

**IME 601 - FUNDAMENTALS OF MFG. ENG.**  
**ELECTRONIC MANUFACTURING**

**BASIC CLASS NOTES**

Reading Review and Class Preparation

This should be filled out prior to class.

Key Concepts to Be Discussed in Class:

Questions About Subject Matter for Class Session:

So What? Why? Who Cares?

- Most Electrical Devices We Use Today Would Not Be Possible
  - If Everything had to be hard wired?
  - Electric Controls are Everywhere

Outline

- Circuits on Circuits on Circuits
  - Dissect the Populated Circuit Board
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
- The Board Itself
  - Fabrication
  - Component Placement and Connection
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
- The IC Package
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
  
- The Integrated Circuit
  - Component Creation
  - Circuit Creation

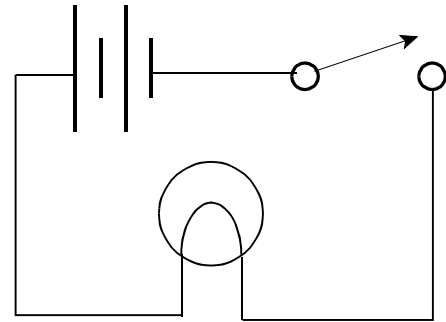
## IME 601 - FUNDAMENTALS OF MFG. ENG.

### ELECTRONIC MANUFACTURING

### BASIC CLASS NOTES

#### Electrical Circuits

- Definition of Circuit
  - A Closed Path for Electricity to Flow in Order to Achieve a Specific Purpose
- Circuits Can Be
  - Hard Wired
  
  - On a Printed Circuit Board
  
  
  
  
  
  
  
  
  
  - On a Silicon Chip Inside a Package


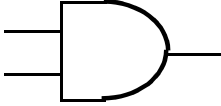
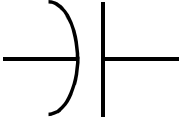
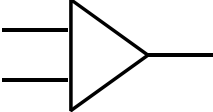
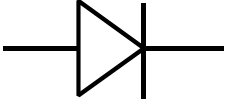
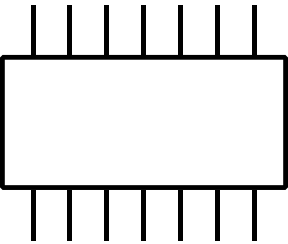
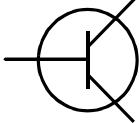


Light Bulb With a Battery and Switch

#### Concept Question

- Obviously Circuits Can Be More Complicated than the one Shown
- What is Necessary for the Light Bulb Circuit to Work?
- What Similar Things Would be Necessary for a Circuit Mounted to a Board?

Electrical Components

<p>Resistor</p> 	<p>AND Gate</p> 
<p>Capacitor</p> 	<p>Op Amp</p> 
<p>Diode</p> 	<p>Integrated Circuit</p> 
<p>Transistor</p> 	

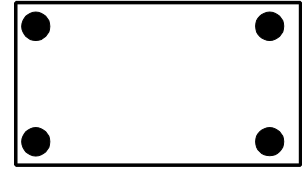
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**ELECTRONIC MANUFACTURING**

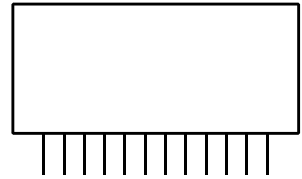
**BASIC CLASS NOTES**

Mounting of Board

- The Circuit Board Must Be Made Part of the Larger Assembly
  - Programmable Thermostat
  - Computer
  - Automotive Sensing Unit



Hard Mount



Connected Mount

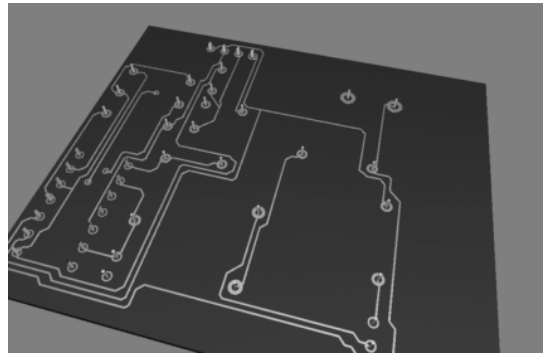
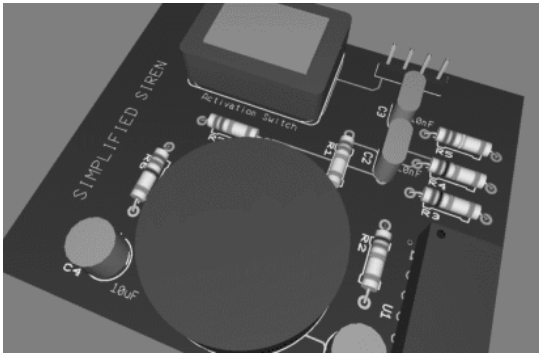
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### ELECTRONIC MANUFACTURING

### BASIC CLASS NOTES

#### Concept Question

- Determine the Steps Needed to Make a Printed Circuit Board
  - Make a Sketch if It Helps
  - Consider the Last Four Slides
  - Try to Order Them
  - What is the End Product?



