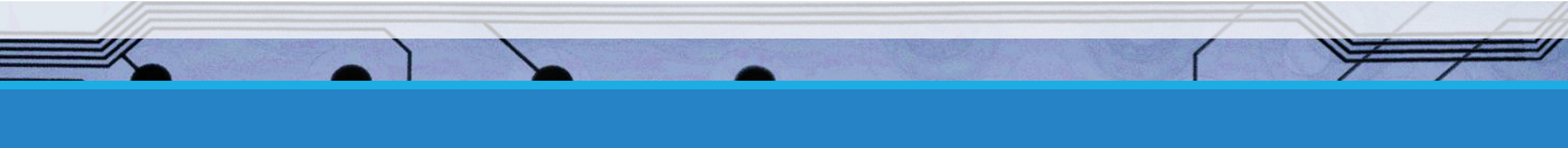


Hands-on PCB Design and Electronic Prototyping with Autodesk Fusion

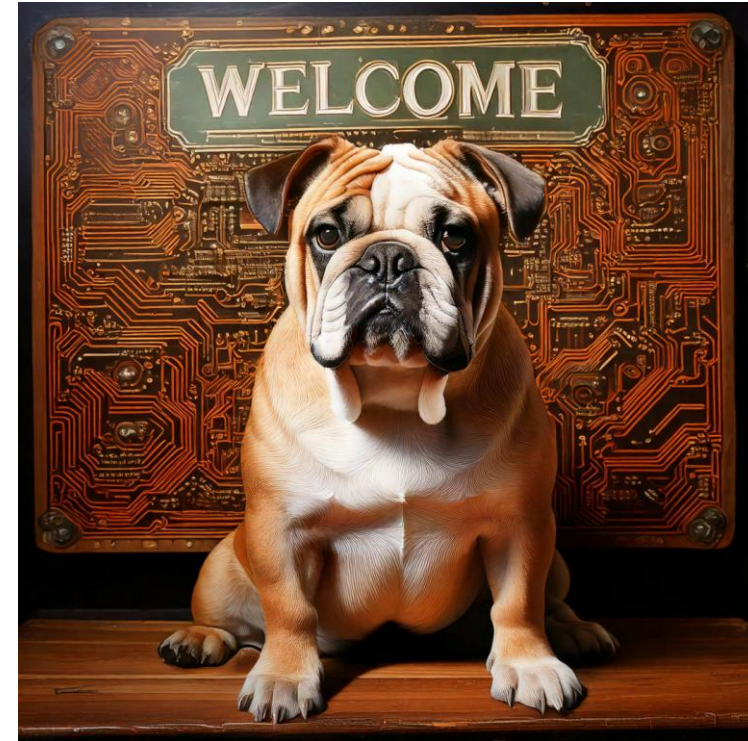
SUMMER ENRICHMENT- LYLES COLLEGE OF ENGINEERING

REVISION 1.0



Introduction

- This workshop will discuss methods of prototyping and specifically how to design and build Printed Circuit Boards (PCBs)
- PCBs are also sometimes called Printed Wiring Boards (PWBs) but the PCB term is more common.
- Although many of the PCB design techniques are applicable to a number of the PCB CAD tools, we will focus mainly on the AutoDesk Fusion Electronic tools.
- We will also provide an overview of some ways AI (Artificial Intelligence) can be used in the design process and for general learning support.



AI Tutor

- AI Assisted Learning is an element of this class.
- AI can be useful but has some limitations.
 - e.g. Hallucinations
- AI platforms include:
 - Chat GPT
 - Gemini
 - Notebook LM
 - Grok
 - Copilot



AI Hallucinations

- AI can provide bad data
 - i.e. Hallucinations
 - e.g.
 - Made-up sources
 - Incorrect text or images
- What do you think of the images to the right?

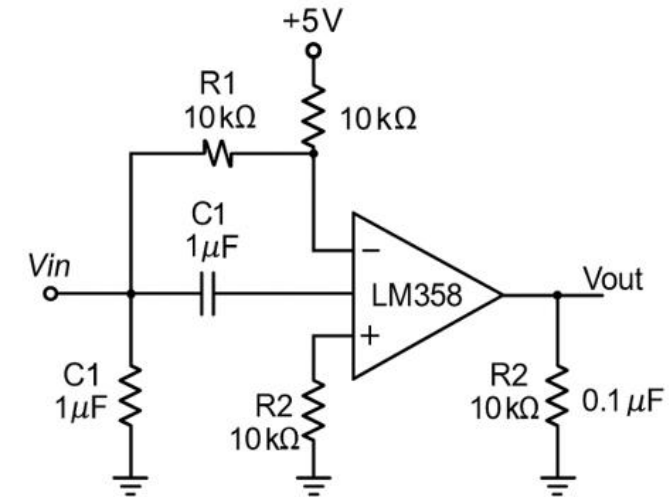
Prompt:

Can you provide a schematic for a non-inverting AC amplifier with a gain of 2 using a LM358 with a power supply that consists of +5V and ground?

