ATOM

3x ATtenuverter Offset Mixer

ATOM is a 3-channel ATtenuverter and Offset Mixer, labeled channels 1, 2, and 3. Each input (A,B) is equipped with a dedicated bipolar control potentiometer for its input. When a cable is plugged into an input jack, the corresponding channel's potentiometer (D,E) acts as an attenuverter. Turning it fully clockwise passes the signal through to the output without attenuation or inversion (Gain = 1). Rotating the potentiometer counterclockwise decreases the signal's volume until it reaches the 12 o'clock position, where the signal is completely attenuated (Gain = 0). Continuing to turn the potentiometer counterclockwise from the 12 o'clock position begins to invert the input signal. At its fully counterclockwise position, the signal is inverted and passed through with full strength (Gain = -1). Each channel is suited with a dedicated bipolar LED, which brightens RED if the output signal is negative and GREEN if positive.

In the absence of an input signal (no cable patched to an input), the input automatically normalizes to a 5 V DC offset. The dedicated potentiometer then adjusts the offset voltage from -5V (fully counterclockwise) to +5V

Specifications

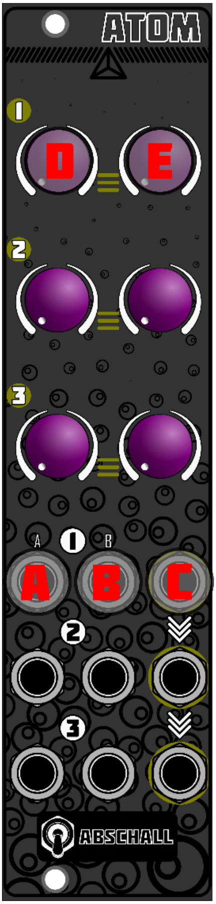
Width: 6 HP / 10 HP (large)

Depth: 21 mm

Current Consumption:

TBD

DC (fully clockwise), with a neutral 0V DC offset at the 12 o'clock position. Each channel combines inputs A and B, providing the summed output at the OUT jack. Should no cable be connected to a channel's OUT jack, its output is cascaded to the next channel, allowing ATOM to function as a versatile mixer with configurations of 2, 4, or even 6 channels, depending on how the outputs are utilized and connected.



Panel Description

- **A** Chanel Input A
- **B** Chanel Input B
- **C** Chanel MIX Output
- **D** Bipolar Control Knob Input A
- **E** Bipolar Control Knob Input B

Quick Recap of Main Rules

Here is a short recap of the main laws and rules useful for analyzing the different circuit stages of ATOM.

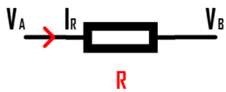
Ideal Op Amp

We consider the laws of an "ideal" or perfect operational amplifier (Op Amp). Mainly, we will use the two following important rules, which are appliable in any ideal Op Amp configuration:

- No current flows into the input terminal: $i_+ = i_- = 0\ A$
- The differential input voltage is zero: $V_+ - V_- = 0\ V$ (Virtual Ground)

Ohm's Law

Also, let us recall Ohm's law applied to a resistor: $I = \frac{V_A - V_B}{R}$



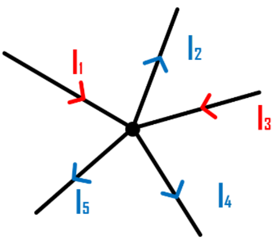


Figure 1 Kirchhoff's Current

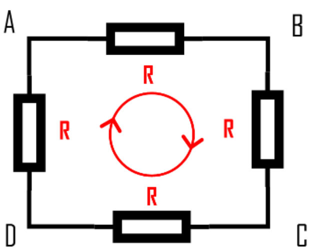


Figure 2 Kirchhoff's Voltage Law

Kirchhoff's Laws

Finally, both Kirchhoff's Current and Voltage Laws are useful in simple circuit analysis:

- Kirchhoff's Current Law (KCL): the algebraic sum of the currents going into a node are equal to the um of the currents going out of a node.

$$I_1 + I_3 = I_2 + I_4 + I_5$$

- Kirchhoff's Voltage Law (KVL): the algebraic sum of all voltages within a complete loop must be equal to zero.

$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

First Stage: Attenuverter

The signal plugged into an input (A or B) first passes through an attenuverter stage, which can attenuate or invert the incoming signal or CV voltage.

