed than the red signal and that is where we apply the simple formula of distance, speed and time.

Distance= Speed/Time

Here, the speed is the speed of radio waves travelling which is equal to the speed of light, and the time is the time taken by the radio waves to bounce back from the object. Therefore, Δt is the time taken by the radio waves to travel from the transmitter and come back after reflecting from the object it hit.

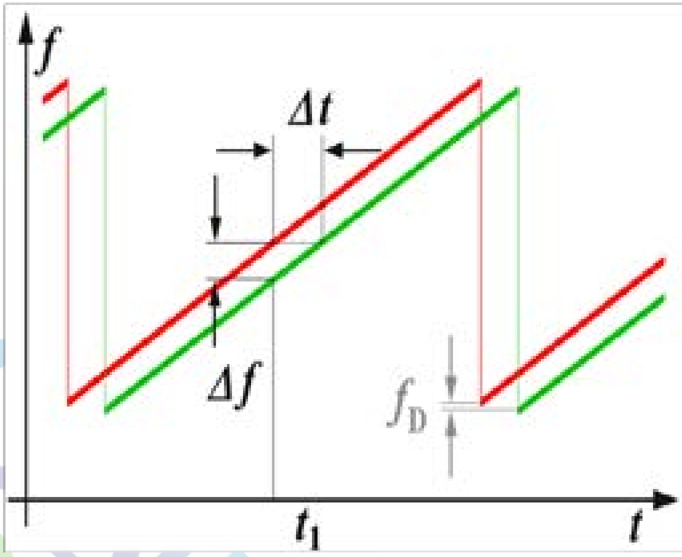


Figure 1 Concept of FMCW Radars

Looking at the graph, we are dealing with frequency. Δt is directly proportional to Δf.

Now, what is Δf? Since, we are continuously transmitting our frequency modulated radio wave, it will keep following the ramp function. The frequency will keep increasing till the ramp cycle ends. So, there will always be some difference in the reflected (received) signal frequency and the current transmit frequency. Thus, Δf or the difference between these two frequencies give us information about the distance of the object from where the radio waves reflected back.

How do we do this in an electronic circuit?

There is an electronic device known as the mixer. The mixer is a non-linear device and when you feed two different frequency signals into it, the output of the mixer is the sum and the difference frequencies as shown in Figure 2.

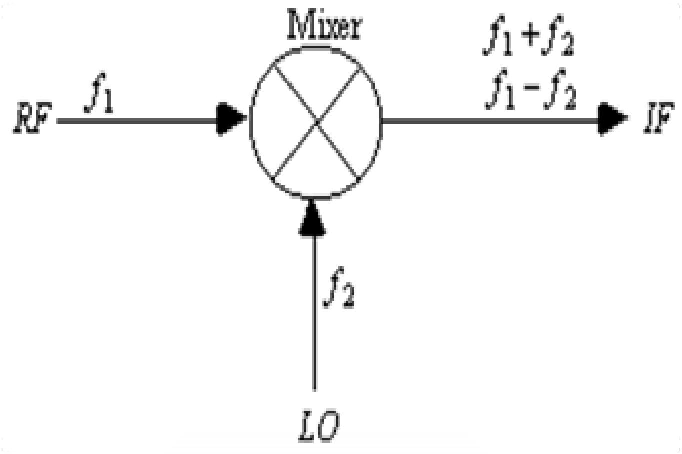


Figure 2 Concept of frequency mixer

For example, f1 = 1GHz and f2 = 5GHz, the IF (output) will be equal to 1GHz + 5GHz = 6GHz and 5GHz – 1GHz = 4GHz.

We can also feed in from the IF port of the mixer and extract a signal at RF port and so on. Now that you have understood the basic operation of mixer, we will get going with the assembly of our FMCW radar.

