20EC105
Linear Integrated Circuit Applications

<u>Program Core</u>

(Common to: B.Tech ECE & also its splns. AIML & IOT)

by

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20EC105 LIC Course Objectives (COs)

1. Illustrate and analyze the basic principles and important characteristics of Linear ICs.
2. Design and develop solutions using Integrated Circuits for specific applications.
3. Elucidate and design the interfacing applications through ICs that promote health and well-being.

Linear Integrated Circuit Applications (LICAs)

Semester	Hours/Week			C	Marks		
	L	T	P/D		CIE	SEE	Total
III	2	-	2	3	60	40	100
Pre-requisite	20ES103 Analog Circuit Analysis						
Note	1. Vide the R22 Course structure is L:T:P/D:C :: 2 : 0 : 2 : 3 2. R22 Lab Integrated Course Academic regulations apply						

UNIT I: Introduction to ICs (05 Hrs.)

- Integrated circuits - basics, types, block diagram, Features & Characteristics: DC and AC Characteristics, Modes of operation. Illustrative Example Overview of ICs (OPAMP IC, Timer IC, Regulator ICs, ADCs, DACs)

LIC: Syllabus & Course Brief (continued)

UNIT II: Linear Applications of Op-Amp. (06 Hrs.)

- Introduction, Inverting and Non-Inverting OPAMPs, Adder, Subtractor, Integrator, Differentiator, Instrumentation amplifier, Voltage follower, V-I/ I-V Converters. Filters First Order and Second Order Active Low Pass Filters; An overview of Band Pass, Band Reject, All Pass Filters.

UNIT III:Non-Linear Applications of Op-Amp (04 Hrs.)

- S/H Circuits, Comparators, Schmitt triggers, Waveform generators, Precision Rectifiers, Clippers and Clampers

LIC: Syllabus & Course Brief (continued)

UNIT IV: Special Purpose ICs (05 Hrs.)

- 555 timer: Functional diagram, Multi vibrators- Astable and Mono stable operations, Illustrative applications; Voltage Regulator ICs – Basics, 78xx/79xx series ICs, 723 General purpose regulator.

UNIT V:D-A and A-D Converters (05 Hrs.)

- DAC – basics, Weighted Resistor type, R-2R Ladder type;
- ADCs- basics, Parallel Comparator Type, Successive Approximation Register Type; ADC and DAC specifications and applications

LIC Practical -Experiments List:

1. OPAMP Inverting Amplifier
2. OPAMP Non-Inverting Amplifier
3. OPAMP Adder
4. OPAMP Subtractor
5. OPAMP Integrator,
6. OPAMP Differentiator,
7. OPAMP Voltage follower,
8. OPAMP Comparators,
9. OPAMP Schmitt triggers,
10. OPAMP Precision Rectifiers (Half wave/ Full Wave)
11. IC 555/ OPAMP Astable Multivibrator
12. IC 555/ OPAMP Monostable Multivibrator
13. IC 78xx/79xx series or IC 723 Voltage Regulator

Linear Integrated Circuits: Learning Resources

TEXT BOOKS

1. D.Roy Choudhry, Shail Jain, Linear Integrated Circuits, New Age International Pvt. Ltd., 2021, Sixth Edition ISBN 978-8122472127.
2. Sergio Franco, -Design with Operational Amplifiers and Analog Integrated Circuits, 4th Edition, Tata Mc Graw-Hill, 2016

REFERENCE BOOKS

1. A. Ramakant A. Gayakwad, -Operational Amplifiers and Linear IC, 4th Edition, Prentice Hall / Pearson Education, 2015
2. B. S.Salivahanan & V.S. Kanchana Bhaskaran, -Linear Integrated Circuits, TMH,3rd Edition, 2018

