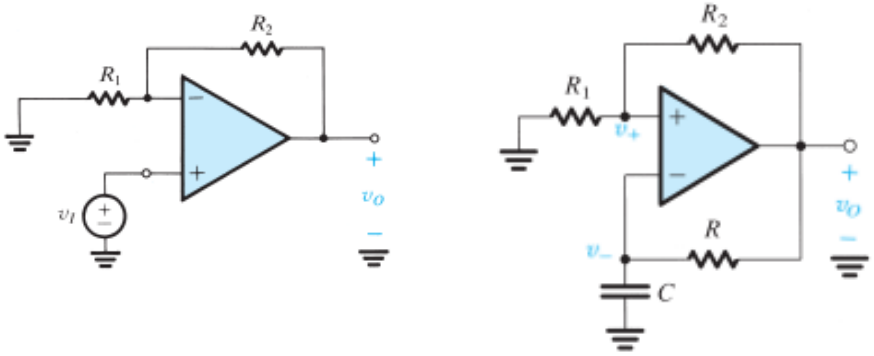
Op Amp Discovery

Fast & Flexible Prototyping and Learning Board



Contents

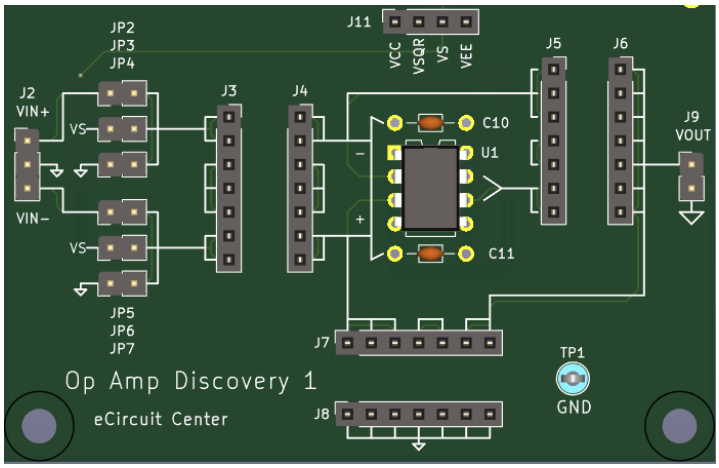
1 Intro

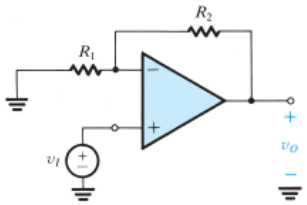
The Op Amp Discovery Board allows students, engineers and DIYers to quickly build and experiment with a variety of op amp configurations. **Hands-on learning boosts understanding and intuition**!

- Easy-to-use hybrid (solderless breadboard / PCB).
- Explore 20+ classic op amp circuits
- Create your own circuits
- Supply Rails & Signal Source Included on-board

2 Fast & Flexible Prototyping

Quickly build and explore many classic op amp circuits with component headers and configurable circuits. Follow self-directed or guided learning.





- Flexible - ***easily install Rs, Cs or jumpers across any headers***.
- Fun problem solving - *How-to-build circuit on headers?*
- Configurable signal - *DC, AC, square-wave, level trimpot*

3 Problems Solved

Standard breadboards can be frustrating:

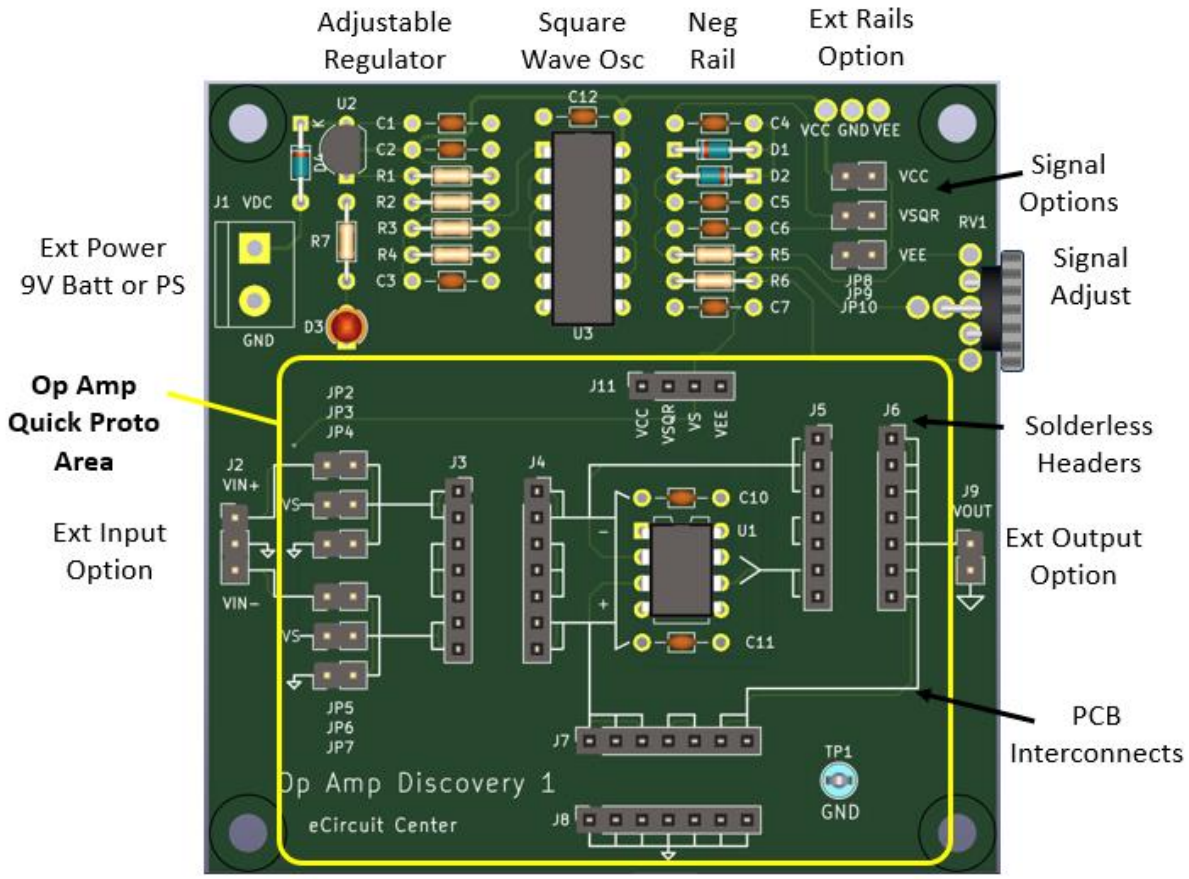
- Prone to opens, shorts, intermittent connections
- Confusing, difficult to probe and debug
- Requires expensive, bulky supplies and signal generators

Op Amp Discovery:

- PCB provides solid, versatile connections, power and a signal source.
- Layout arranged like schematic to reinforce learning.
- Minimal cost and PCB space - an affordable & portable learn-anywhere lab.
- Learning possible with a $10 DMM only.

4 Overview

The Op Amp Discovery provides essential support circuitry for **a stand-alone learning lab**. Circuit flexibility allows for custom or more complex setups. *The "Schematic" style of the PCB layout builds understanding and intuition*.