From: Prof. M. Thompson

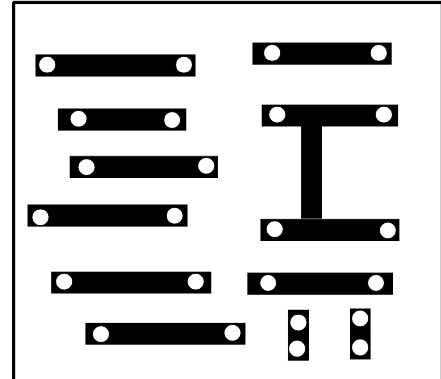
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## ELECTRONIC MANUFACTURING

## BASIC CLASS NOTES

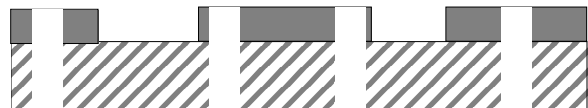
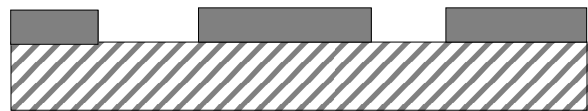
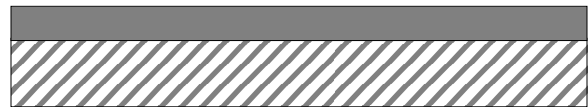
### The Goal

- A Board on Which Components Can Be Placed
  - Appropriate Electrical Connections Made
  - Appropriate Insulation
  - Holes



### The General Process

- Start With Insulating Material
- Place Copper on Top
- Remove Unwanted Copper
- Drill Holes



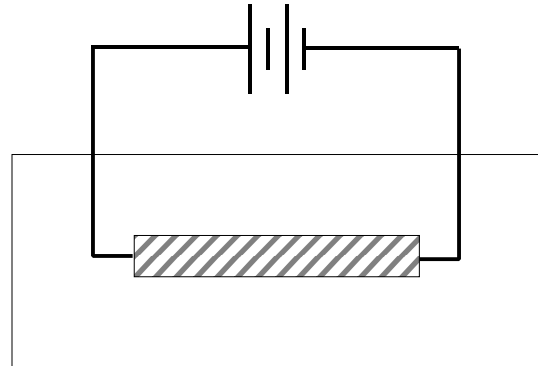
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**ELECTRONIC MANUFACTURING**

**BASIC CLASS NOTES**

Step One - Copper on Board

- Board
  - Insulating Polymer
  - FR-4 (Resinated Glass Cloth) Most Common
- Copper Application
  - Plating (Dipping)
  - Electrolytic Process
  - $7 \times 10^{-4}$  mm/min
  - $320 \text{ A/m}^2$



