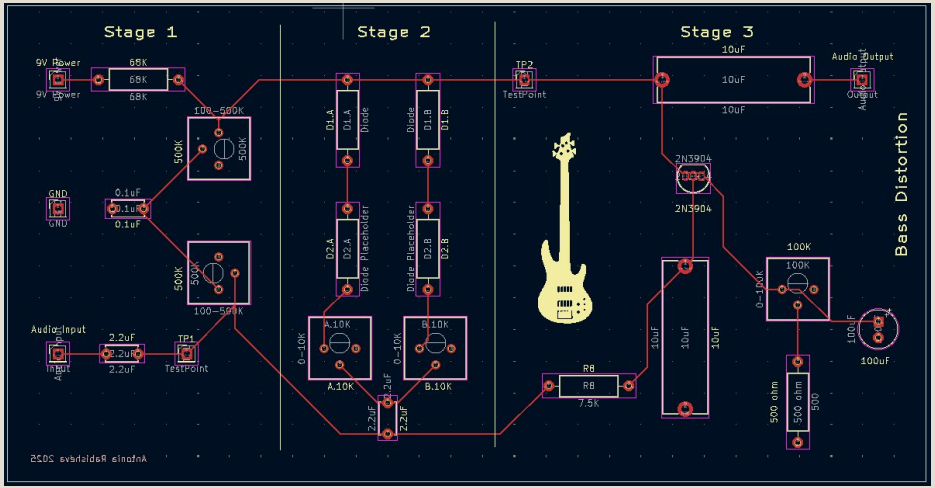
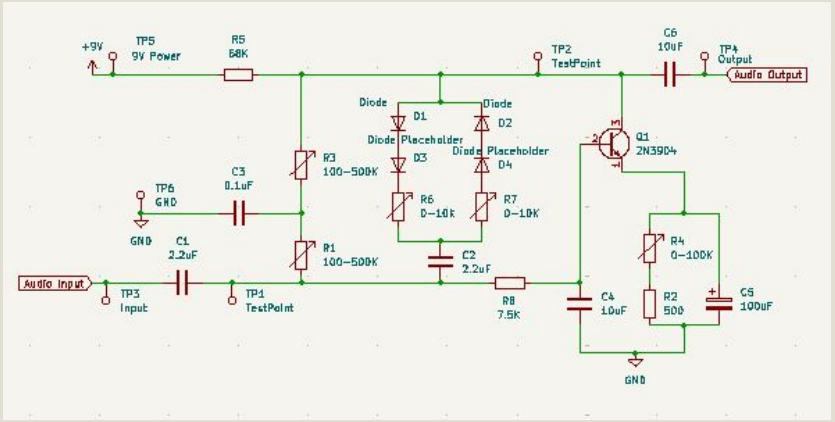
MPI Lead: Toni