Overview

- Quick Proto Headers for easy install of components.
- PCB interconnects for versatile circuit options.
- Op Amp socket for DIP (or SMD on 8-pin header).
- Power from single source (9V battery)

Signal Source

- Scalable Square Wave (0 to 5V)
- Selectable DC or AC coupling.
- Adjustable Amplitude (Trim Pot RV1)
- External Input / Outputs (Optional)

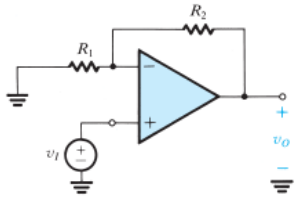
Power Rails

- Positive Rail VCC: Adjustable Regulator (5V default)
- Negative Rail VEE: Cap Charge Inverter (-4.5V)
- Solder pads for External Rails option.

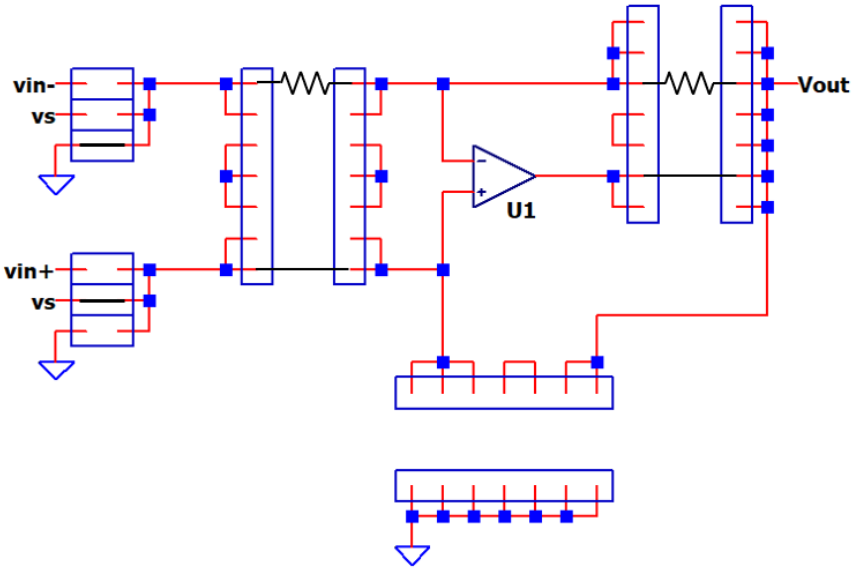
5 Quick Start Guide

5.1 Inverting Amplifier

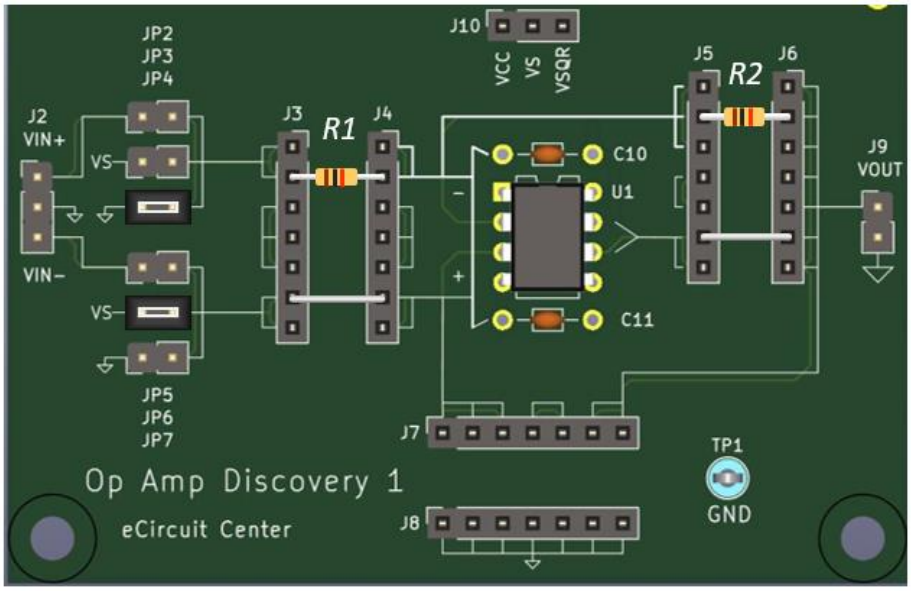
Let's jump in with the Non-Inverting Amplifier. From the circuit diagram, how can you build the amplifier on the Op Amp Discovery board?



First, sketch out a possible build on the proto-area schematic.

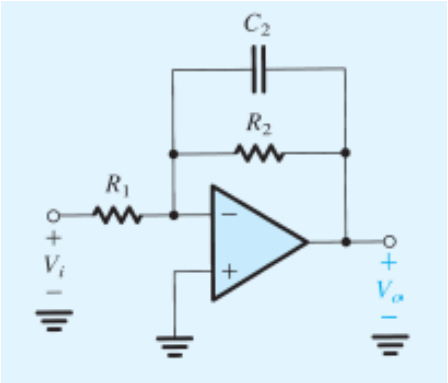


Then, simply install the resistors and wire jumpers - and the circuit's ready to explore!

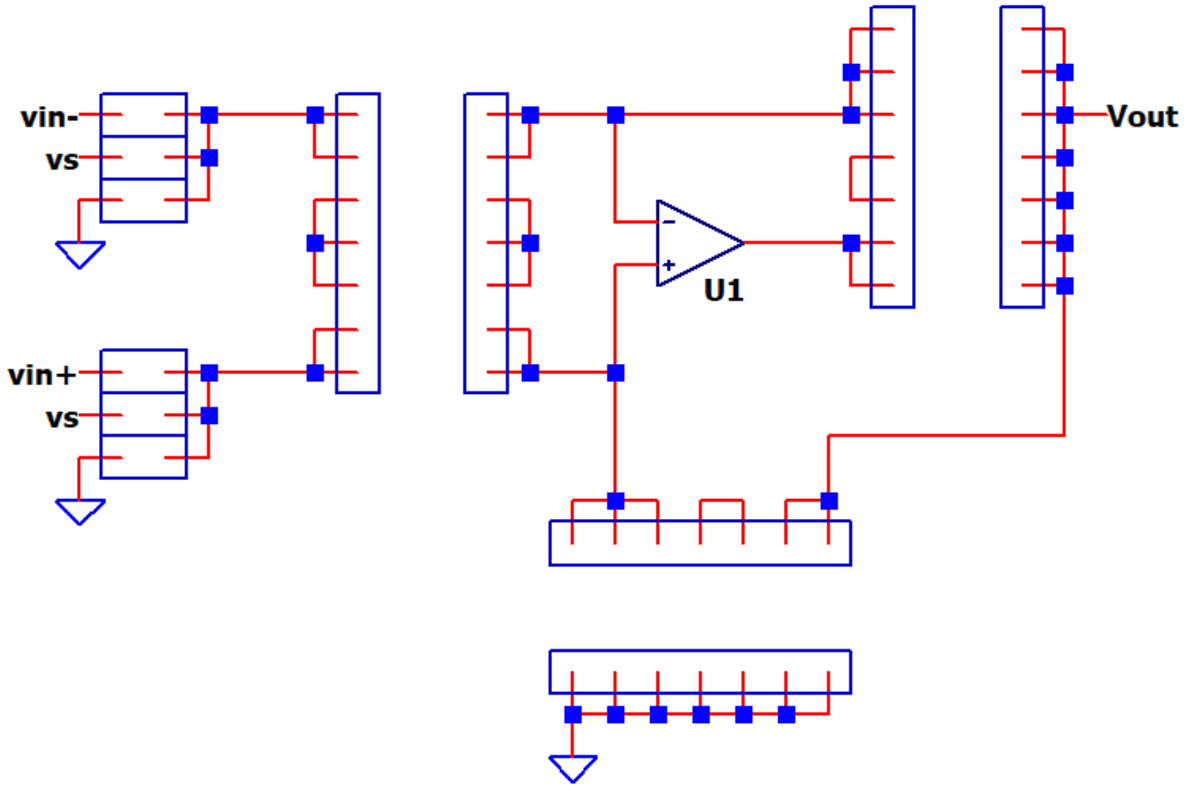


5.2 Your Turn!

How can you prototype the Inverting Low-Pass Filter?