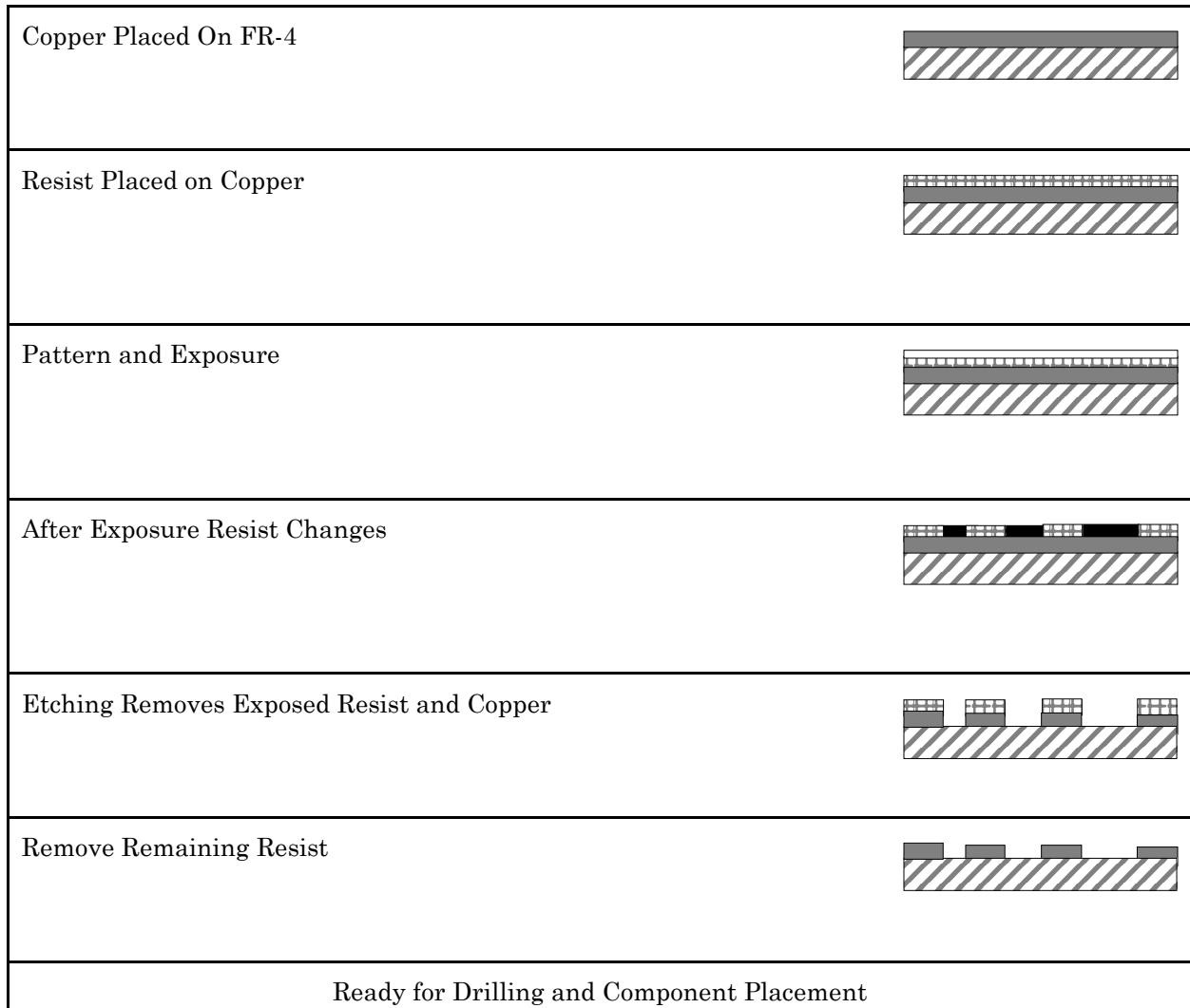
Electrolytic Process

Plating Enhanced by Application of Electric Current



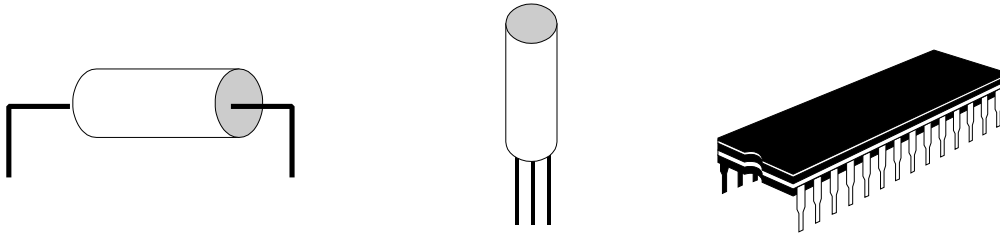
Removal of Copper

- Copper Removed From Areas
  - Provide Resistance
  - Only Required Connections Remain
- Five Step Process
  - PhotoResist Application
  - LayOut of Pattern
  - Exposure
  - Etching
  - Resist Removal



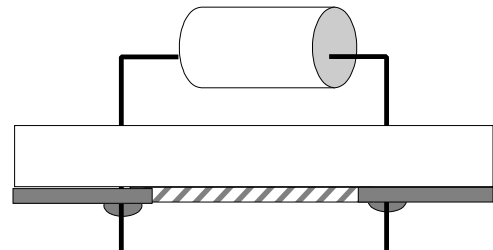
Mounting of Components

- Components
  - Oddly Shaped
  - Have Different No. of Leads
- Must Be Fixed
  - Can't Move Around
  - Fall Off