2/2

ChatGPT said:

Yes, you can create a non-inverting AC amplifier with a gain of 2 using the LM358 op-amp and a single +5V power supply (with ground). However, because the LM358 is a single-supply op-amp, you'll need to bias the input signal to operate within the 0V to 5V range. Here's how to do it:



Non-inverting AC Amplifier with Gain of 2

Where AI May Help

- Create test quizzes for learning
- Ask questions on how to perform tasks in Fusion
- Ask questions about designing PCBs



**AI ASSISTED
LEARNING**

AI Prompt Exercises (Prompt Engineering)

- Using the AI Large Language Model of your choice, type the following prompts:
 - **What is the best way to determine how wide a trace should be to handle a specific amount of current? Give a table of the advantages and disadvantages of each method?**
 - **Which engineering standard is used to standardize the methods of determining the current handling capability of a trace?**
 - **What is a via in a PCB? What are the different types of Vias and in what circumstances is each via used?**
 - **How Do I create a new schematic symbol in Autodesk Fusion Electronics?**



**AI ASSISTED
LEARNING**

OK, how about one more prompt

- Using the AI Large Language Model of your choice, type the following prompts:
 - **I am interested in (fill in the blank). Can you suggest 25 simple PCB projects for a University-Level Electrical Engineering program PCB workshop related to this interest that would be suitable for this workshop?**
 - **For example: I am interested in driving brushless DC motors for drones. Can you suggest 25 simple PCB projects for a University-Level Electrical Engineering program PCB workshop related to this interest that would be suitable for this workshop?**



**AI ASSISTED
LEARNING**

Day 1: Introduction to PCB Design and Autodesk Fusion

- Course Overview
 - Workshop goals and objectives
 - Importance of PCB design in engineering
- The Electronics Design Process
- Electronics Prototyping
- PCB Basics
 - Terminology (pads, vias, layers, copper pours, etc.)
 - PCB manufacturing process overview
- Autodesk Fusion Setup
 - Installation and licensing (Educational version)
 - Navigating the Fusion 360 Electronics workspace

Day 2: Schematic Capture Basics

- Schematic Capture Essentials
 - Creating and saving a new project and schematic
 - Component libraries and management
 - Placing and wiring components
 - Netlists
- Hands-on Activity
 - Creating a basic schematic circuit

Day 3: Advanced Schematic Techniques

- Complex Schematics
 - Creating custom symbols and parts
 - Hierarchical and modular schematic designs
- Schematic Validation
 - Error checking and electrical rule checking (ERC)
- Hands-on Activity
 - Creating a schematic for a Raspberry Pi Expansion Card

Day 4: PCB Layout Essentials (Part 1)

- Transitioning from Schematic to PCB
 - Generating PCB from schematic
 - Understanding PCB workspace and tools
- Component Placement
 - Placement strategies (signal integrity, EMI/EMC, thermal considerations)
 - Floor-planning
- Hands-on Activity
 - Component placement for a simple project PCB

Day 5: PCB Layout Essentials (Part 2)

- Routing Basics
 - Trace routing (width, spacing, clearance rules)
 - Via usage and types
- Design Considerations
 - Ground and power planes, copper pours, and polygon regions
- Hands-on Activity
 - Routing traces for the project PCB initiated previously

Day 6: Advanced PCB Design and Best Practices

- Signal Integrity and EMC
 - Managing crosstalk and noise
 - Proper grounding and decoupling capacitors
- High-speed and RF considerations
- Hands-on Activity
 - Implementing ground planes, decoupling, and improved layout strategies

Day 7: PCB Design Verification and Manufacturing Prep

- Design Rule Checks (DRC)
 - Setting up rules and constraints
 - Identifying and correcting common errors
- Generating Fabrication Files
 - Gerber file generation and drill files
 - Bill of Materials (BOM) and assembly documentation
- Hands-on Activity
 - Generating manufacturing outputs for previous design

Day 8: Electronic Prototyping Techniques

- Rapid Prototyping Overview
 - Breadboarding best practices and limitations
 - Transitioning from breadboard to PCB prototype
- Hands-on Prototyping Skills
 - Soldering refresher: through-hole and basic SMT soldering techniques
 - Component selection and substitutions
- Hands-on Activity
 - Building and verifying circuit prototypes on breadboards and protoboards

Day 9: Advanced Prototyping and Troubleshooting

- Testing and Debugging
 - Essential lab instruments (oscilloscope, DMM, logic analyzer)
 - Debugging common circuit issues (short circuits, open circuits, noise)
- Rapid Iterative Prototyping
 - Quick-turn PCB manufacturers and assembly services
- Hands-on Activity
 - Debugging and validating electronic prototypes