Grab a pencil an solve the quest of how-to-build the circuit on the blank proto schematic! More than one solution typically possible.



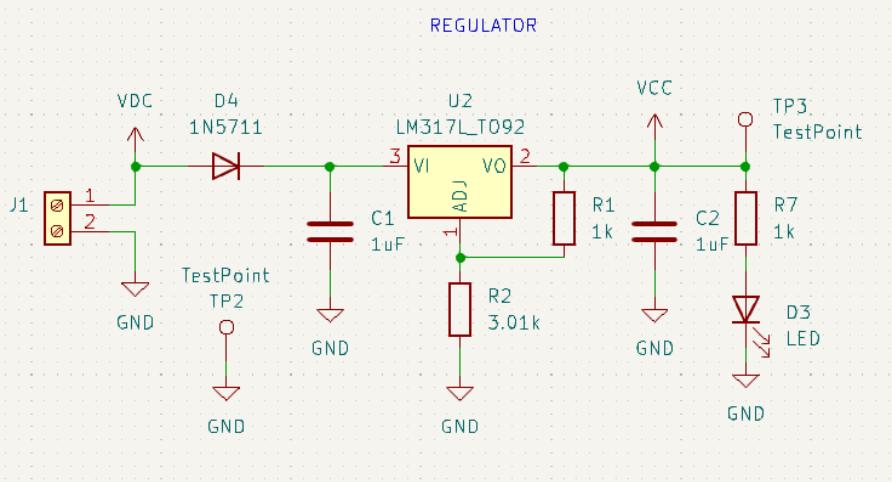
Next step: install the components, jumpers and then power up and explore the circuit.

Print out blank Proto Area Schematics from Section 10.

6 Schematic

The system implements classic circuits for easy implementation as well as for lessons of theory and practice.

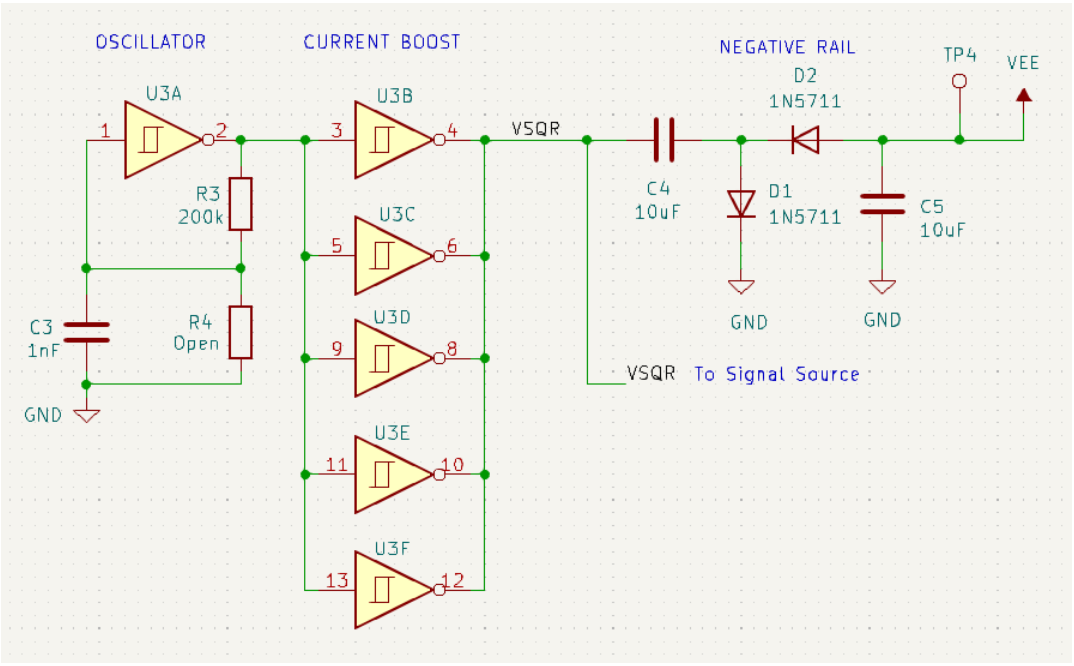
6.1 Positive Adjustable Supply



- U1 regulates external battery or power source to 5V
- R1, R2 adjust output VCC = 1.25V x (R1+R2)/R1
- D4 prevents Vin reverse bias diamage.
- D3 provides visual power indicator

6.2 Square-Wave Oscillator and Negative Rail

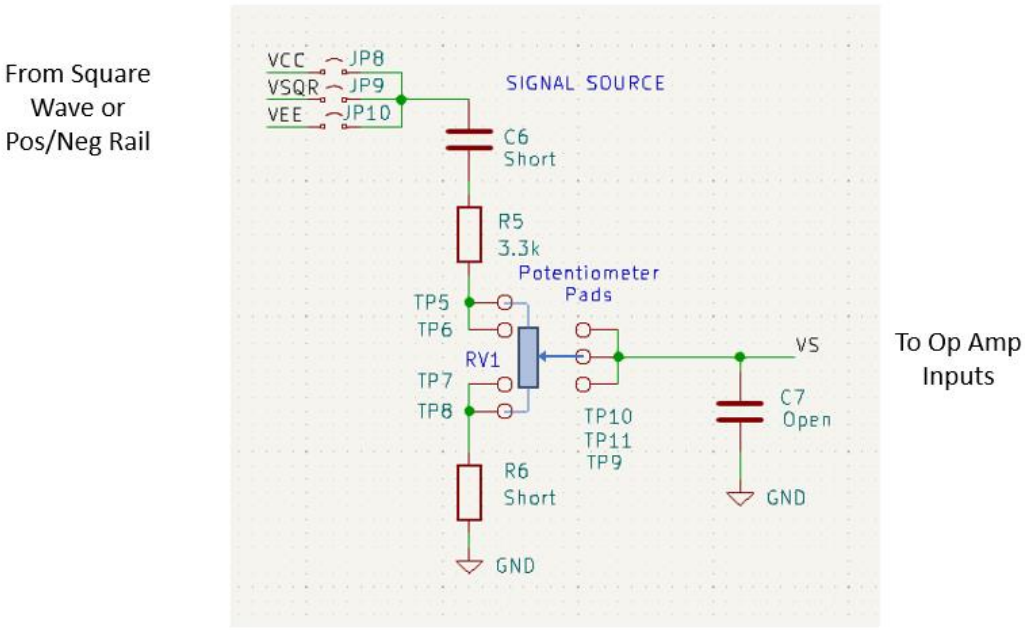
Square Wave provides Signal Source and drives Neg Rail Generator.



- Square-Wave Oscillator (U3A, R3, R4) creates 0-5V, 200kHz signal.
- Negative Rail developed by Capacitive Charge Pump (C4, C5, D1, D2).

6.3 Signal Source and Scaling

Signal components C6, R5, R6 and C7 easily changed on 4-pin headers for user flexibility.



RV1's multi-pad PCB layout accommodates a wide variety of Trim Pot types. Flexible signal options.

- Select Signal Source (JP8-10): Square Wave (VSQR) or DC Level (VCC, VEE).
- Choose DC Coupling (C6=short) or AC Coupling (C6=cap)
- Scale signal between 0 and 5V (Resistor Divider R5, RV1 and R6).
- Adjust signal level (RV1)
- Apply Low-Pass Filter (C7 optional).