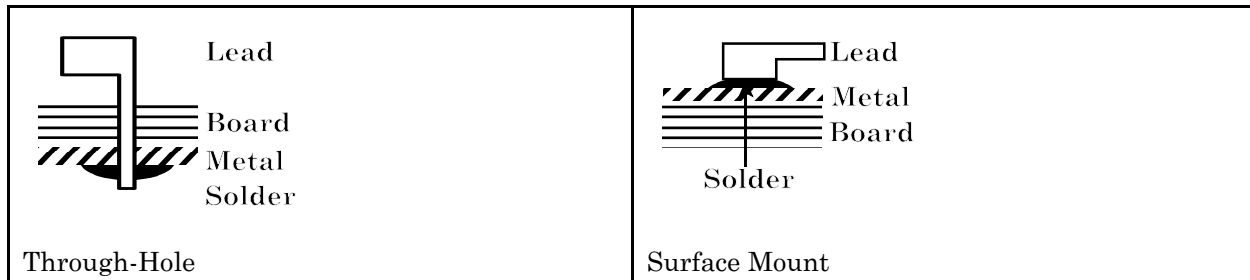
Establishing Electrical Connection

- The Components
  - Must Be Connected Electrically
  - Insulated From Each Other
- Electrical Connection
  - Requires Metal Path
  - Requires Connection to Path



Component Placement

- Through Hole
  - Connection on Bottom
  - Components on Top
  - Solder Applied After Placement
- Surface Mount
  - Connection on Top
  - Components on Top
  - Solder Applied Before Placement

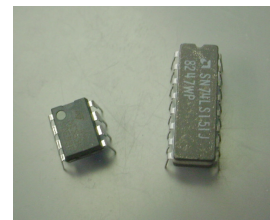
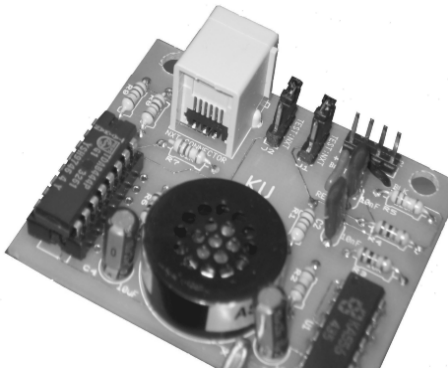


Recent Technical Challenges

- Multilayer Circuit Boards
  - Double Sided
  - True Multilayer
- Solder Changes
  - Sn-Pb Solder Being Banned
  - Sn-Ag-Based Solders Higher Melting Point
- Environmental Consciousness
  - Material Bans
  - Processing
  - Recycling

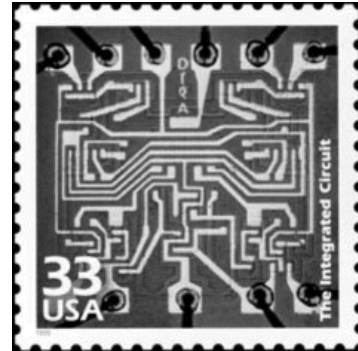
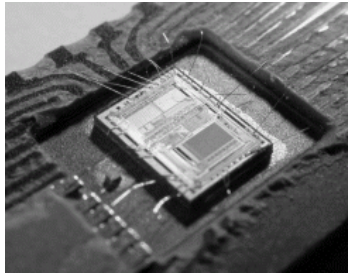
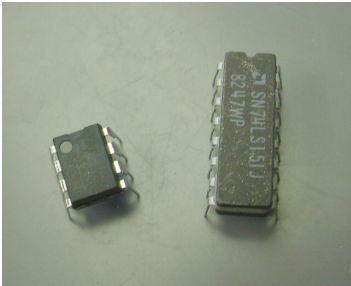
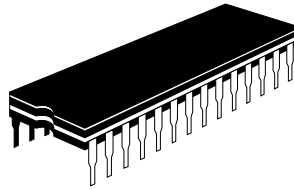
Integrated Circuits - Need

- Populated Circuit Boards are Too Large for Many of Today's Applications
  - The Overall Size Would Make Many Products Unrealistic
  - Electronics are Based on IC's
  - Ref: Prof. M. Thompson



Integrated Circuit

- Commonly We Hold the IC Package
  - Integrated Circuit Inside
  - Packaging Surrounds IC



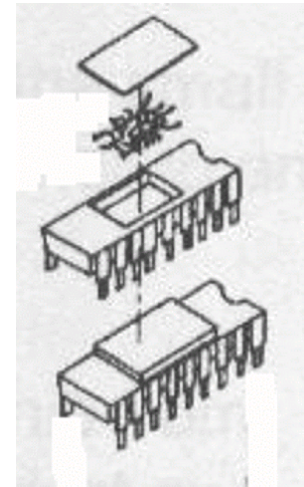
Prof. M. Thompson

Wikipedia

USPS

Packaging

- The Integrated Circuit Must Be Placed in a Package
  - Safety from Surroundings
  - Thermal Dissipation
  - Electrical Connection to Printed Circuit Board



Concept Question

- The Integrated Circuit is
  - Small 3mm x 3mm (or smaller)
  - Contains Upwards of 100,000 Devices
  - Is a Complete Circuit
- How Is This Similar to a Printed Circuit Board?