Useful Links

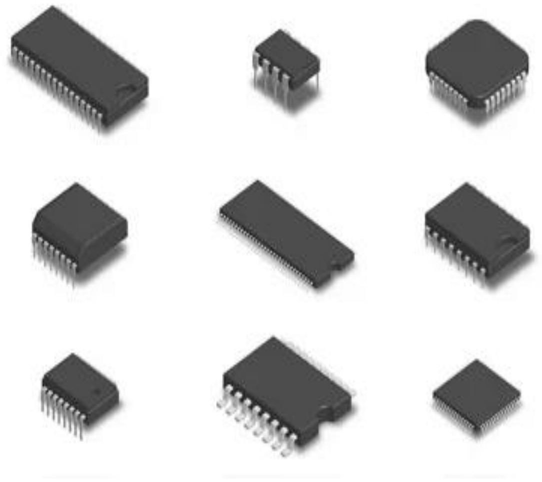
1. https://nptel.ac.in/courses/108/108/108108111/
2. https://nptel.ac.in/courses/117/107/117107094/
3. https://onlinecourses.nptel.ac.in/noc20_ee13/preview

MODULE-I Introduction to ICs

- Integrated circuits - basics, types, block diagram, Features & Characteristics: DC and AC Characteristics, Modes of operation. Illustrative Example Overview of ICs (OPAMP IC, Timer IC, Regulator ICs, ADCs, DACs)
- Historical landmark developments are:
  - 1958: Invention of the Integrated Circuit (Jack Kilby, Texas Instruments) and got patent awarded in 1961.
  - 1959: Robert Noyce was working at the small Fairchild Semiconductor startup company
  - 1960s: BJTs and SSI (hundreds) and MSI (thousands)
  - 1970s: LSI (10’s of thousands) and VLSI (Millions)
  - 2000s:ULSI (billions)

Integrated Circuit (IC) An Introduction

- Integrated Circuit (IC) is an assembly of electronic components, fabricated as a single unit (called chip) using miniaturized active devices (e.g., transistors and diodes) and passive components (e.g., capacitors and resistors), hundreds to billions in no., with interconnections built up on a thin substrate of semiconductor material (typically silicon) but all working together for a function.



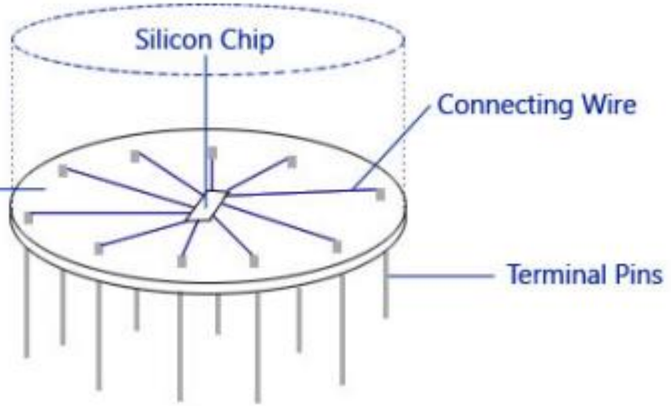
- 1958: Invention of the Integrated Circuit (Jack Kilby, Texas Instruments) and got patent awarded in 1961.
- 1959: Robert Noyce was working at the small Fairchild Semiconductor startup company
- 1960s: BJTs and SSI (few – hundreds per substrate) and MSI (thousands)
- 1970s: LSI (10’s of thousands) and VLSI (Millions)
- 2000s:Ultra Large Scale Integration (billions)

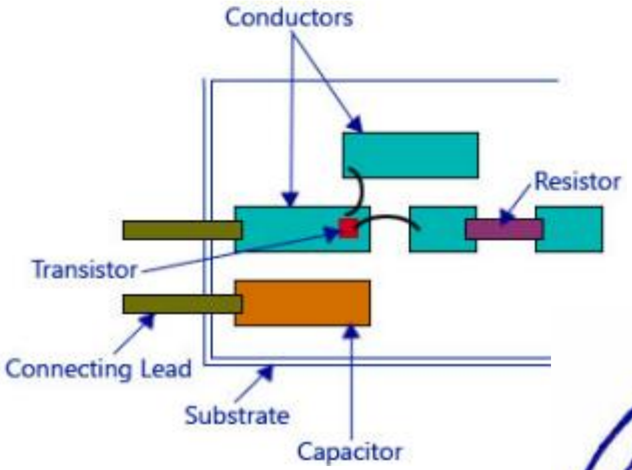
- 2022: 2.5D/ 3D – IC Packaging – CPUs, GPUs, SoCs – Silicon interposers, Through-silicon vias (TSVs)– High Performance in terms of speeds and bandwidths

Intro to IC (contd.)