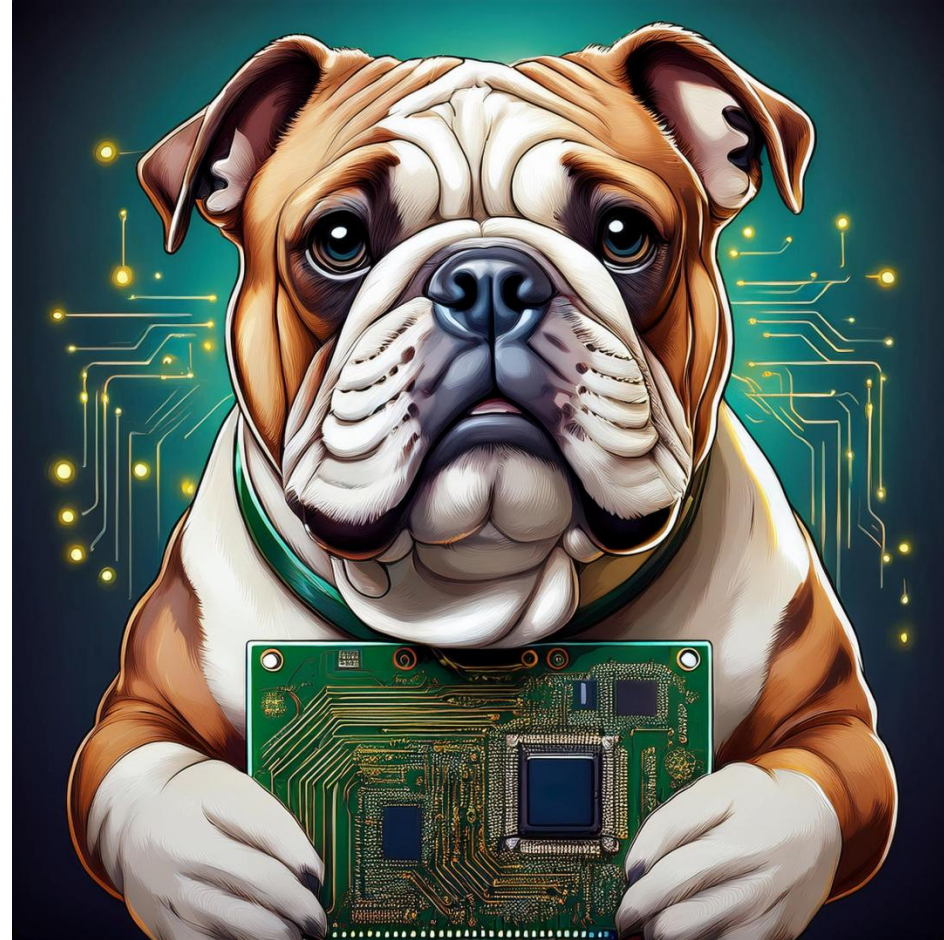
Day 10: Final Project and Workshop Wrap-up

- Integrating Workshop Knowledge
 - Finalize and present individual or group PCB design projects
- Peer Reviews and Project Critiques
 - Constructive feedback session
- Future Resources and Next Steps
 - Recommendations for further self-learning
 - PCB design community resources, forums, manufacturers
 - Industry insights and practical tips for career readiness

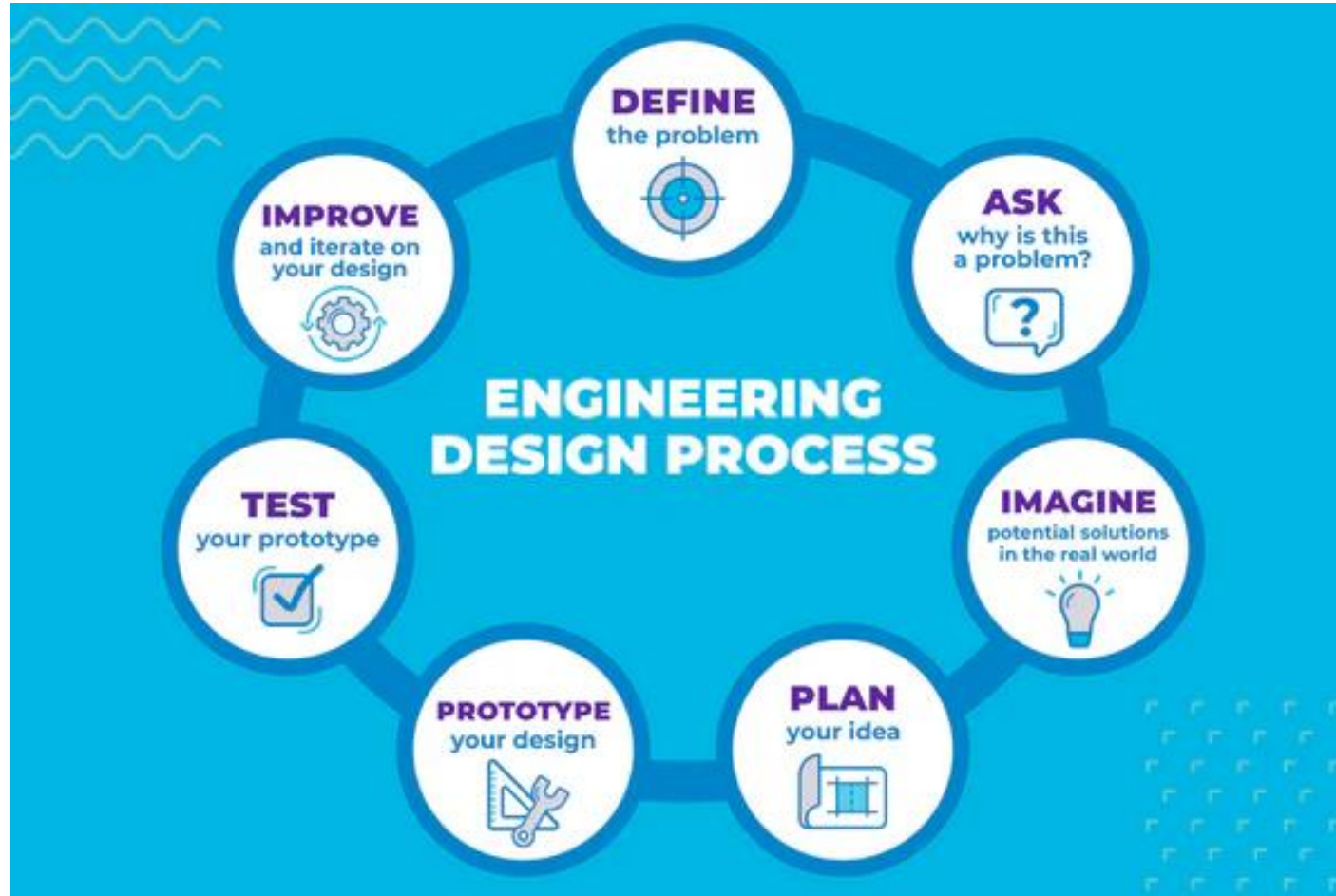
Final Project:

Students complete a functional PCB design (e.g., sensor-based project, microcontroller-based system, IoT module, or simple instrumentation amplifier board). Projects integrate schematic capture, layout, prototyping skills, and demonstration of PCB design best practices.

Day 1: Electronics Design Process



The General Engineering Design Process



Problem Definition

- Determine what problem you are trying to solve
 - e.g. I need a radio frequency amplifier for 7.5MHz signals
- Determine what success looks like.
- Determine functionality requirements.



Why?

- Why is this a problem?
- Is this a problem we really need to solve?



Imagine

- How can we solve this problem- **Research!**
 - Can we buy an existing solution?
 - Do we design and build this solution?



Plan

- Design
 - Can the problem be solved with a circuit discovered during the research phase?
 - If not, do some more research...
 - Select Components.
 - Create a schematic diagram.



Prototype

- Simulate first if possible before building a physical prototype.
- Physical Prototype options (More than one may be used).
 - Solderless Breadboard
 - Dead Bug
 - Soldered Breadboard
 - PCB Design



Test

- Test to make sure design meets functionality requirements.



Improve

- The design process is a cycle.
- In industry, if you have a successful product you have to innovate to keep the product relevant.
 - Imagine if you had the option to buy an iPhone from five years ago or a current competing smart phone.
 - Which would you buy?

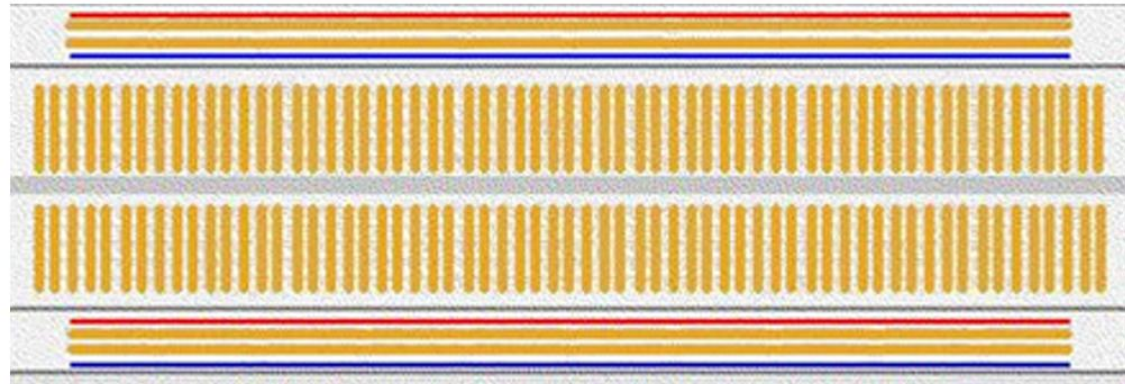
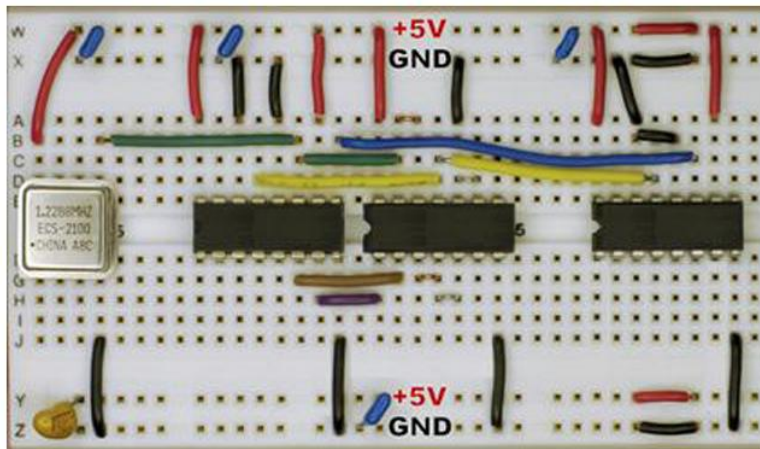