DC Signal Scaling (R-Divider)

- Minimum

$$VS_{min} = Vin \cdot \frac{R6}{R5 + RV1 + R6}$$

- Maximum

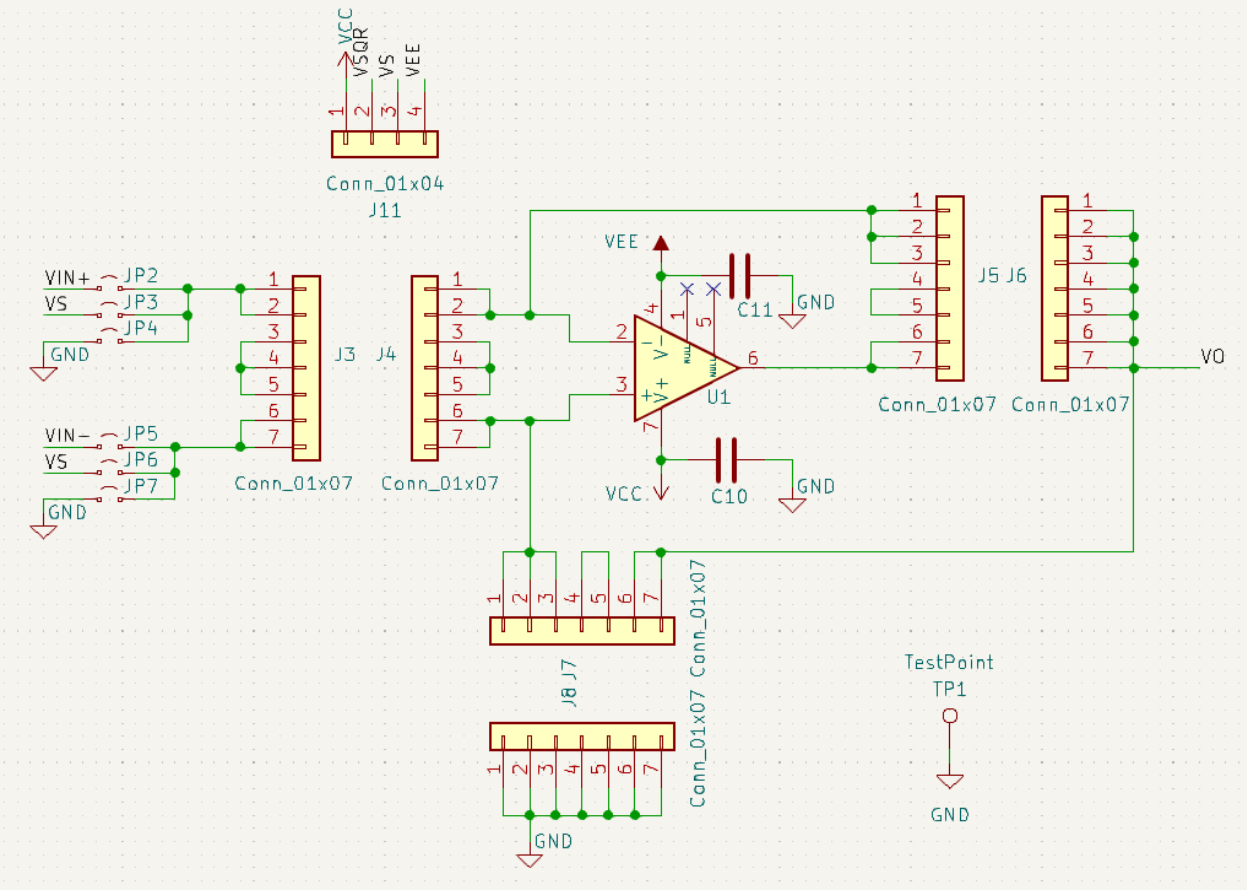
$$VS_{max} = Vin \cdot \frac{R6 + RV1}{R5 + RV1 + R6}$$

Default Signal Settings

- C6=short, R5=3.3k, RV1=1k, R6=short, C7=open, JP9=ON.
- RV1 adjusts VS for a 0 to 1.2V Square-Wave.

6.4 Op Amp Proto Area

Component headers and jumpers create a flexible and intuitive proto lab for exploring op amp circuits.



Prototyping

- Easily install components (Rs, Cs, etc.) *across or within* any Header Sockets (J3 - J8).

Input Signals

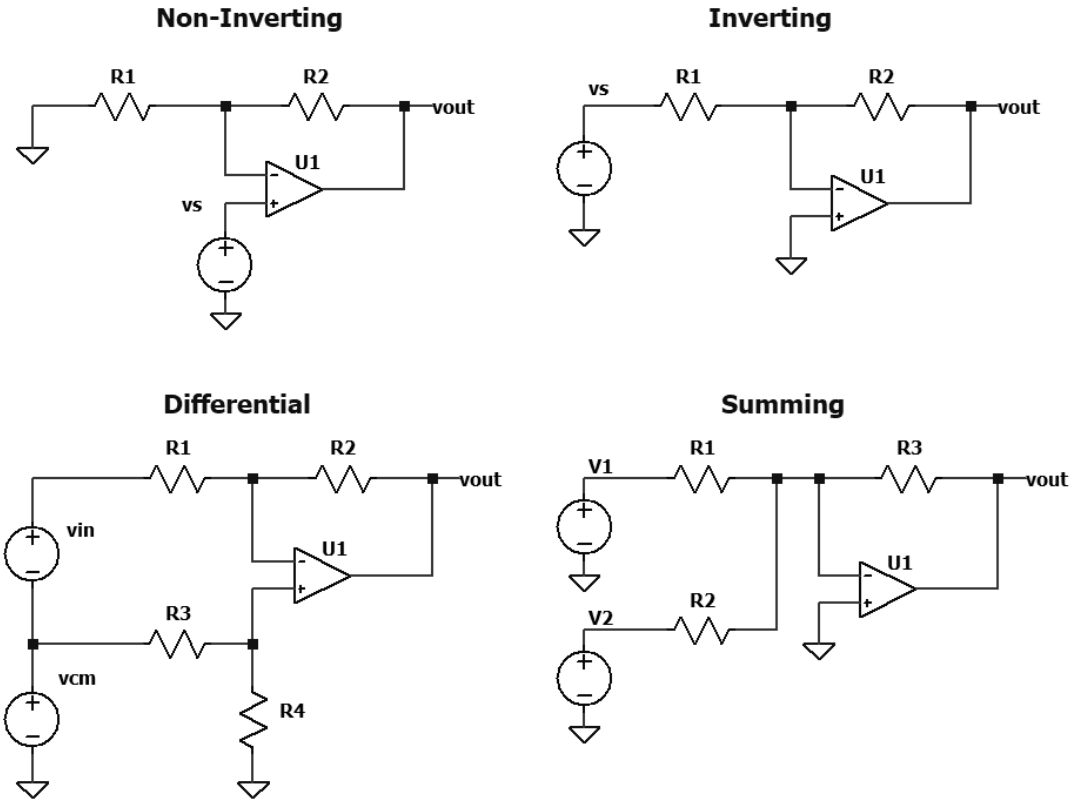
- Select VS, GND or VIN- (ext) to U1 NEG input path (JP2-4).
- Select VS, GND or VIN+ (ext) to U1 POS input path (JP5-7).

