Epicycloid Engineering Turbo Entubulator

Distortion/Multiplier/Wavefolder

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Cautions

The Turbo Entubulator is a vacuum tube circuit, and as such contains high voltages and components that may become hot during operation. Voltages as high as 300V DC are present on the circuit board. To avoid serious injury or death, always mount the module in a rack before operating, and ensure that no fingers, other body parts, wires with insulation not rated 300V or higher, or other components can come into contact with the circuit board. Before removing the module or reaching inside the rack, ensure that power from the Illuminox Prime is turned off.

Setup

The Turbo Entubulator requires 41 mm depth from the faceplate for mounting, and uses 60 mA from both the +12V and -12V supplies for its semiconductor circuits. The 10 pin power connector on the board is a latch type header for secure mounting; to install the cable, push the latches away from the center, press the cable connector in until the latches snap back toward the center, and then pinch the latches in to secure them. To detach, push the latches apart and the connector will be ejected.

Power for the tube portion of the Entubulator comes from the Illuminox Prime via a separate cable, which uses a 4 pin Molex connector. An 18 inch/460 mm cable is supplied with the Entubulator; do not cut or modify it without consulting with Epicycloid. To minimize electromagnetic interference, connect the end of the cable with the black sleeve to the Illuminox Prime and the end with the red sleeve to the Entubulator.

The tube used can be of any of the beam deflection types 6ME8, 6AR8, and 6JH8. Each tube type, and indeed each individual tube, will give different sounds. To maximize tube life, shut off power before swapping tubes; this allows the heater time to warm up the tube, so that any gas that has leaked into the tube since it was last operated can be captured by the getters before high voltage is applied.

Operating Principle

In most vacuum tubes, including the ones used here, electrons are emitted from a heated electrode called the *cathode*, and are attracted to a positively charged electrode called the *plate*, or *anode*. Just after leaving the cathode, they encounter an electric field created by one or more *grids*, which are arrays of fine wires connected to terminals of the tube. If a grid's voltage is more negative than the cathode's, it repels electrons, choking off the flow. Since a grid is much closer to the cathode than the plate is, even a few volts negative applied to a grid can overcome the attraction of a plate charged to hundreds of volts positive. Most of the influence on the strength of the electron beam comes from the first grid, called the *control grid*. In tubes with more grids, the last grid (closest to the anode) is called the *screen grid*, and the one in between is called the *suppressor grid*.

The beam deflection tubes used here add a few extra elements: they have two plates side by side instead of one, and they have electrodes called *deflectors* that can form electrons into a beam and steer them to one plate or the other. This allows them to act as analog multipliers, if the output transformer is connected between the two plates. With zero difference between the deflectors' voltages, the electrons strike the two plates equally, which gives zero output voltage, no matter how strong the electron beam that makes it through the grids may be. If the deflectors are at different voltages, however, the beam is pushed off center and hits one plate more than the other. This creates a voltage between the plates, which induces current in the transformer and appears on the output. Thus, the output is roughly proportional to the strength of the electron beam passing through the grids (which gets weaker as grid voltage becomes more negative), multiplied by the difference between the deflectors' voltages. This is what you may know as a two quadrant multiplier.

Getting the tube to work this way and respond linearly requires appropriate DC bias and AC levels on all the electrodes: the control grid must be a few volts negative compared to the cathode, the screen grid and deflectors should be ½ to ¾ the plate voltage, and the AC components of the voltages on the control grid and deflectors should not be too high. However, this is boring – analog multipliers can be made cheaper and more precise with semiconductors. Where the tube makes its contribution is the distortion it can create. Operating the tube away from these ideal values allows all kinds of interesting effects to occur.

Since the deflectors form the electron beam in addition to steering it, adjusting their average voltage (the *bias voltage*) changes the width of the beam, and if it is set low enough, it can choke off the beam almost entirely. At higher voltages, it can be used to create discontinuities in the waveform, a bit like a diode ring modulator; adjusting the voltage can move them around, creating a "shimmering" effect.

If the voltage between the deflectors (the *offset voltage*) is high enough, the electrons can be deflected so much that they miss the plates entirely on their first pass and float around for a while, repelling the next batch of electrons to come through the grids. This causes a slight "wave folding" effect: the waves are not just clipped at their peaks but are slightly reflected about the clipping point. They can also interact with other electrons that were knocked off the plates by the impact of electrons from the cathode (*secondary emission*), producing a wide variety of complex behaviors. These behaviors will depend both on DC bias points and AC levels, so if those levels are modulated, the result is reminiscent of a filter sweep or PWM, but sounding unlike any semiconductor circuit.

The Entubulator can also produce the classic tube distortion effects you've likely heard before: overdriving the control grid, or setting its DC bias out of the tube's linear range, creates "soft clipping" of the audio fed into the grid, or an even stronger wave folding effect.