Day 1: Electronics Prototyping

- First, Simulate circuit in a tool such as Multisim, LT Spice, etc., if practical.
- Then use one, or more, physical prototyping techniques, e.g. Solderless breadboard then PCB.
 - Solderless Breadboard
 - Dead-Bug
 - Soldered Breadboard
 - PCB

Solderless Breadboards

- Solderless Breadboard



Solderless Breadboards

Advantages

1. No Soldering Required: Easy to use without specialized tools or skills.

2. Reusable: Components and the breadboard can be reused many times.

3. Fast Prototyping: Quick to assemble and modify circuits.

4. Good for Beginners: Excellent for learning and experimenting safely.

5. No PCB Design Required: Eliminates the need for custom fabrication.

6. Component Friendly: Works with through-hole components (e.g., DIP ICs).

Disadvantages

1. Poor Electrical Connections: Contacts can be loose or unreliable over time.

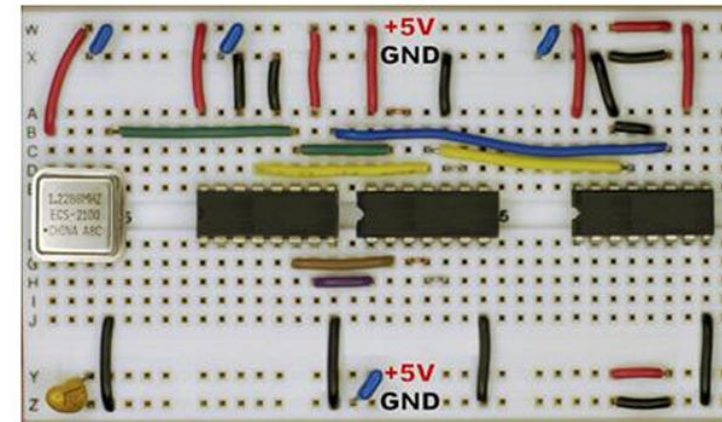
2. Limited Current Capacity: Not suitable for high-current applications.

3. Parasitic Capacitance & Inductance: Can affect high-frequency signals.

4. Not Permanent: Circuits can fall apart if moved or bumped.

5. Layout Limitations: Difficult to manage complex or dense circuits.

6. Not Suitable for Surface-Mount Devices (SMDs): Can't be used with SMDs.



Why do they call this a “Breadboard”

- In early prototyping, sometimes they would build circuits on a wooden board that looked like a board they would cut bread on...



Solderless Breadboard Evolution

- Older Solderless breadboards, e.g. pre-1980, were larger, more expensive, and harder to use than current breadboard designs.



Deadbug Prototype Construction

- Deadbug uses copper-clad PCB material to create prototype circuits.
- The ground plane allows higher speed circuits to operate.



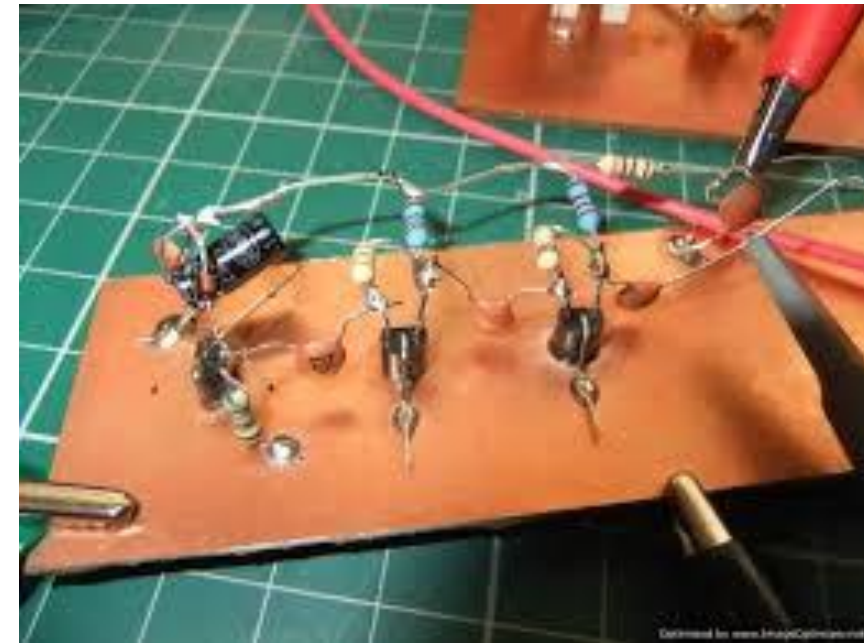
Deadbug Prototype Construction

Advantages

- 1. Excellent High-Frequency Performance:** Minimal parasitic inductance and capacitance due to short connections.
- 2. Compact Layout:** Enables very tight, space-efficient circuit designs.
- 3. No PCB Required:** Useful when PCBs are unavailable or too costly for small runs.
- 4. Custom Grounding Options:** Easily attach components to a grounded copper plane for low noise.
- 5. Good for RF and Analog Circuits:** Reduces signal path length and interference.
- 6. Works with SMD Components:** Allows use of surface-mount parts without a PCB.