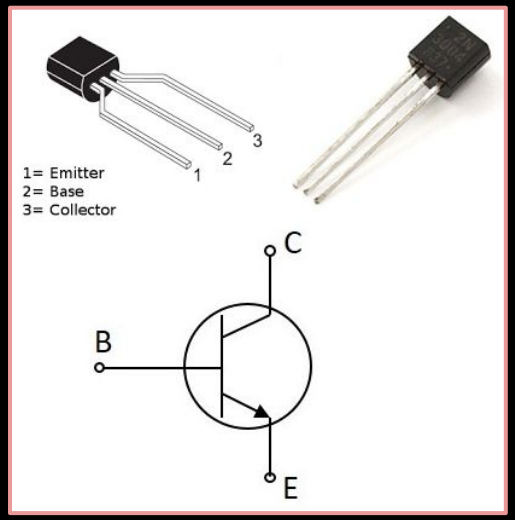
Transistors in Analog Design

Bass Distortion

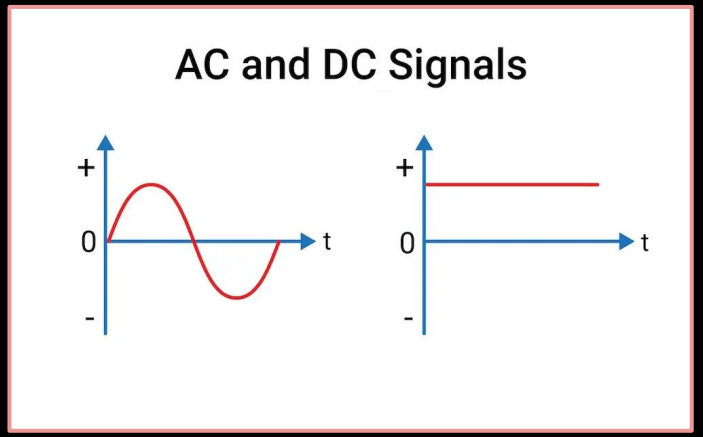


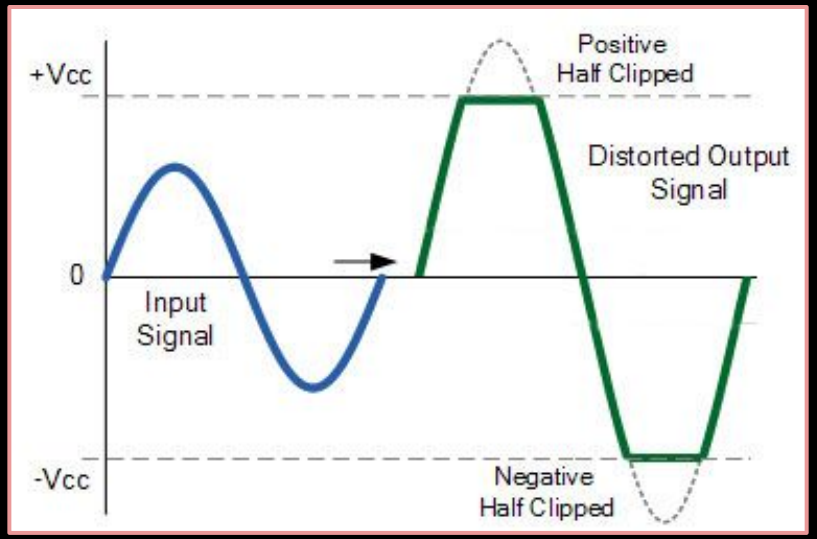
Audio Amplifier	A circuit that increases the amplitude of low-power audio signals to a level suitable for driving loudspeakers, usually including filters in their design for better sound reproduction
Filter	A circuit that selectively allows signals of certain frequencies to pass while attenuating others. It's commonly used to remove unwanted noise or to separate different frequency components in a signal
Amplification vs Switching	In BJT transistors, **amplification** occurs when the transistor operates in the **active region**, where it linearly increases the input signal's amplitude. In contrast, **switching** uses the transistor in either **cutoff** (off) or **saturation** (on) regions, acting like an electronic on/off switch rather than varying signal strength.
AC vs DC	**AC (Alternating Current)** is a signal that constantly changes direction and varies in voltage over time, often forming a wave-like shape such as a sine wave. **DC (Direct Current)** is a flat, constant signal that stays at the same voltage level
DC Offset	Refers to biasing of transistors → A constant DC voltage needs to be set and applied to the base to ensure the transistor operates within the correct region (active in our case)
Clipping	**Clipping**, in relation to diodes, occurs when diodes are used in a circuit to limit the voltage of a signal by cutting off (or "clipping") parts of the waveform that exceed certain voltage levels. This creates a flattened top or bottom of the signal
Feedback	**Feedback** in a BJT transistor circuit involves routing a portion of the output signal back to the input to influence the transistor's behavior. Can be negative or positive.