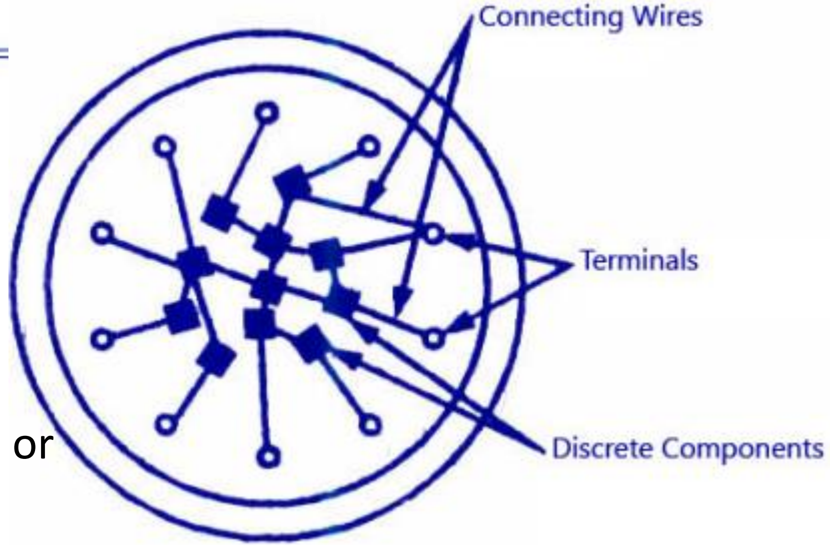
- Integrated circuits are created using photolithography, a process that uses ultraviolet light to print the components onto a single substrate all at once — similar to the way one can make many prints of a photograph from a single negative.
- ICs are cheaper (mass production), extremely reliable offer higher-speed, better performance & consume Lower power than the discrete circuits;