Advanced Circuits

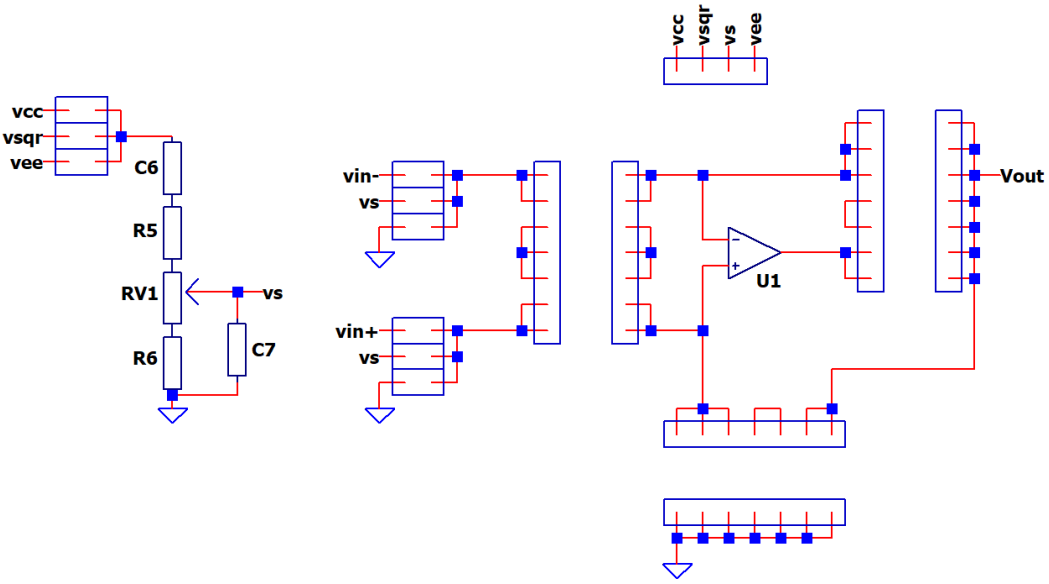
- Connect to VCC, VSQR, VS or VEE (J11) for more advanced circuits.
- Install alternate op amps into U1 socket.
- Circuit stabilty provided by C10, C11 bypass capacitors.

7 Op Amp Basic Circuits

- Fast prototyping of key topologies.
- Basic to advanced applications.
- More op amp circuits possible!



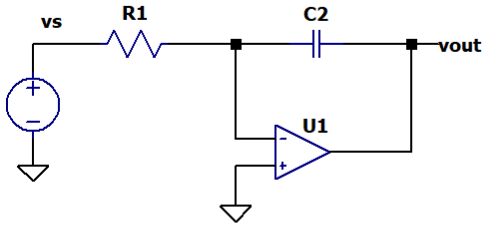
- Grab a pencil - find a way to create the circuit on the Proto Area!



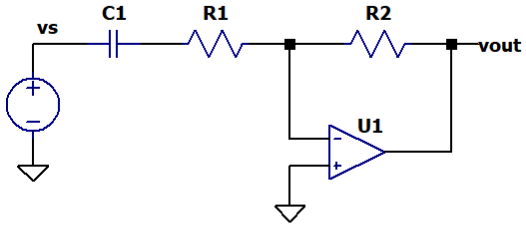
- Print out more Proto Area Schematics (Section 10).