Terminology & Concepts

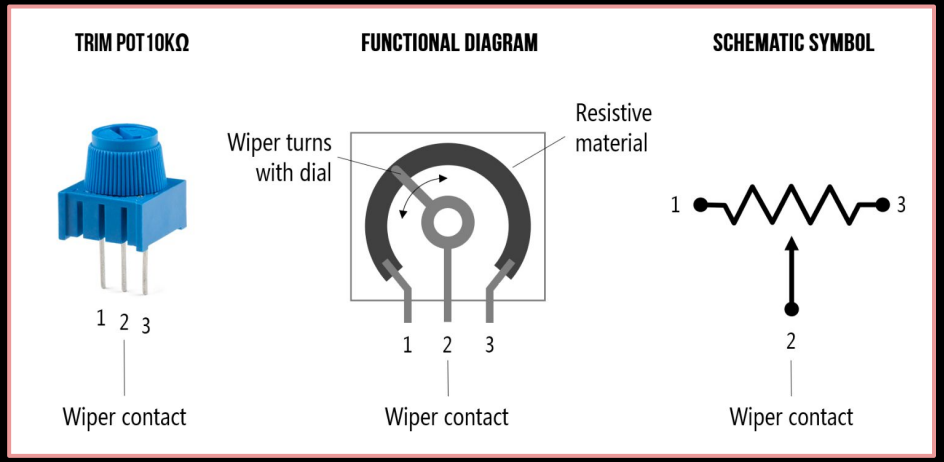


NPN BJT Transistor



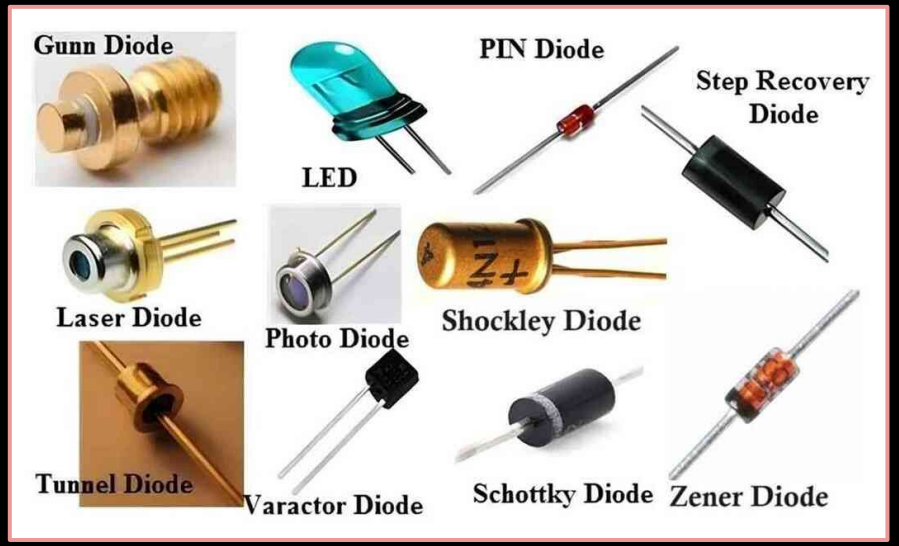


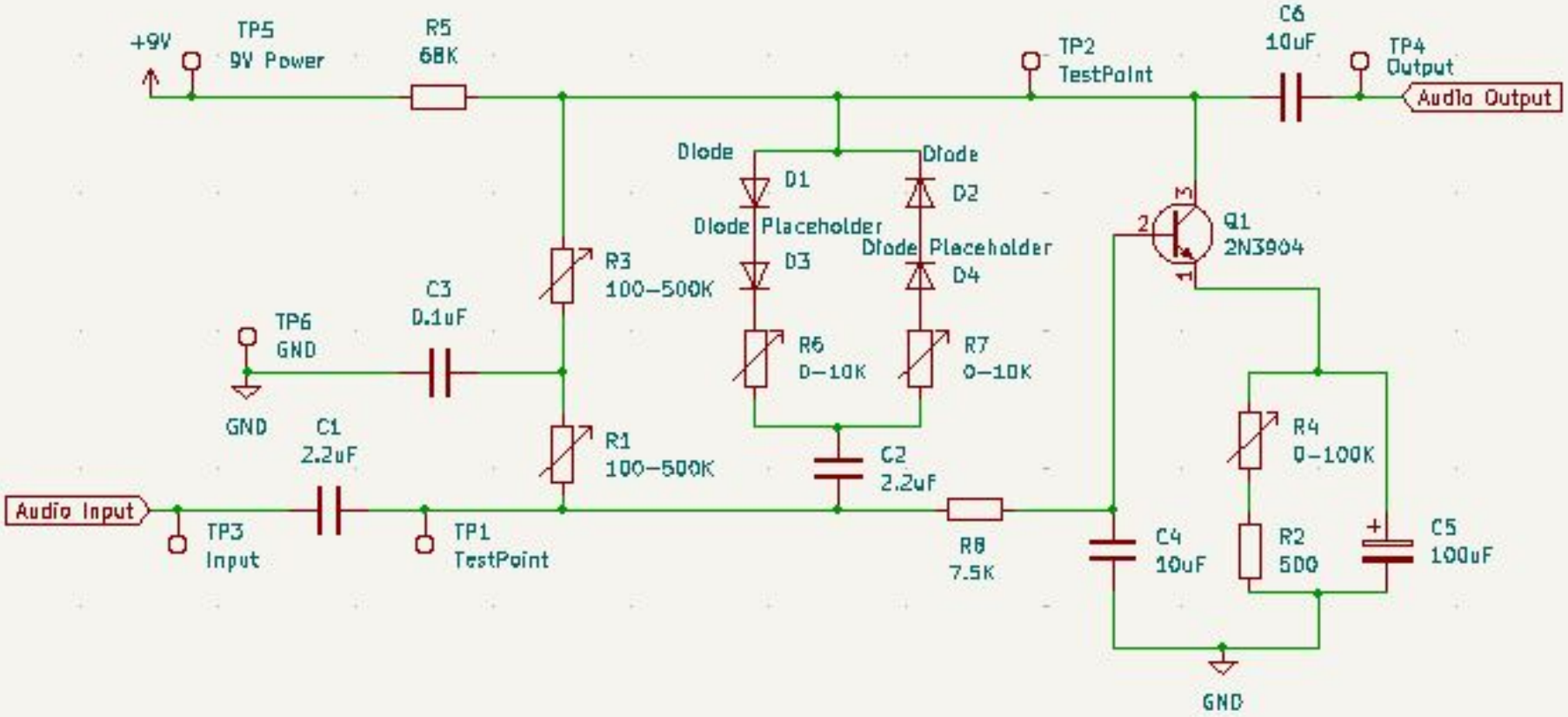
Clipping

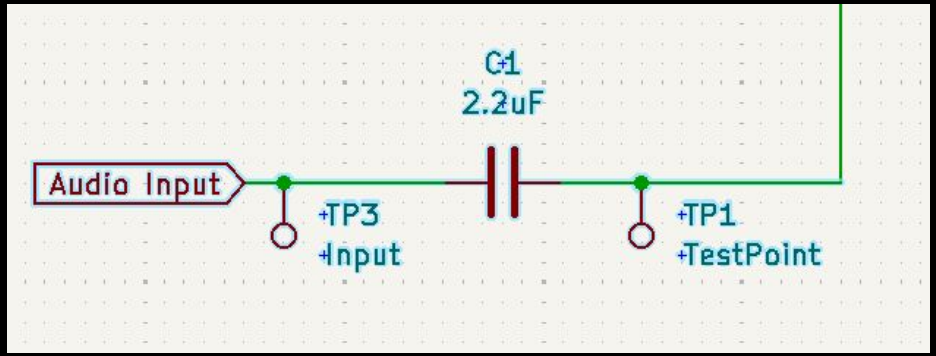


Potentiometer

Diodes

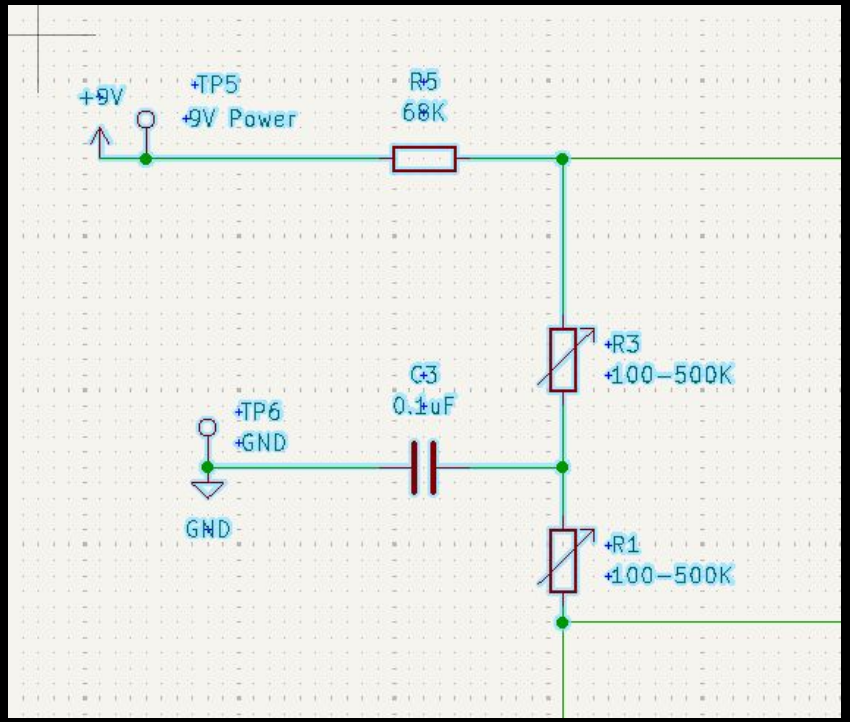



+9V
TP5
9V Power
R5
68K
TP2
TestPoint
C6
10uF
TP4
Output
Audio Output
Diode
D1
Diode
D2
Diode Placeholder
D3
Diode Placeholder
D4
Q1
2N3904
R3
100-500K
C3
0.1uF
TP6
GND
GND
C1
2.2uF
R1
100-500K
R6
0-10K
R7
0-10K
C2
2.2uF
R4
0-100K
Audio Input