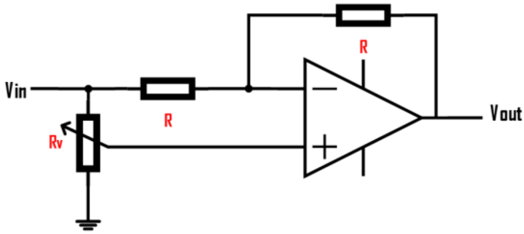
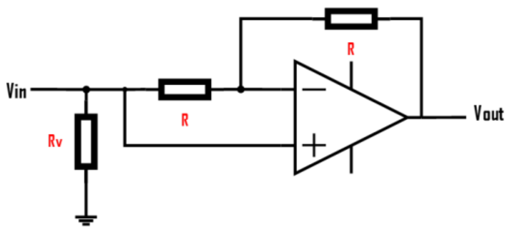
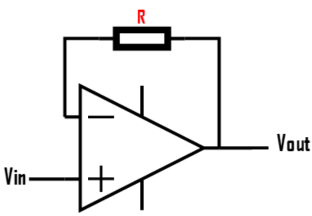


Figure 3 Attenuverter Circuit

Full Clockwise



If the **R$_v$** Potentiometer is turned fully clockwise, the following schematic can be considered which simplifies into a simple **buffer circuit**.



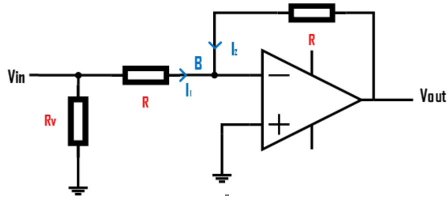
Where: $V_{out} = V_{in}$

The input signal is passed through without attenuation. The transfer function is:

$$G = \frac{V_{out}}{V_{in}} = \mathbf{1}$$

Full Counter-Clockwise

The circuit becomes an **Inverting Amplifier**, when the potentiometer is turned fully counter-clockwise.



Let us apply Kirchhoff's Current Law at node B:

$$I_1 + I_2 = 0$$

$$\frac{V_B - V_{in}}{R} + \frac{V_B - V_{out}}{R} = 0$$

Multiplying the equation by **R**:

$$V_B - V_{in} + V_B - V_{out} = 0 \Leftrightarrow V_{in} = -V_{out}$$

And the transfer function becomes: $G = \frac{V_{out}}{V_{in}} = \mathbf{-1}$

Second Stage: Summing Amplifier

Simple Summing Amplifier

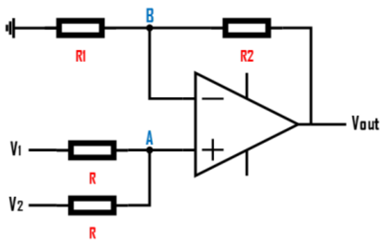


Figure 4 Summing Amplifier, simplest configuration

Once both input signals (A and B) are processed through the first attenuverter stage they are summed together using a **Summing Amplifier**, whose schematic is given on the left.

If we apply KCL at the node A, we have:

$$\frac{V_A - V_1}{R} + \frac{V_A - V_2}{R} = 0 \Leftrightarrow V_A = \frac{(V_1 + V_2)}{2} \quad \textbf{(1)}$$

Let us apply Kirchhoff's law again at node B:

$$\frac{V_B - V_{GND}(0V)}{R_1} + \frac{V_B - V_{out}}{R2} = 0$$

$$R_2 V_B + R_1(V_B - V_{out}) = 0 \Leftrightarrow \frac{R_2 + R_1}{R_1} V_B = V_{out} \quad \textbf{(2)}$$

As: $V_{-} = V_B$ and $V_{+} = V_A$, then: $V_B = V_A$

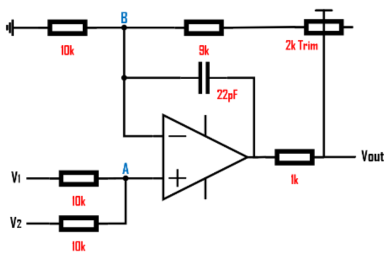
Insert **(1)→(2)**:

$\frac{R_1 + R_2}{R_1} \frac{V_1 + V_2}{2} = V_{out}$ and if $R_1 = R_2$, then $\boldsymbol{V_{out} = V_1 + V_2}$

Using Kirchhoff's Voltage Law would have given the same results. There is no unique way to analyze a circuit!

Used Version

The Summing Amplifier utilized in ATOM is further enhanced for precision, as illustrated on the right. Mainly a 2 kΩ trimmer potentiometer is added for calibration. A 22pF capacitor is placed between the inverting input and the Op Amp's output to improve stability and prevent self-oscillation.



The 2k trimmer in series with the 9k is used to compensate for small (unity) gain errors introduced by resistor mismatch and an Op Amp's Offset voltage compensation. A real Op Amp may present a small differential input voltage ($V_+ \neq V_-$).