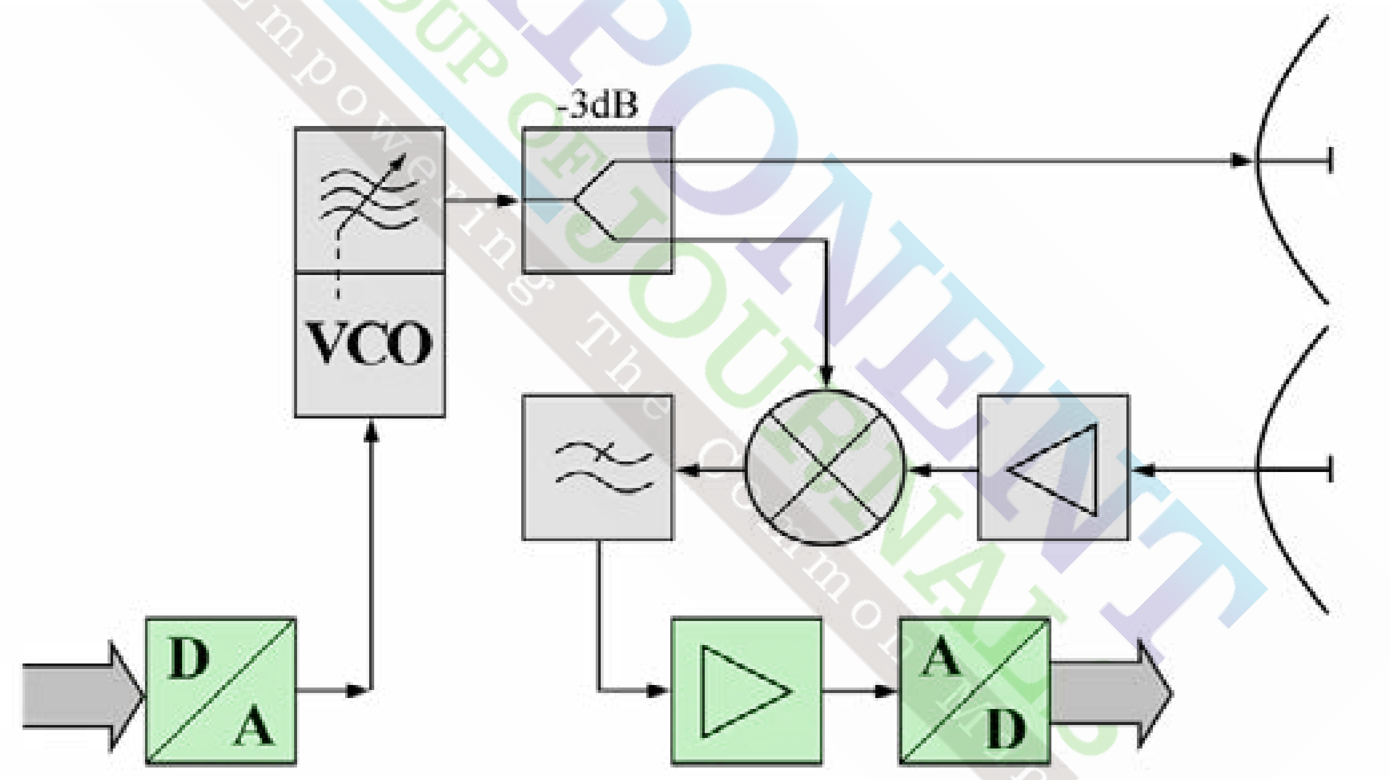


Figure 3 Block diagram of the FMCW radar

- Generate a Frequency modulated radio wave. I have used the frequency of 10GHz and a 500MHz ramp. Since, we are modulating our signal with ramp function, I will have to linearly ramp up my frequency from a start point to a stop point. My start point being 10.000GHz, whereas the stop point being 10.500GHz. To achieve this, I had a function generator at disposal.
- The block diagram above tells us that we need to split the signal, because we need to mix the transmitted signal and the received signal to obtain Δf. For this, I have MAC technology P82672 RF power divider.
- Next is the Mixer. I had Mark M90540 mixer. One of the inputs to the mixer is the transmit signal which has been split with the help of power divider and the other input being the received signal. The output