TP3
Input
TP1
TestPoint
R8
7.5K
C4
10uF
R2
500
C5
100uF
GND



- The input is a small AC voltage signal with a frequency of **60Hz - 250Hz**
- High pass filter → why include it and how does this work?
- Test points → why are these important?

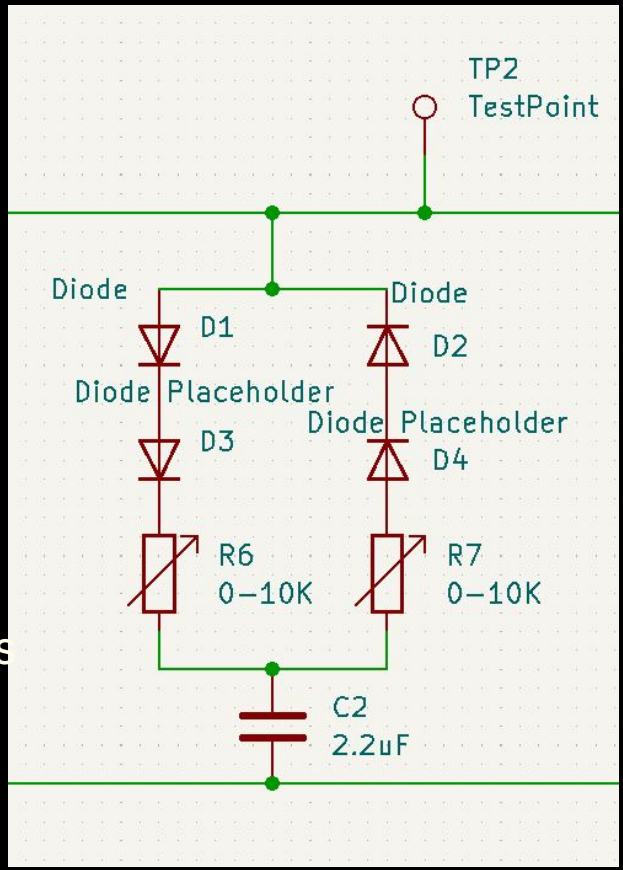
Part 1: Input



- **R5** → Connects 9V to the R3, R1 junction, forming a voltage divider that sets the DC offset for the base of the transistor
- **R3, R1** → Adjustable voltage divider
- **C3** → Used for AC coupling (ensures DC bias is stable by shunting AC noise signals)