Disadvantages

- 1. Time-Consuming:** More labor-intensive than breadboarding or PCBs.
- 2. Fragile:** Physical connections can be mechanically weak or easily damaged.
- 3. Difficult to Modify:** Changes are harder once components are glued and wired.
- 4. Messy Aesthetic:** Results can be visually unappealing and harder to document.
- 5. Risk of Shorts:** Exposed leads and wires can touch unintentionally.
- 6. Not Scalable:** Unsuitable for mass production or replication.



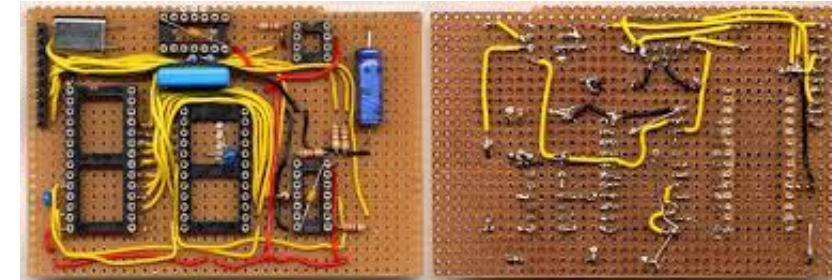
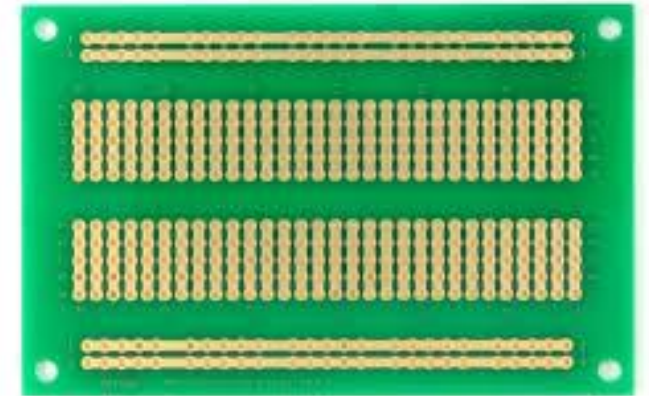
Soldered Breadboard Construction

Advantages

- 1. More Permanent Than Solderless Breadboards:** Components are fixed in place, reducing the risk of disconnection.
- 2. More Reliable Electrical Connections:** Solder joints provide solid and consistent electrical contact.
- 3. Better for Field Use:** More rugged and portable than solderless breadboards.
- 4. Suitable for Moderate-Frequency Circuits:** Less parasitic effects than solderless boards.
- 5. Works with Through-Hole Components:** Compatible with common prototyping parts like DIP ICs.
- 6. Inexpensive and Accessible:** Widely available and cost-effective for small projects.