8 Op Amp Circuits II

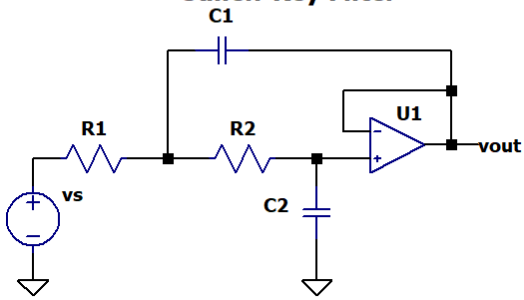
Integrator



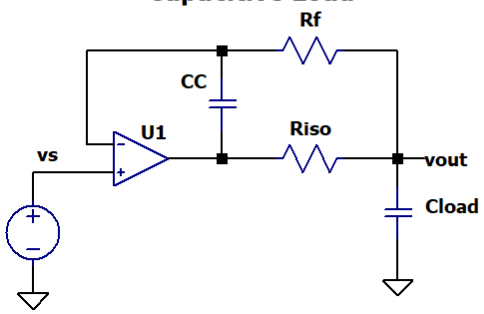
Differentiator



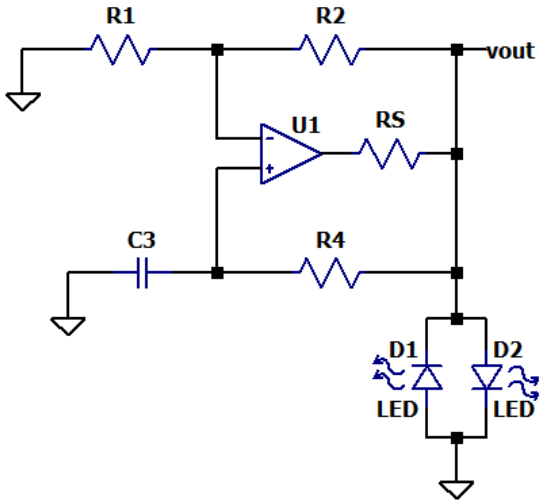
Sallen-Key Filter



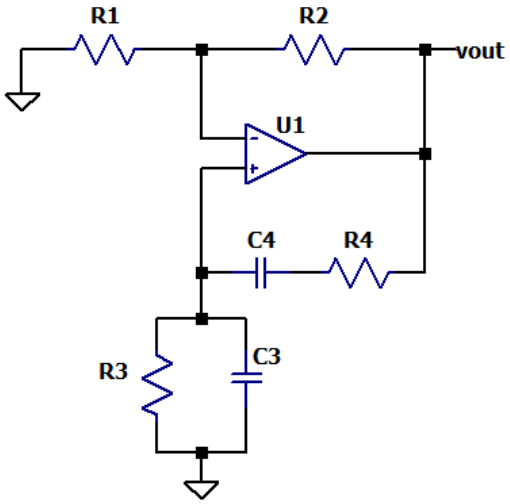
Capacitive Load



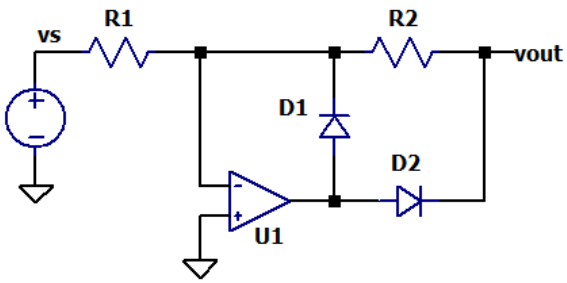
Square-Wave Oscilator



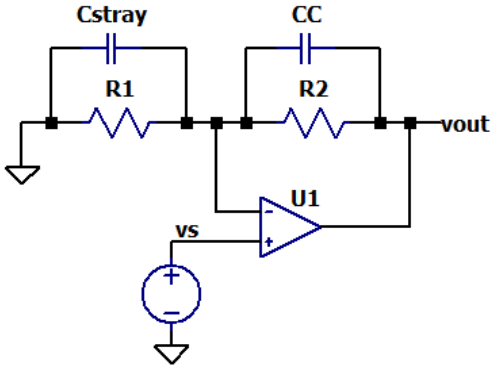
Wein-Bridge Oscillator



Precision Rectifier

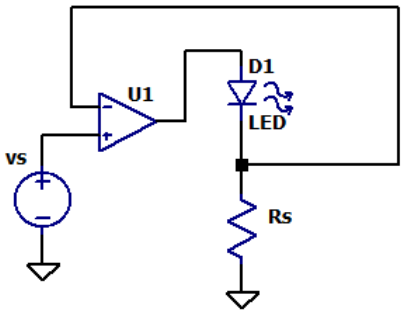


Stray Capacitance

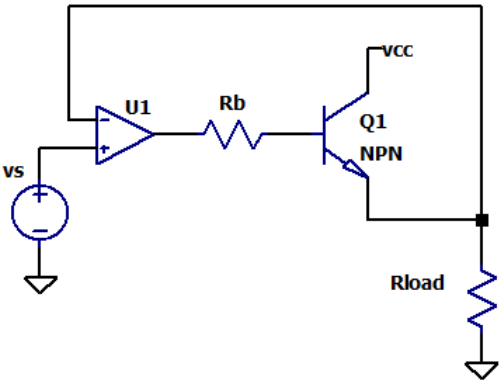


9 Op Amp Circuits III

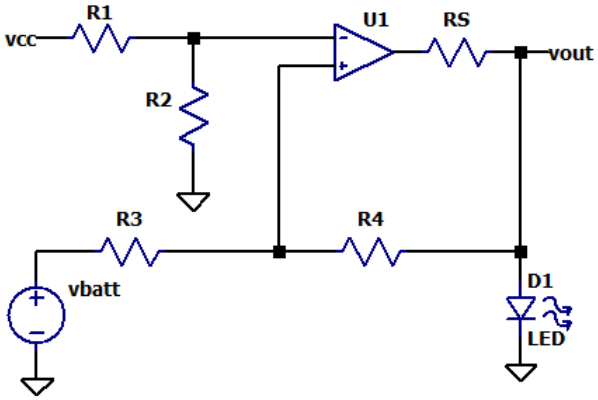
LED Current Drive



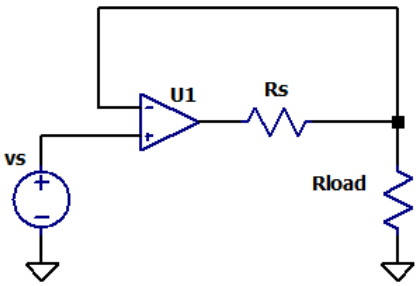
Voltage Regulator



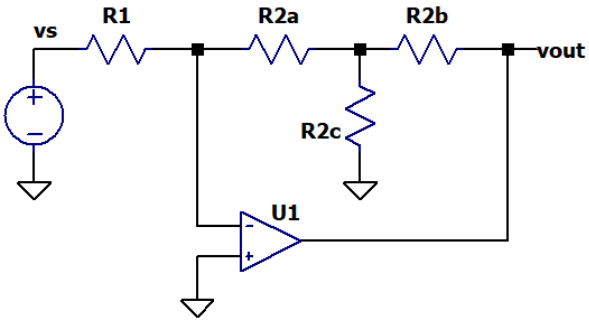
Comparator (Lo-Batt)



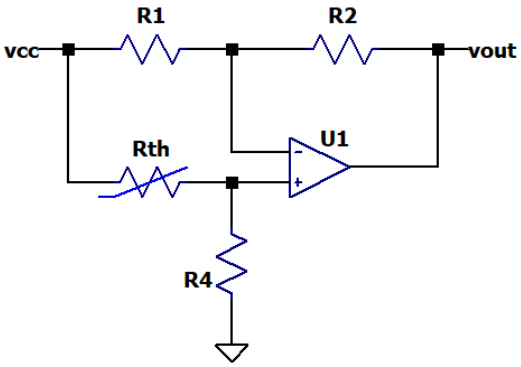
Buffer (Remote Sense)