Part 2: DC Offset + Bias

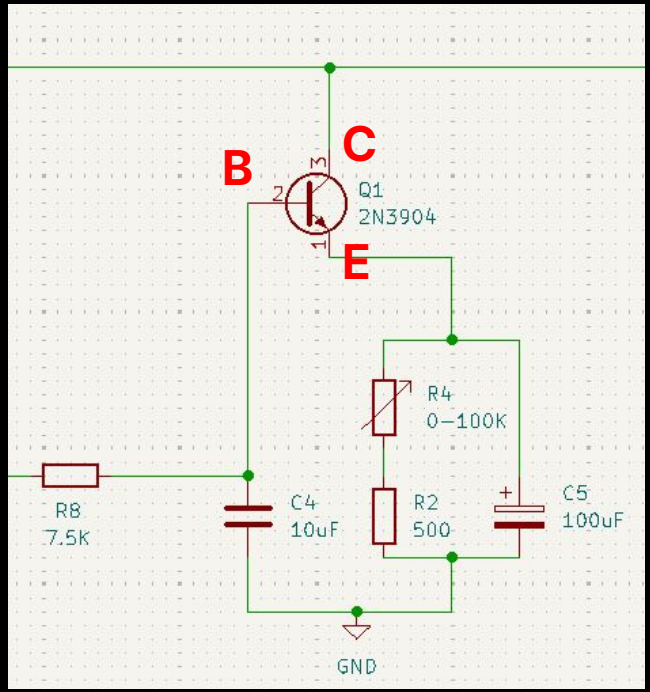
- **Left branch** → Clips positive values of signal (AC) waveform
- **Right branch** → Clips negative values of signal (AC) waveform
  - ↑ diodes = ↑ voltage threshold = ↓ clipping
  - Adjustable resistor → sloped clipping
- **C2** → AC coupling
  - Blocks DC signal from clipping branches
  - Passes AC signal to base of the transistor
  - Ensures DC signals from clipping branches don't affect bias voltage divider from previous stage