The 1k resistor is an output current limiting resistor, which avoids the Op Amp to fail in case the output is unintentionally connected to ground, even though most modern Amplifiers are now internally short circuit protected. Nevertheless, placing a current limiting resistor at their output will prevent them of overheating. More information about current limiting resistors can be found at REF.

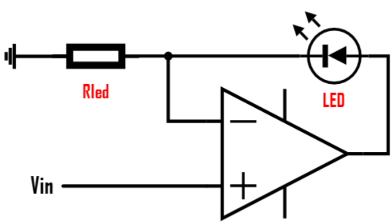
Finally, placing a small capacitor between the Op Amp's inverting input and output, will prevent eventual self-oscillation at high frequency operation. It forms a first order low pass filter with the equivalent 10k resistor (9k + 1k trimmer value). The cutoff frequency is:

$$f = \frac{1}{2\pi R_{eq} C} = \frac{1}{2\pi \cdot 10k \cdot 22pF} = 723\ kHz$$

At DC or low frequency operation, the capacitor simply acts as an open-circuit (or a very high impedance) and is not taken into account. (Theoretically the impedance of a capacitor is $Z_c = \frac{1}{C2\pi f j} \xrightarrow{f \to 0\ Hz} \infty$).

Simple LED Driver

Even though there are commercially available **LED drivers** as Integrated Circuits (IC), a simple LED Driver can be built op from the remaining Op Amp of the TL074 chip.

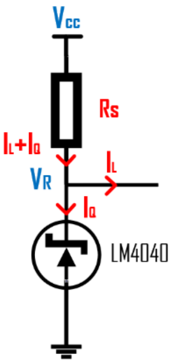


The amplifier will adjust the LED's current until the voltage across the resistor **R_{LED}** matches the one at the non-inverting input, taken at the summing amplifier's output.

$$V_+ = V_{in} \text{ and } V_- = R_{LED} \cdot I_{LED},$$

$$\text{So: } I_{LED} = \frac{V_{in}}{R_{LED}}$$

Shunt Regulator



In the absence of an input signal (no cable patched to an input), the input automatically normalizes to a 5 V DC offset. The 5 V DC voltage is provided using a simple LM4040 5 V **shunt regulator**. R_S is determined by the supply voltage, (V_{cc}), the load and operating current, (I_L and I_Q), and the LM4040's reverse breakdown voltage, V_R.

$$R_s = \frac{V_{cc} - V_R}{I_L + I_Q}$$

The design requires that $V_{cc} > V_R$, which is the case here as the supply voltage V_{cc} = 12 – 0.3 V (Schottky diode voltage drop) = 11.7 V and V_R = 5 V (regulator output voltage).

The first Op Amp stage of each input channel uses 100 kΩ potentiometers and 100 kΩ resistors. Each stage draws a current I_L:

$$I_L = \frac{V_r}{(R_v||R)} = \frac{5\ V}{50\ k\Omega}\ 0.1\ mA$$

As there are 6 such identical input channels, the total load current is $I_{L,tot} = 6 \times I_L = 0.6\ mA$.

The operating current needs to be kept between $60\,\mu A < I_Q < 15\,mA$. According to the datasheet a value between 0.1 mA and 1 mA are a good starting point. Choosing I_Q to be 1 mA, the resistor is calculated to be:

$$R_s = \frac{6.7\,V}{7\,mA} \approx 1\,k\Omega$$

Calibration

Both inputs of an ATOM channel are normalized to a precise 5 V DC reference if no patch cable is plugged.

1. Leave both inputs A and B unconnected. Channel 1 is in offset mode.
2. Connect a cable in Channel 1's OUT Jack.
3. Using alligator clips, connect a voltmeter to the cable's unconnected male jack.
4. Set a Voltmeter capable of measuring at least 10 VDC precisely, to DC read mode.
5. Turn both Bipolar Control Knobs of inputs A and B fully clockwise. Expect to observe a voltage around 10 VDC on the voltmeter, as both 5 V sources are combined.
6. Flip the board to locate the topmost trimmer (R13). Adjust the trimmer's 2k resistor using a small screwdriver until you read an exact +10.00 VDC on the voltmeter.
7. Proceed to the calibration of Channels 2 and 3, by **repeating step 1. To 6.** The trimmer of Channel 2 is R26 (middle) and the one of Channel 3 is R39 (bottommost trimmer).

It's crucial to note that if the output of Channel 1 remains unpatched, it will add to the sum of Channel 2. **To prevent this, insert a jack into the output of Channel 1 to break the internal connection.** The same procedure should be followed for Channel 2 when calibrating Channel 3.

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