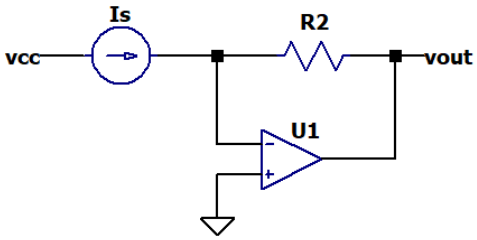
T Feedback



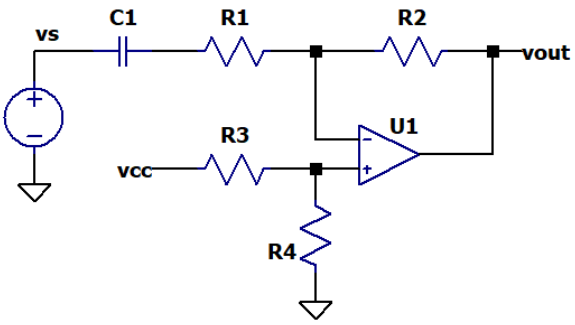
Temperature Sense



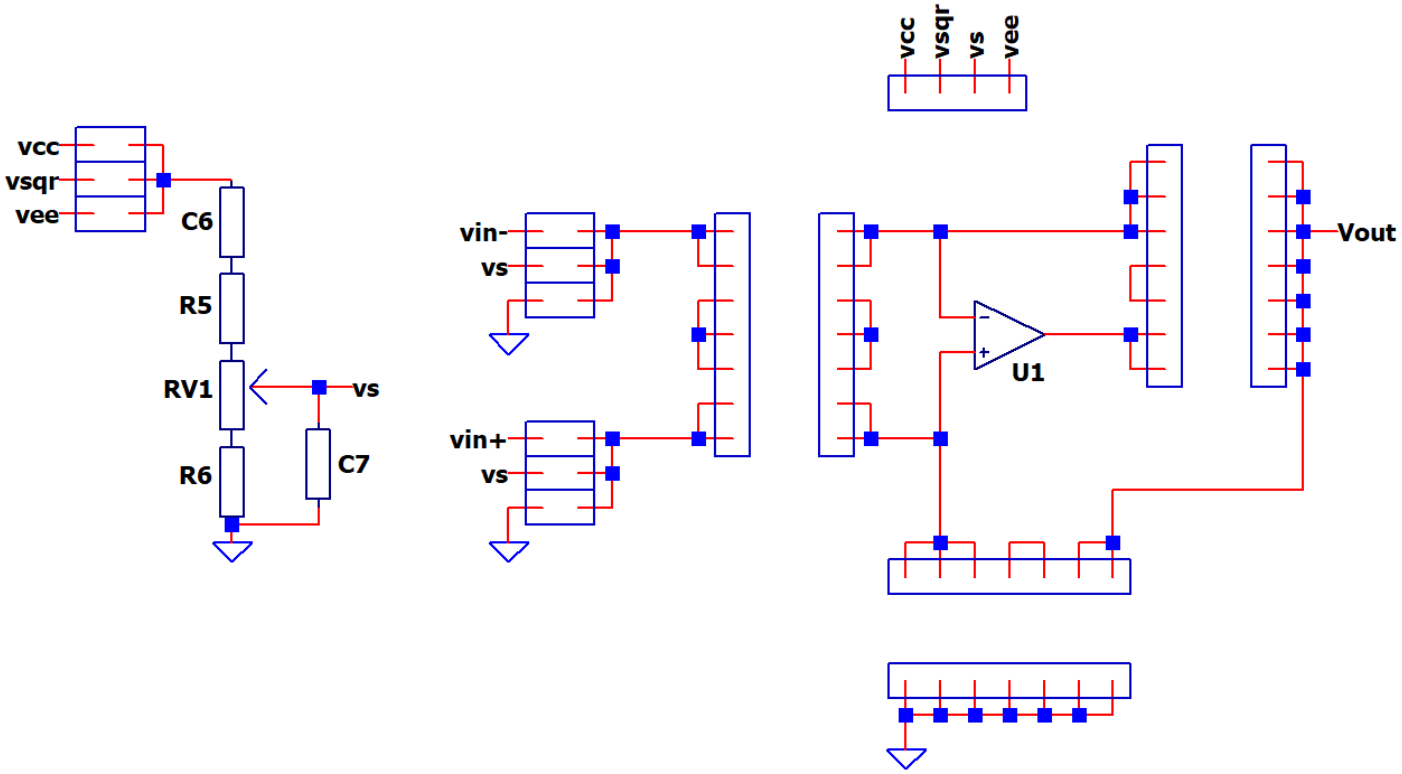
I-to-V Converter

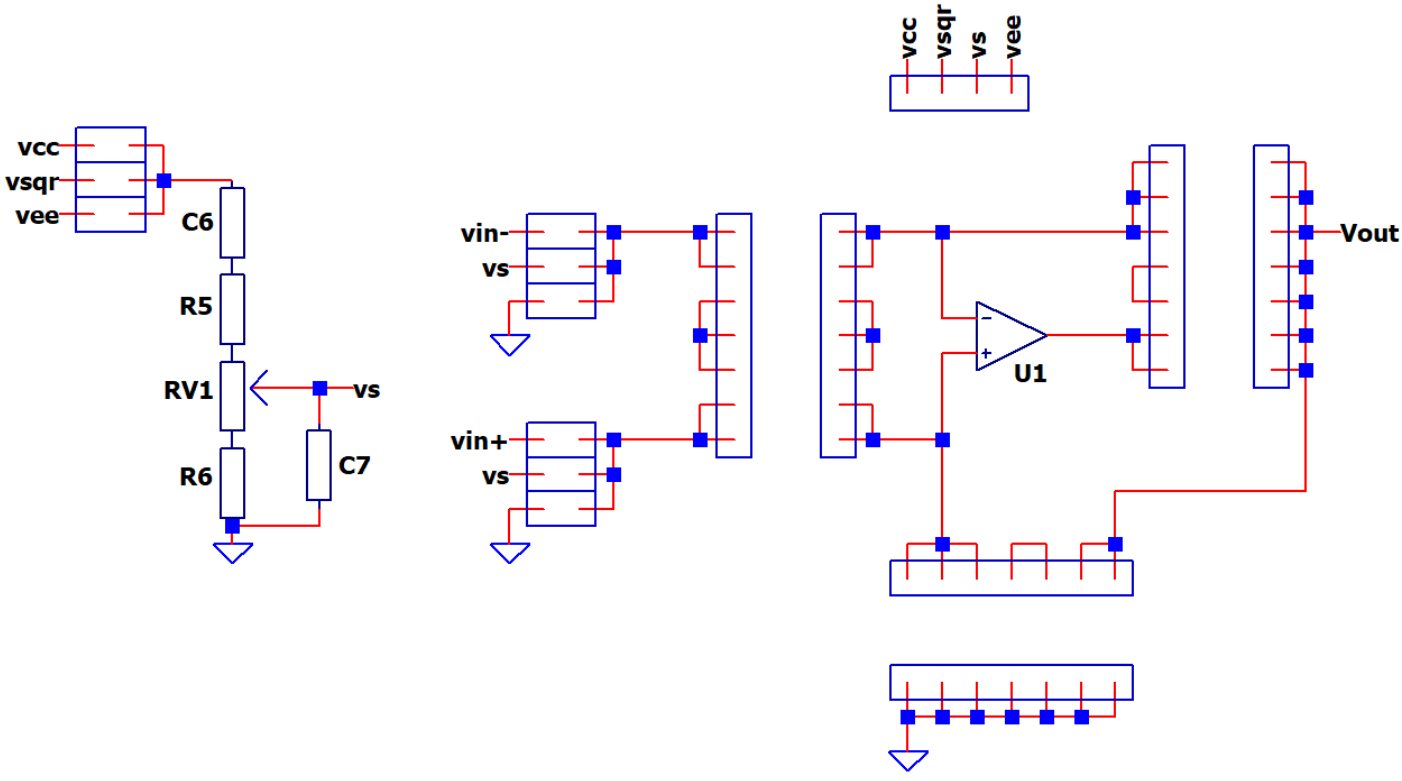


Single Supply Amp



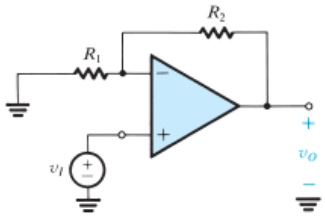
10 Proto Area Schematics





11 Non-Inverting Amp Walk-Thru

1. Define It *– Draw Schematic, choose gains, signal levels, etc.*



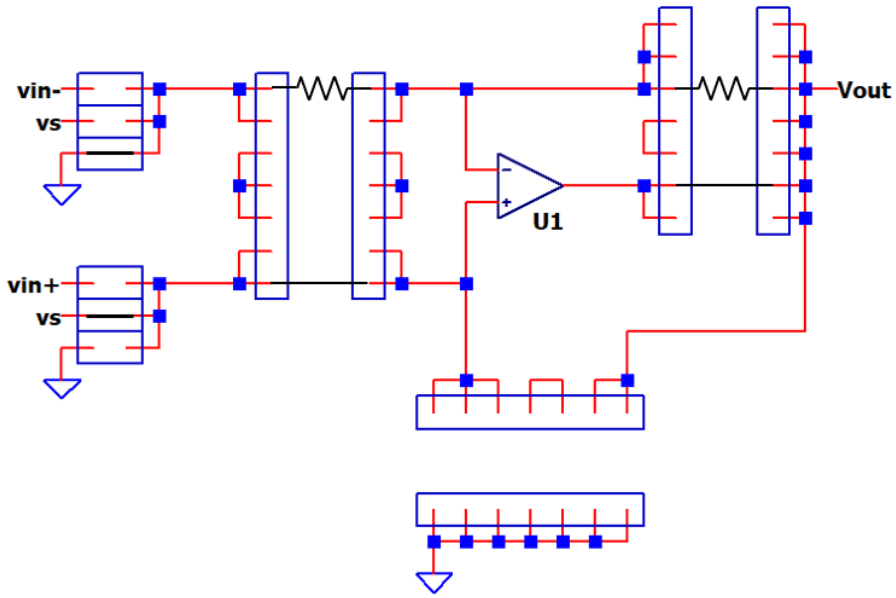
Let's amplify a signal by +3.
K = Vout/Vs = R1/R2+1 = 3
Choose Vs = 0.5V

2. Design It *– Calculate component values, signal levels.*

Choose R1 = 10k,
Calc R2 = (K-1) * R1 = 20k

Vout = Vs*K
= 0.5V*3
= 1.5V

3. Build It - *Find a way to create it (sketch circuit below, install parts on Discovery Bd.)*



4. Test & Learn It – *Plan setup, make measurements, verify levels, observe, connect to theory.*

Power up the circuit (connect 9V Battery).
Connect Probe 1 to VS (Jumper at J3,4).
Connect Probe 2 to VOUT (R2 at Vout side).
Verify a unipolar square wave at VS.

Adjust RV1 for VS = 1V peak.
Did Vout achieve the goal?

Move Probe 2 to U1 input- (R1 at U1 side).
Does U1.in- follow VS?