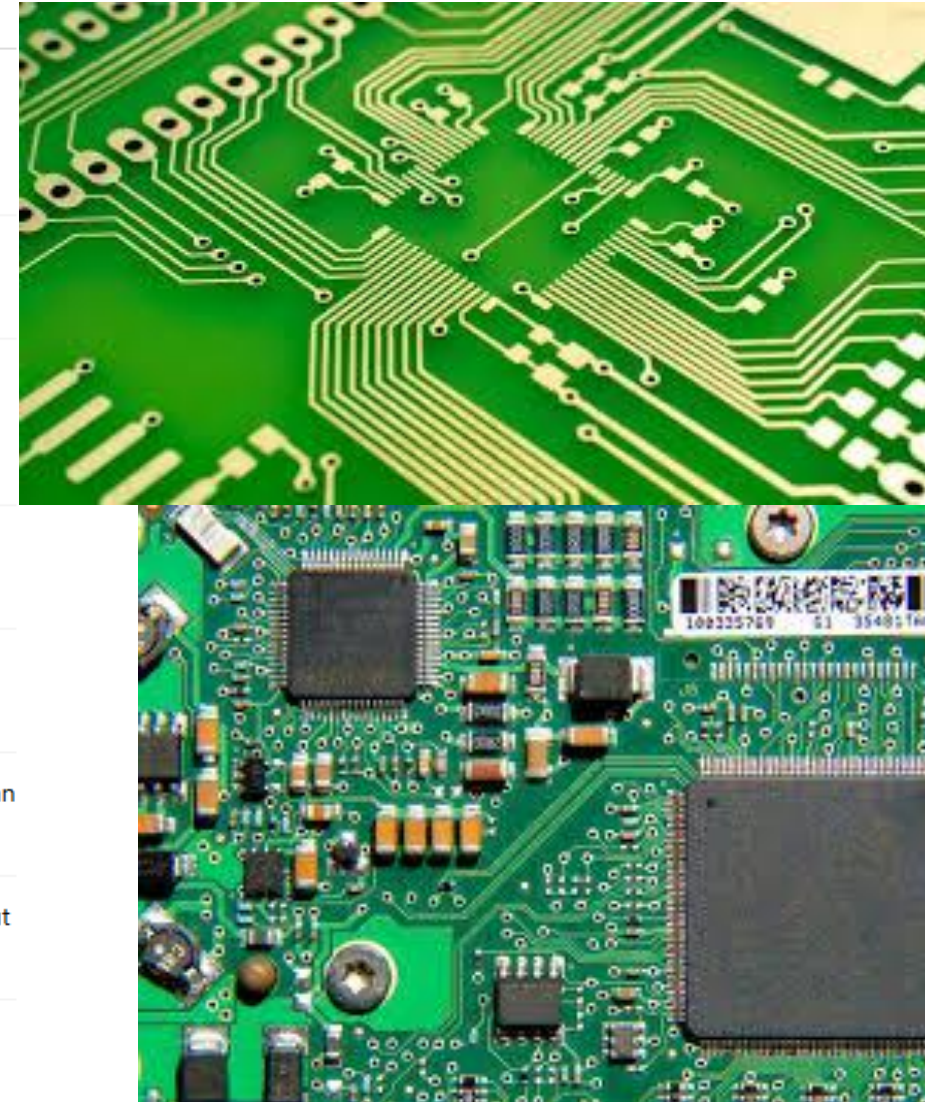
Disadvantages

- 1. Time-Consuming Assembly:** Requires planning, soldering skills, and patience.
- 2. Harder to Modify:** Difficult to rework or change circuit layout after soldering.
- 3. No Built-In Traces (Perfboard):** Must manually wire all connections, which can be error-prone.
- 4. Limited Trace Layout (Stripboard):** Fixed copper strips can restrict circuit flexibility.
- 5. Not Ideal for SMDs:** Difficult to use with surface-mount components without special adapters.
- 6. Manual Wiring Can Be Messy:** Poor wire management can lead to troubleshooting difficulties.



Printed Circuit Boards

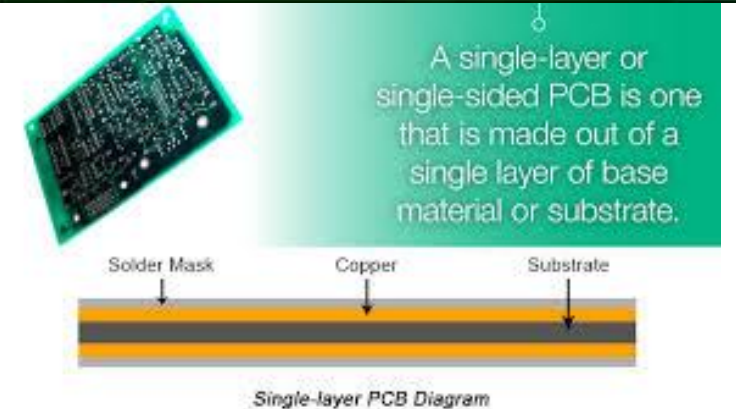
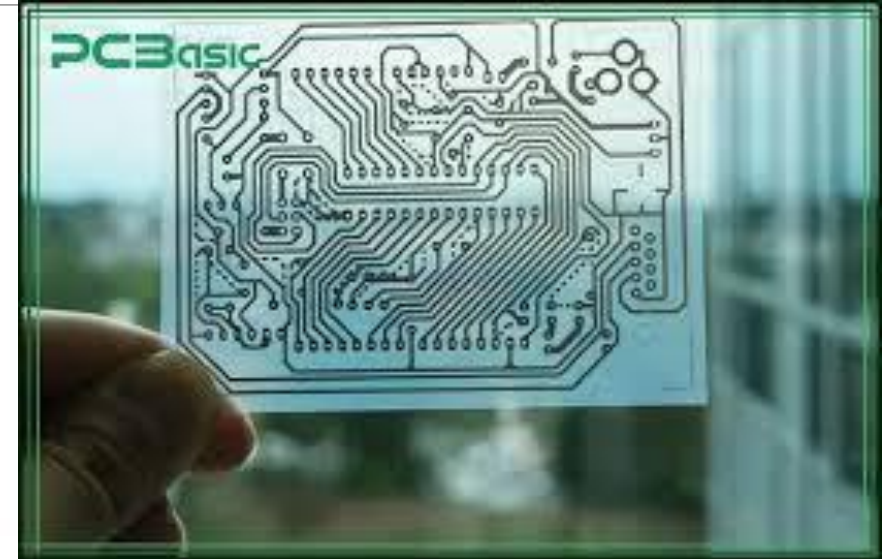
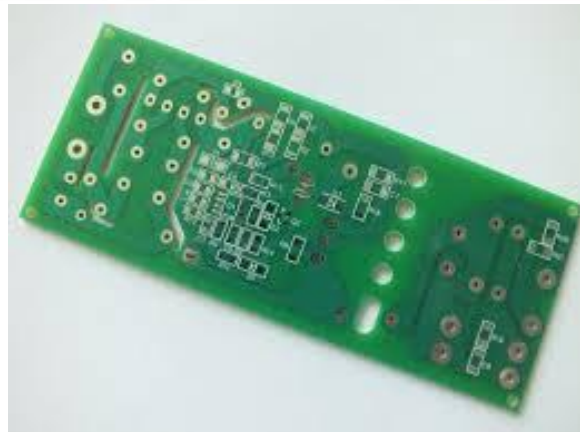
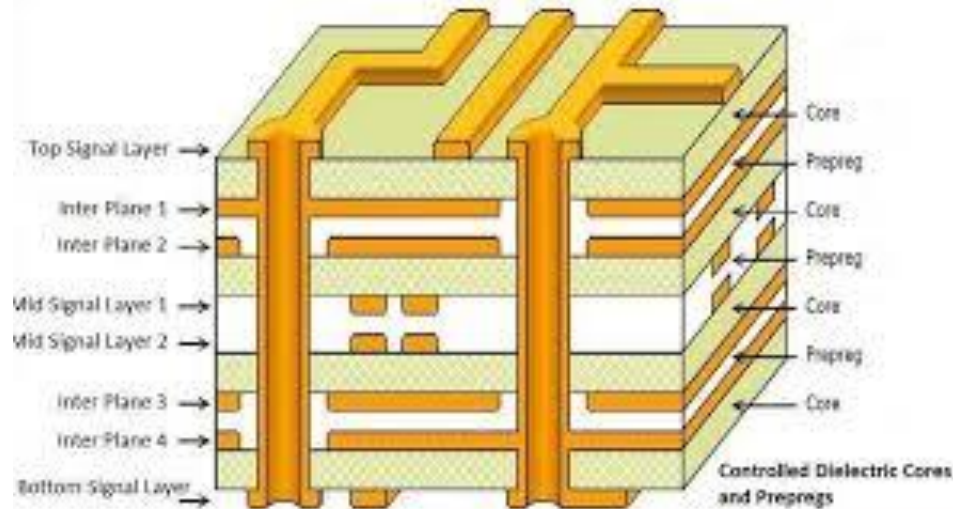
Aspect	Advantages	Disadvantages
Design Optimization	Allows for precise component placement, routing, and layout tailored to the circuit's requirements	Requires detailed design work and software proficiency (e.g., with KiCad, Altium)
Compact and Professional Appearance	Results in a cleaner, more compact, and professional-looking product	Mistakes in the design can be costly and time-consuming to fix
Signal Integrity	Enables better control over signal paths, grounding, and noise reduction	High-speed or high-frequency layouts may require advanced design knowledge
Reliability	Stronger mechanical connections and reduced risk of wiring errors compared to breadboards or perfboards	Fragile if improperly handled during soldering or usage
Reproducibility	Easy to replicate for small- or large-scale manufacturing	Turnaround time for fabrication can slow down rapid prototyping
Customization	Allows integration of special shapes, logos, and board features	Custom shapes or multilayer boards can increase fabrication cost
Integration	Facilitates integration of surface-mount devices (SMD) and complex ICs	Soldering SMDs can be difficult without proper equipment or skill
Documentation	Encourages creation of schematic and layout files useful for revision tracking and collaboration	Requires proper version control and documentation habits