○ What Features are Necessary?

○ What Processing Steps are Necessary?

○ Think Like Aristotle

Silicon


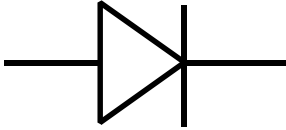
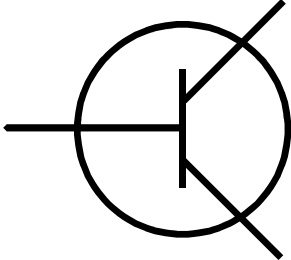
- Silicon is an Intrinsic Semiconductor
  - Small But Measureable at Room Temperature
  - $\sigma=4.5 \times 10^{-6} (\Omega\text{cm})^{-1}$

H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar
K	Ca	Ga	Ge	As	Se	Br	Kr
Rb	Sr	In	Sn	Sb	Te	I	Xe
Cs	Ba	Tl	Pb	Bi	Po	At	Rn

Versatility of Silicon

- Can Change Conductivity / Resistivity
  - Add B, Al -OR- P, As
- Can Metallize
  - Deposit Metal on to Si
  - Create Polysilicon
- Can Create Insulating Layer
  - Oxidize form Silica
- Made From Most Abundant Material on Earth

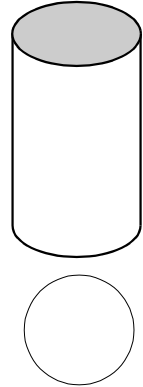
Making Devices [Components]

Resistor		Add a p-type or n-type Dopant
Diode		Create Adjacent p-type and n-type Regions
Transistor		Create p-n-p or n-p-n Regions



Single Crystal Silicon Wafer

- Must Be Extremely Pure (EGS)
  - React Silica with C in Furnace
  - 98% Pure Si Forms
  - Form Trichlorosilane
  - Purify
  - Form Si from Trichlorosilane
  - Form Single Crystal



Adding Impurities

- Two Methods
  - Diffusion
  - Ion Implantation
- Chemical Reactions
  - Metallization
  - Oxidation

<p><b><u>Diffusion</u></b></p> <p><b>When Different Materials are Placed in Contact - They Will Mix Even in Solid State</b></p>
<p><b><u>Ion Implantation</u></b></p> <p><b>Use Electrical Field to Force Ions into Material</b></p>



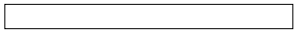





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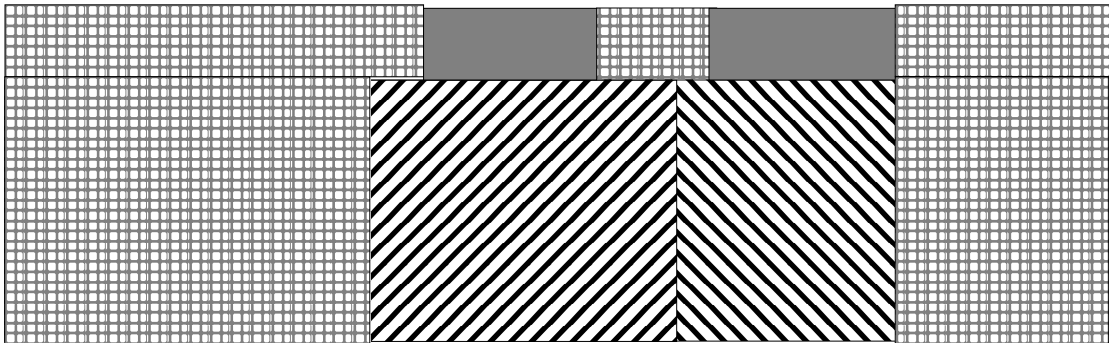
Making Diode (n-p)

- Need to Make Adjacent n and p regions

Silicon Wafer	
n-type dopant	
n-Silicon	
Add Photoresist	
Pattern Exposure	
Develop Photoresist	
Etch Photoresist	
Ion Implantation	

Finishing Job

- Need to Add Metal and Insulation for Devices on Circuit



This is one device on the IC  
There may be  $10^5$  or More.