Part 3: Clipping

- **Transistor** → Biased in active region, it acts as an amplifier
  - Amplifies AC signal on **base**
- **R8** → Limits base current going into Q1 (protection: think bass guitar) and, with C2, creates a low-pass filter
- **Negative feedback loop**:
  - C4 → ↑ signal frequency = ↑ shunted to ground = ↓ gets amplified
  - R4, R2 → ↓ voltage drop across transistor (V=IR) = ↓ amplification of signal
  - C5 → in parallel with R4 + R2...

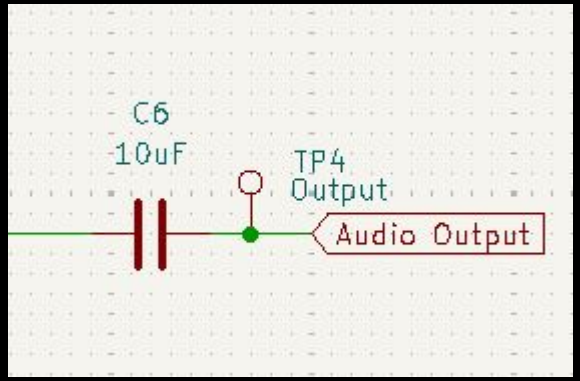
↑ signal frequency = capacitor → short = ↑ voltage drop across transistor = ↑ amplification



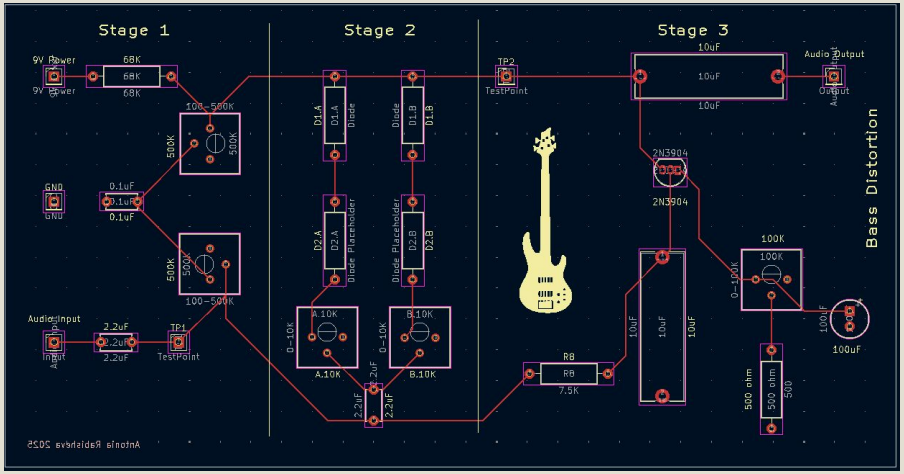
Part 4: Amplification

- C6 →AC coupling capacitor that blocks any DC offset present at the collector of the transistor while only passing the amplified AC signal

Think practically: what would happen if it wasn't there?