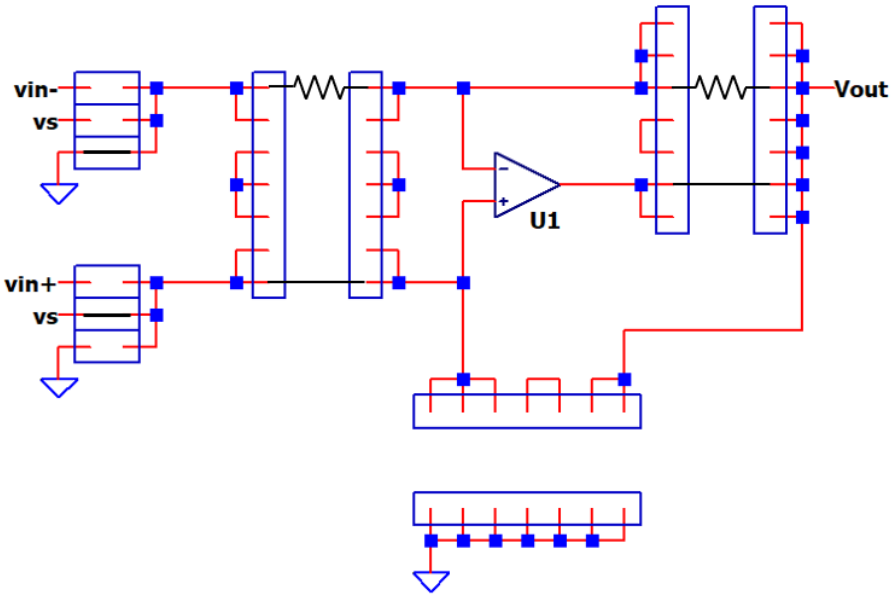
What happens if you double R1 or R2?

12 Op Amp Discovery Sheets

1. Define It *– Draw Schematic, choose gains, signal levels, etc.*

2. Design It *– Calculate component values, signal levels.*

3. Build It - *Find a way to create it (sketch circuit below, install parts on Discovery Bd.)*



4. Test & Learn It – *Plan setup, make measurements, verify levels, observe, connect to theory.*

13 Parts List

Here's the default Bill of Materials. Modify and build for your own learning goals.

Reference	*Qty*	*Value*	*Part #*	*Comment*
C1, C2	2	1uF		All caps ceramic, ≥ +25V
C3	1	1nF		
C4, C5	2	10uF		
C6, R6	2	Short		Short wires or resistor leads.
C7, R4	2	Open		
C10, C11, C12	3	0.1uF		
D1, D2, D4	3	Diode	1N5711	
D3	1	LED Yel	LTL-4253	Any color you prefer.
J1	1	2-pin Terminal Block screw type		Optional: Solder 9V Battery Leads or Power Supply Leads directly to pads.
J2	1	3-pin Header	TSW-103-08-T-S	Optional: for external inputs.
J9	1	2-pin Header	TSW-102-08-T-S	Optional: for external output.
JP2, JP3, JP4, JP5, JP6, JP7, JP8, JP9, JP10	9	2-pin Header	TSW-102-08-T-S	3 Shunts needed typically SNT-100-BK-T
J3, J4, J5, J6, J7, J8	6	7-pin Socket Header	SSW-107-01-T-S	Sockets for circuit prototyping.
J11, J12, J13	3	4-pin Socket Header	SSW-104-01-T-S	J12,13 sockets for signal scaling components C6, R5, R6, C7.
R1, R7	2	1k		All resistors 1/4W, 5%.
R2	1	3.01k		
R3	1	200k		
R5	1	3.01k		
RV1	1	1k trimpot side adjust	3352W-1-102LF	5 PCB pads available for various pin styles. Alternate part with top adjust: 3386P-1-102TLF
TP1	1	TestPoint	5011	
U1	1	Op Amp	LMC6081IN/NOP8	Single op amp, rail-to-rail output, +/-7.5V supply max, DIP.
U1 socket	1	DIP-8 Socket	4808-3000-CP	
U2	1	Linear Regulator	LM317LZ	
U3	1	Hex Inverters Schmidt Trigger	74HC14APF	
U3 socket	1	DIP-14 socket	4814-3000-CP	

14 Bonus Sections

14.1 Revision & Notes

Op Amp Discovery User's Guide: Rev 1a

I was looking to clear some roadblocks to the hands-on learning of op amps: *driving to a limited-hours lab, clearing a work space at home, buying expensive / bulky supplies / generators or struggling with messy circuit wiring on breadboards*.

A bit of research and brainstorming led to the idea of the Op Amp Discovery Board - *the best of both the solderless breadboard and PCB worlds*. A small board with handy component headers, PCB interconnections, supply rails and a square wave generator is where I could learn on my kitchen table, in the library or coffee shop.

In a short time, I got up and running 20+ classic op amp circuits **rediscovering the fun and joy of learning about circuits**, developing understanding and intuition about their topologies and device behaviors.

Rick Faehnrich

https://www.linkedin.com/in/rick-faehnrich-2671a911/

14.2 Learning Styles

Dive in any way that propels your learning with Open or Guided learning (or combinations of both).

1. *Explore circuits entirely on your own with Self-Directed Learning.*
2. *Follow Guided Examples of circuits to observe op amp functions and behaviors.*
3. *Borrow ideas from circuit examples and follow-through on your own.*

14.3 DMM Only Learning (No Scope)

A Digital Multi-Meter (DMM) serves a low cost alternatve to an oscilloscope. Budget DMMs are available from $10 and up. See the Guided Examples document for tips on getting the most from a DMM.

14.4 Circuit Options

External Inputs/ Outputs

- Install header pins J2 (input) and J9 (output).
- Install 2-pin shunts at JP2 or JP5.

External Power Supplies

- Un-install U2, R1, C2, R7, C5, D2
- Connect external supplies to PCB plated holes labeled VCC, GND and VEE.

14.5 KiCAD Software

KiCad is a free and open-source software suite that provides a complete EDA toolset including schematic capture, PCB layout, 3D visualization, and circuit simulation. https://www.kicad.org/

14.6 GitHub

The Op Amp Discovery Bd is an open-source project intended to make op amp learning as accessible and affordable as possible. You can down load the documentation and KiCAD project files at https://github.com/rick-ecircuit

14.7 Experimenters Parts List

Here's a suggested selection of parts to explore the circuits.

Reference	*Qty*	*Value*
Resistors	3 each	100, 1k, 3.3k 10k, 20k, 33k, 39k, 47k 100k, 200k, 330k, 390k, 470k 1M, 4.7M
Capacitors	2 each	100pF, 1nF, 10nF, 100nF, 1uF
Seniconductors	2 each	BJT 2N3904 Diode 1N5711
LEDs	2 each	RED, GRN
Sensors	1 each	Thermistor 10k Photodiode
Jumpers	10 each	Use cut resistor leads

14.8 Feedback eCircuitCenter

Feedback on eCircuit Center

- ✓ How is Op Amp Discovery helpful for you?
- ✓ What circuits could be added?
- ✓ What needs clarity?

Send your thoughts on the feedback form at eCircuit Center.
https://ecircuitcenter.com/op-amp-discovery/form/feedback1.html

> ***eCircuit Center*** *strives to provide informal, hands-on and fun experiences that lead to a deeper, more intuitive understanding of circuit design and analysis.*

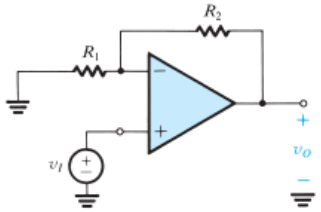
14.9 Advanced Topics

The Discovery Board allows learning of advanced characteristics and limitations!

- Bandwidth
- Slew-Rate
- Stability
- Voltage / Current Limits
- Linear Regulator and Capacitive Charge Pump
- Heat (Thermal) Management
- RC Oscillators

14.10 The Power of Play

- Key to analog success: *play, play, play with circuits!*



- Analog circuits appear more inviting (and less intimidating) when playing and tinkering.
- Learning and passion grow when you
  - Ask “what if” questions
  - Play with component values - *Predict the outcome!*
  - Small discoveries and learning fuel motivation and the joy of learning.