Inputs and Controls

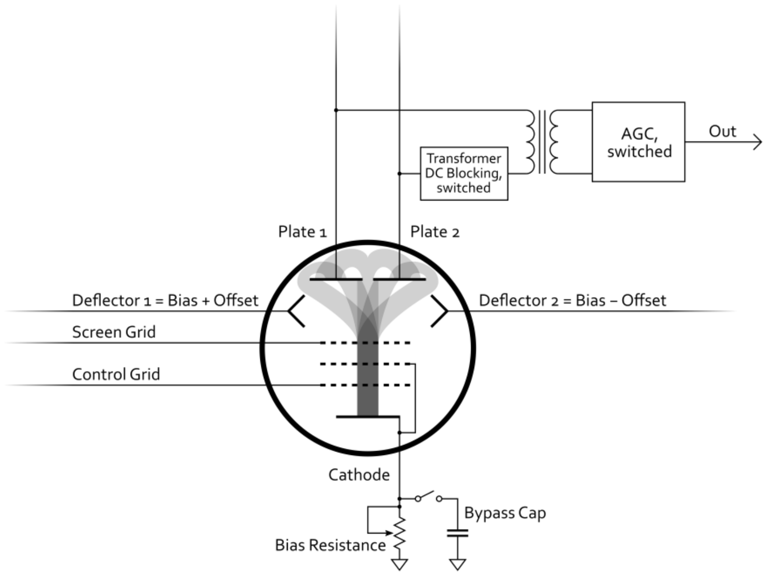

Figure 1: Diagram of the Entubulator, schematically showing the different paths that electrons take depending on deflector offset voltage.

Every input has both DC offset and gain controls, and passes both DC and AC to the tube. This makes it possible to feed either control voltage or audio into the inputs. Due to capacitance between electrodes, the tube responds strongly to high frequency harmonics, such as those seen with square or sawtooth waves; the output from these may sound harsh unless a lowpass filter is used.

Deflector Bias: Sets the voltage around which the deflectors are centered. This controls the shape of the electron beam, determining the response to deflector offset, and can create small discontinuities, giving a "shimmering" effect.

Deflector Offset: Steers the electron beam to one plate or the other. Some offset is needed to produce output, since otherwise the beam strikes both plates equally and produces no difference that the transformer can pick up. In effect, this input is distorted by the effect of the deflector bias level, and the result multiplied by the strength of the electron beam to give the output.

Control Grid: Adjusts the strength of the electron beam. The response of the beam to the voltage here is nonlinear, so driving it with a high AC level or setting its DC bias appropriately can give soft clipping or wave folding effects.

Screen Grid: Also adjusts the strength of the beam, but with a different response curve than the control grid.

Cathode Bias: Causes the cathode's voltage to rise with beam current, potentially giving rise to more wave folding and clipping effects. The bypass capacitor, if switched on, somewhat softens the edges of the distorted waveforms that result.

AGC (Automatic Gain Control): The output amplitude of the tube can vary widely as bias voltages are changed, potentially becoming inaudible or producing clipping in the output amplifiers. Switching the AGC on adjusts the gain of the output to maintain a consistent level without clipping, so you can produce a wider range of sounds by modulating the inputs with an LFO or EG. You may notice that there are brief spikes or dips in amplitude when changing bias levels suddenly; this is because the AGC is designed to average out the signal level over a short period of time before it makes adjustments. Otherwise, a low bass note would get clipped because the AGC would mistake its peaks for signal level changes.

Transformer DC Blocking: Part of the soft sound character of tube circuits actually comes from the saturation of iron-core transformers. This effect becomes more pronounced when DC current is passing through the transformer as well as AC. By turning DC blocking on, you can obtain a "sharper" sound when deflector offset is high. Because charging the blocking capacitors takes some time, you may notice a delayed response to some bias changes.

Suggested Connections

You can get a basic tube distortion effect by plugging audio into the **CONTROL** input and setting **SCREEN DC** and **BIAS DC** to 60-80% CW. Adjusting **CONTROL GAIN** and **CONTROL DC** will change the distortion gradually, while modulating **SCREEN** and **BIAS** will introduce wavefolding effects that may begin suddenly. Modulating **OFFSET** will adjust volume; by adjusting **OFFSET DC** to slightly above zero (the exact level will depend on the tube you have installed) and feeding a CV into **OFFSET**, you can operate the Entubulator as an analog multiplier or VCA.

More than anything else, you will learn how to get the sounds you want through experimentation. The beam-deflection tube is a simple device with complex behaviors, and trying out different signal paths and operating points will keep revealing new effects. There are no settings that will damage the tube, so feel free to explore!