Part 5: Output



- **For resistors** → find the indicated value (500 ohm, 68k, 7.5k) in the Hive benchtop drawers
- **For diodes** → this is part of the distortion you get to personalise! Pick and choose from the Hive benchtop drawers

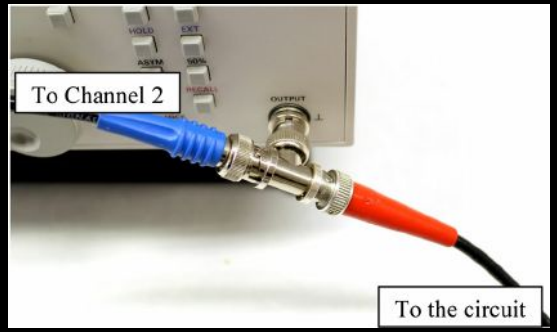
Fabrication

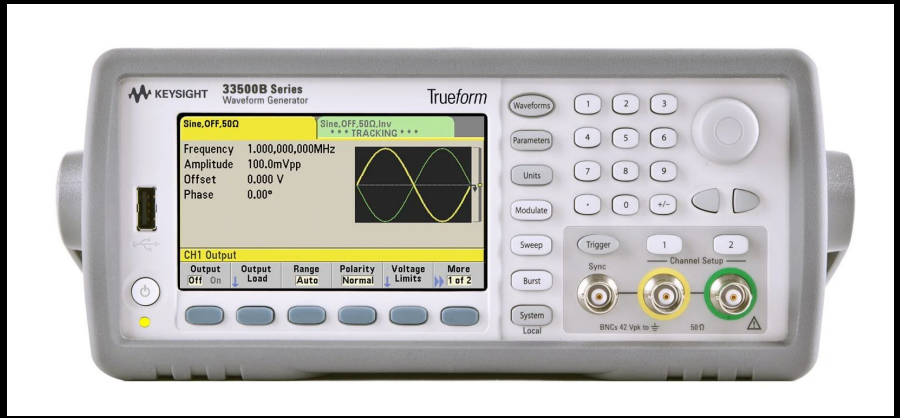
Component List

Name	Quantity	Symbol(s)
2N3904 NPN Transistor	1	Q1
10K pot	2	R6, R7
100K pot	1	R4
500K pot	2	R1, R3
100 uF cap (polarized)	1	C5
2.2uF cap	2	C1, C2
10uF cap	2	C4, C6
0.1 uF capacitors	1	C3
Male/looped pin header	6	TP1 - 6
Female pin header	4	D3 (2), D4 (2)
Resistors	3	R2, R5, R8
Diodes	2	D1, D2

Simulation/Testing

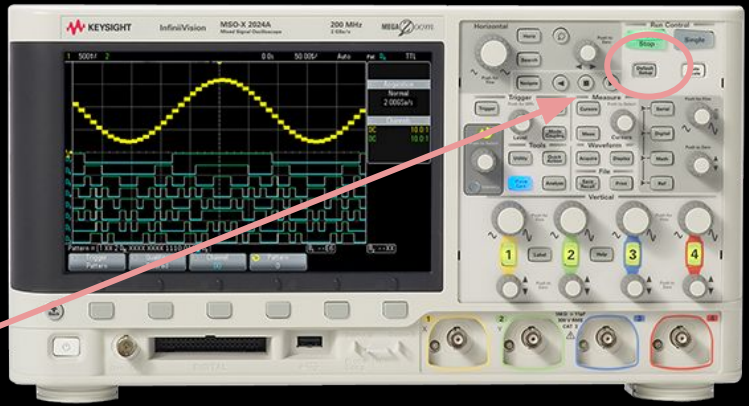
1) **Function generator**:
   a) Use 1 BNC → banana cable and 1 BNC → BNC cable
   b) Use a T-splitter on the input of the generator
   c) Connect the BNC → BNC cable from the T-splitter to the o-scope input
   d) Connect other cable from T-splitter to circuit
   e) Hook up red to input TP
   f) Hook up black to GND TP
   g) Set generated function to:
      i) High-z impedance
      ii) 100 Hz frequency
      iii) 1 Vpp amplitude (sine wave)





Simulation/Testing

1) **Oscilloscope**:
    a) Use 1 BNC → banana cable
    b) One input should have the function generator signal
    c) Connect the BNC → banana cable to the other input
    d) Hook up red to output TP
    e) Hook up black to GND TP
    f) Turn on scope and hit Default Setup



Simulation/Testing

1) **Power Supply**:
   a) 2 banana → banana cables
   b) Connect 1 cable from +20V to +9V TP
   c) Connect other cable from COM to GND TP
   d) Set power supply to 9V on the 20V output

What you should expect to see...

For questions/comments on this circuit and workshop, contact:

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~
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