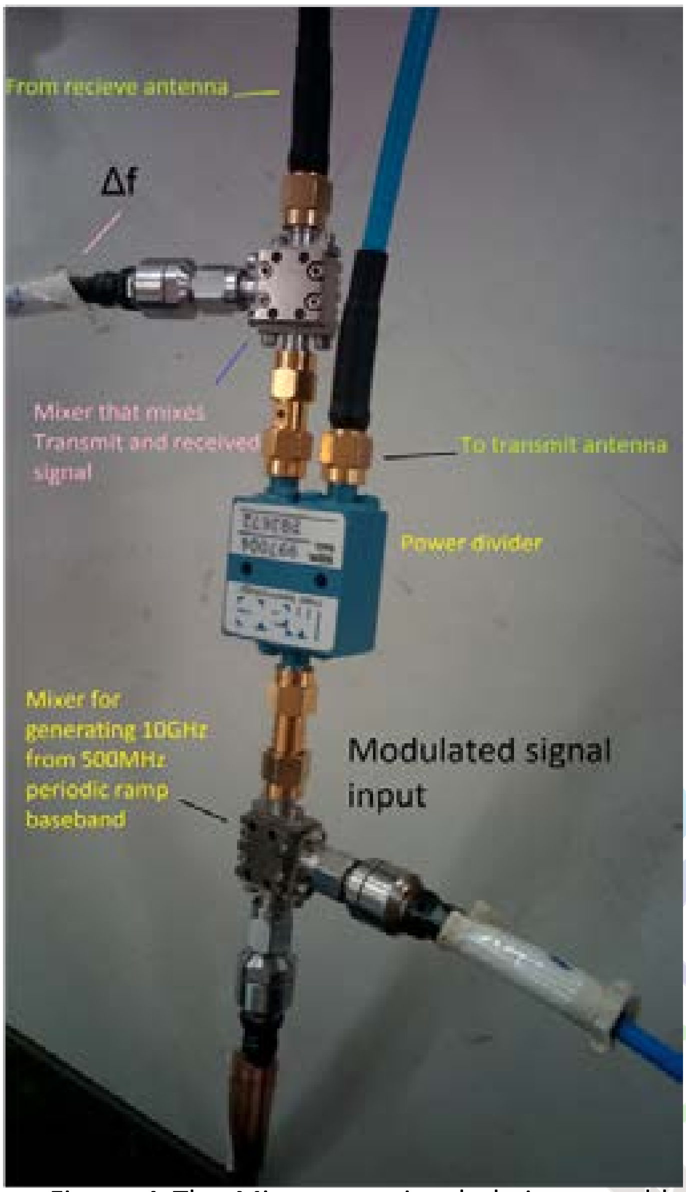


Figure 4 The Microwave signal chain assembly

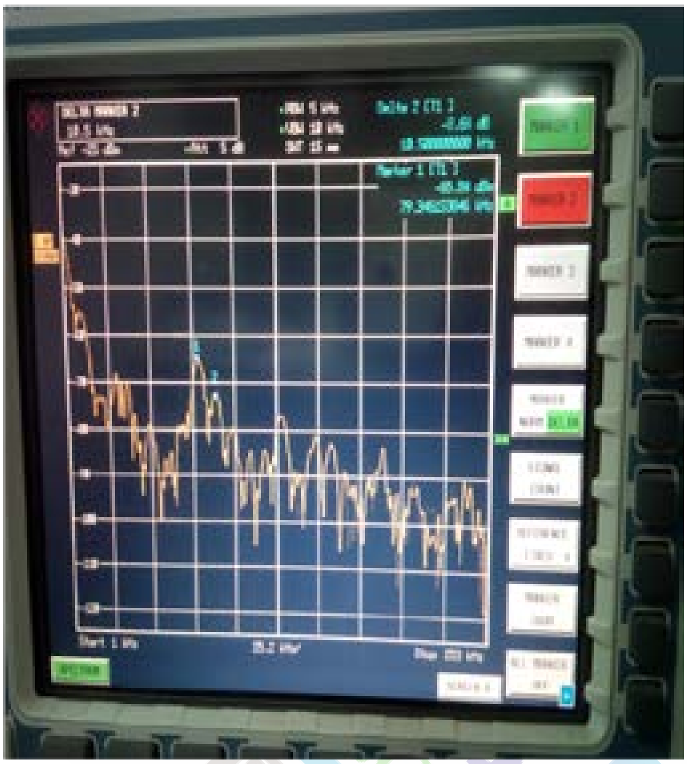
of the mixer will be the difference between instantaneous (at that time) transmit frequency and the reflected signal frequency. In short, Δf.

- I have two horn antennas, one for transmit and one for receiving. My targets are two metallic plates placed on chairs that are separated by a certain distance.

Figure 5 Transmit and receive antennas with test objects for detection

Let us have a look at the actual assembly in the following Figure 4. Starting from the bottom, we encounter the first mixer. This mixer has two inputs, a 10GHz fixed frequency source and a 500MHz ramp generator input. The result of the mixer is the 10GHz to 10.5GHz periodic ramp signal with 500MHz sweep. Further, this signal is split by the power divider in two equal power levels. One of the output of the power divider is directly connected to the transmit antenna, whereas the other output is fed in to another mixer. The second mixer also receives input from the receiving antenna where the delayed signal or the signal reflected from the object comes in. When the transmitted signal and reflected signal are mixed together, the frequency output of the mixer will be proportional to the distance of the object from the transmitter.

This can be seen in the Figure 6, where we can see two bumps on the screen. If we were to detect only one object, there would have been only one peak, but since we have two metal plates sitting at a distance from each other, we see two bumps on the spectrum.



Conclusion

FMCW radars are extensively used in speed guns by the traffic police. On the other hand, it is also used for sensing levels of chemicals, grains, oil, etc. inside of a storage tank.

As the vehicular driver assistance systems develop further, FMCW radars in the 66GHz band will become even more popular. For automotive applications, FMCW radars will be useful for detecting vehicles around you and alerting the driver when two vehicles get too close to each other.

FMCW radars find their use extensively in aircraft altimeters for detecting the altitude of the aircraft. These are known as non-imaging FMCW radars since, no image is displayed but only the altitude of the aircraft.

In practical applications, high power transmitting sources are used which can pump out kilowatts of power continuously. In our experiment, we have used only 15dBm power level.

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