=> A Typical can type Monolithic IC





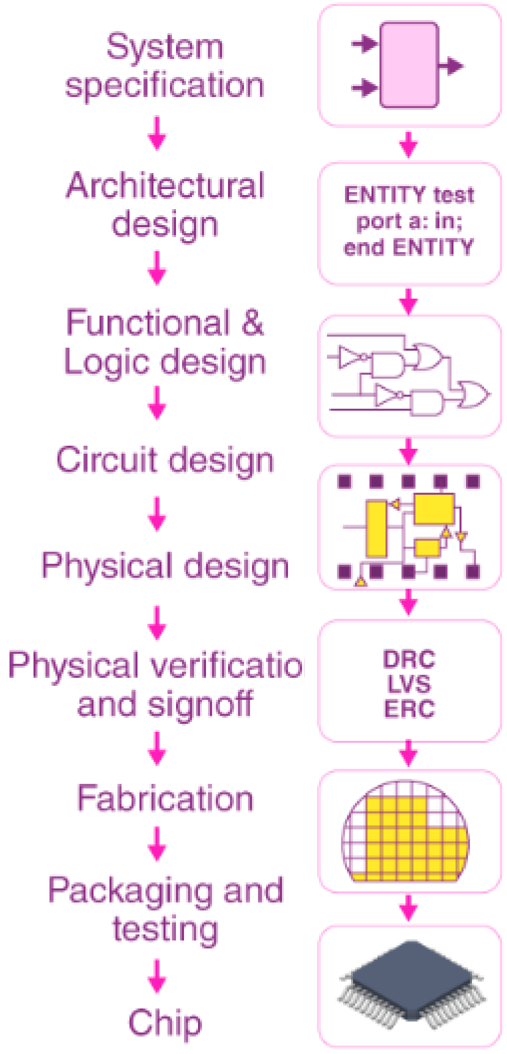
<= A Typical Thick Film IC



=> A Typical Hybrid or Multi-chip IC

IC Types, Functions, Applications and Design Process – A Glimpse

- Types
  - Digital ICs (Gates, Flip Flops as in IC 74xx series ICs etc.): deals with discrete signals and uses components, such as logic gates, flip-flops, registers, and memory, to perform functions like arithmetic, logic, control, and data processing
  - Analog ICs (OPAMPs IC 741, Timer IC 555, Regulators IC723 etc.): deals with electric signal levels that vary continuously with time such as signal amplitude, frequency phase etc.
  - Mixed signal ICs (ADCs, DACs etc.,)
- An IC functions typically as: a microprocessor, amplifier, memory etc.
- IC Applications in real life include: children’s toys, cars, computers, mobile phones, spaceships, subway trains, airplanes, video games, toothbrushes, and more.
- Design process of Digital Integrated Circuits is as depicted:
- Analog versions employ
  - a top-down design and implementation process followed by
  - a bottom-up verification process



Analog Circuit Design phases

1. Develop a high-level specification for the design. What functions will it perform? What are the performance, power, and area (i.e., cost) targets for the design?
2. Develop a top-level design to achieve the required results using macro-functions such as filters, comparators, and amplifiers
3. Create the device-level circuit descriptions to support the top-level design using components such as transistors, resistors, and capacitors. This step often draws from a library of pre-defined functions which will need to be customized for the specific requirements of each unique design.
4. Verify using simulation that the design delivers on all its specifications. The software used here will typically model the circuit using linear and non-linear elements that have been tuned for the target fabrication process. It is during this step that manufacturing process and operational variability will be modeled to ensure the device design remains robust in the face of these uncertainties.

Analog Design Phases (contd.)

5. Implement a physical layout of the design by assembling the pre-defined layouts of all components. During this step, the density of the layout is optimized to minimize cost. There are many placement rules that must be followed to ensure that the design is optimized for manufacturability and signal integrity. Validation that these rules are followed occurs during this step, which is called physical verification.
6. Extract the equivalent circuit from the layout. Parasitic effects such as crosstalk and wiring resistance are now present in the design description, and the design is re-simulated to ensure it still operates as intended with these new effects added. The extracted design is also compared to the original design to ensure the correct devices were used and connected correctly. This process is called logic versus schematic, or LVS checking.
7. Add any structures required for testing the circuit during this phase as well. Once complete, the design is ready for either manufacturing or integration into a larger digital design. Integrating analog designs into a larger digital design is referred to as: analog/mixed signal design (AMS)

IC: Block Diagram, Characteristics

- An IC's block diagram is a diagram depicting various functional blocks of an Integrated Circuit in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks.
- Typically IC block diagrams are employed in engineering especially to describe the internal hardware/ electronic circuit's functional design blocks and/or the associated software design, and/or the process functional flow.
- AC or DC Characteristics of a typical IC
    - Digital IC Typical Characteristics include the below, but not limited to:
        - Speed of Operation, Power dissipation, Figure of merit, Fan Out, Fan In, Current and voltage parameters, Noise Immunity, Operating temperature range
    - Analog IC Typical Characteristics include the below, but not limited to:
        - The fidelity/precision, consistency, and performance in both time and frequency domain operations

On Typical IC Characteristics (AC and DC)

- OPAMP IC
  - DC: Input bias current, Input offset current, Input offset voltage, Thermal drift
  - AC: Frequency response, Stability, slew rate, CMRR,
- Timer IC:
  - Functioning voltage range of 4.5 to 15 volts; Sources or sinks current of up to 200 mA. Operational temperature range (0°C to 70°C) and supports timing resistances in the range: from 2 kΩ to 100 kΩ; and, timing capacitances in the range: from 0.001 μF to 100 μF.
- Voltage Regulator IC: Efficiency, Output Regulation, Input Voltage Range, Nominal voltages, Size in kVA, Colling Media, Voltage Step Up/Dwon etc.
- DAC: resolution, speed, dynamic range, SFDR, ENOB, and SNR
- ADC: speed, resolution, dynamic range, and accuracy

Modes of Operation of various ICs

- For
  - a Timer IC: Astable, Monostable, Bistable Modes
  - an Op-Amp IC: Single-Ended , Differential-Ended, Common Mode operation
    - **Configurations**: Inverting and Non inverting configurations
  - an IC Regulator:
    - Linear, Switching or DC/DC, AC/AC, AC/DC Modes of operation.
    - **Switching Mode Regulators** operate in: Step-down, Step-up Low Drop-Out (LDO), buck-boost modes.