Day 1: PCB Basics

- Terminology

- Pads
- Vias
- Layers
- Copper Pours
- Traces



Day 1: Autodesk Fusion Installation and licensing (Educational version)

- Link:
 - <https://www.autodesk.com/education/edu-software/overview>
 - Click on “Sign In”
 - Click on “Create Account”

The screenshot shows the Autodesk website's 'Education' section. The top navigation bar includes the Autodesk logo, a search bar, and links for 'Products', 'Support', 'Learn', 'Community', and 'Education'. Below this, a secondary navigation bar lists 'Education', 'Products', 'Students', 'Educators', 'Administrators', and 'Get Help'. The main heading is 'Autodesk software access for students and educators', with a link to 'Education eligibility terms'. The text explains that students, educators, and educational institutions can get free access to Autodesk products for one year. Below this, there are links to guides for 'students', 'educators', and 'IT administrators'. A horizontal bar categorizes products by industry: 'All industries', 'Architecture, Engineering & Construction', 'Product Design & Manufacturing', and 'Media & Entertainment'. The 'All products' section is visible, with 'Sort' options for 'Featured' and 'Alphabetical'. Four product cards are shown: Tinkercad (Simple 3D design and 3D printing app), Fusion (Cloud-based product design software for manufacturing, 3D modeling, electronics, simulation, and data management), Revit (Plan, design, construct, and manage buildings with powerful tools for Building Information Modeling), and Inventor (Powerful product design and engineering tools for 3D mechanical design, simulation, visualization and documentation). A chat bubble for 'Autodesk Assistant' is in the bottom right corner.

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All products

Sort
Featured Alphabetical

Tinkercad
Simple 3D design and 3D printing app

Fusion
Cloud-based product design software for manufacturing, 3D modeling, electronics, simulation, and data management

Revit
Plan, design, construct, and manage buildings with powerful tools for Building Information Modeling.

Inventor
Powerful product design and engineering tools for 3D mechanical design, simulation, visualization and documentation

Hi, I'm Autodesk Assistant!
I can help with product selection, support questions, or connect you to an agent.

Questions?



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