Modes of Operation

- For
  - Modes in a single ADC are: Single-channel, single conversion/ Multichannel (scan) single conversion, single channel continuous conversion, Multichannel (scan) continuous conversion, Injected conversion mode.
    - NOTE: modes **in Dual ADCs** are: regular simultaneous, fast/slow interleaved, Dual alternate trigger, dual combined regular/injected simulations modes and their combinations.
  - a DAC
    - based on application domain the modes are:
      - Voltage (normal) mode or Current (inverted) mode;
      - Fast mode (in asynchronous conversion rate applications), Slow (reduced power)/ Impulse mode
      - One Shot/ Direct Voltage Output Mode; Continuous (Wave Output)/ DMA Mode; Cosine Wave Output (Cosine) Mode

Review Questions on Module-1

- When and Who invented an Integrated Circuit
- 1958: Jack Kilby, Texas Instruments and got patent awarded in 1961 and in 1959: Robert Noyce, Fairchild Semiconductor startup company
- How is an IC created?
- Integrated circuits are created using photolithography. It is a process that uses ultraviolet light to print the components onto a single substrate all at once (similar to the way one can make many prints of a photograph from a single negative)
- What are the typical features of an IC compared to discrete circuits
- ICs are cheaper (mass production), extremely reliable offer higher-speed, better performance & consume Lower power than the discrete circuits;

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Review Questions on Module-1

- What is the latest (say, Jan.2022 & beyond) IC Technology?
- 2.5D/ 3D – IC Packaging – CPUs, GPUs, SoCs – Silicon interposers, Through-silicon vias (TSVs)– High Performance in terms of speeds and bandwidths
- What is an IC?
- IC is an acronym for “Integrated Circuit”. IC is an assembly of electronic components, fabricated as a single unit (called chip) using miniaturized active devices (e.g., transistors and diodes) and passive components (e.g., capacitors and resistors), hundreds to billions in no., with interconnections built up on a thin substrate of semiconductor material (typically silicon) but all working together for a function

Review Questions on Module-1

- List different IC types?
- Digital ICs (Gates, Flip Flops as in IC 74xx series ICs etc.): deals with discrete signals and uses components, such as logic gates, flip-flops, registers, and memory, to perform functions like arithmetic, logic, control, and data processing
- Analog ICs (OPAMPs IC 741, Timer IC 555, Regulators IC723 etc.): deals with electric signal levels that vary continuously with time such as signal amplitude, frequency phase etc.
- Mixed signal ICs (ADCs, DACs etc.,)
- What are the levels of Integration in ICs and what it means
- More the density of components and devices on a single silicon wafer higher is the level of Integration (I) viz.: Small Scale (SSI), Medium Scale (MSI), Large Scale (LSI), Very Large Scale (VLSI), Ultra Very Large Scale (UVLSI) …

Review Questions on Module-1

- List some of the IC Applications in real life.
- IC Applications in real life include: children's toys, cars, computers, mobile phones, spaceships, subway trains, airplanes, video games, toothbrushes, and more
- What does an IC's Block diagram depict or provide?
- An IC's block diagram depicts various functional blocks of an IC in which the principal parts or functions are represented by blocks; blocks are connected by lines to show the relationships/ signal flow between blocks.
- Block diagrams also describe the internal hardware/ electronic circuit's functional design blocks and/or the associated software design, and/or the process functional flow

Review Questions on Module-1

- List the typical characteristics of a Digital IC.
- Speed of Operation, Power dissipation, Figure of merit, Fan Out, Fan In, Current and voltage parameters, Noise Immunity, Operating temperature range
- List the typical characteristics of an Analog IC.
- The fidelity/precision, consistency, and performance in both time and frequency domain operations