Analog Metropolis

AM2140
Voltage Controlled
Resonant Filter

Project Notes
V1.0

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1 Module Description

This module is a clone of the Resonant Filter in the Eμ Systems Modular.

The Resonant Filter is an audio filter with an output capable of producing virtually any two pole pass characteristic. The FREQUENCY control can be varied from 20Hz – 20 kHz, and a resonant peak may be added in the response by means of the Q control. The height of the peak can be adjusted from zero to +40dB.

The filter has three functions; Low Pass, Band Pass and High Pass. The Low Pass and High Pass have a 12dB slope, the Band Pass has 6dB slope on both sides. The filter does not oscillate at high Q settings.

An output mixer sums the simultaneous three filter functions to produce a single output, and three attenuators (HIGH PASS, BAND PASS and LOW PASS) mix the relevant signals. A wide range of responses can be produced and several 2140's can be cascaded to produce interesting complex resonant formants. Lower input levels should be used to prevent clipping at high Q levels.

There is a signal input and output on the front panel, as well as an internal CV input on the board.

The original Eμ Systems 2140 is a basic filter with no external CV control of Q or FREQUENCY. There was a firmware CV for FREQUENCY on the board, which was typically connected to the 2145 Filter Controller which enabled multiple 2140's to be voltage controlled.

The AM circuit has voltage control of Q and FREQUENCY.

INPUTS	AUDIO INPUT FREQUENCY CV INPUT FREQUENCY CV INPUT2 (optional) Q CV INPUT (optional)
OUTPUTS	AUDIO OUTPUT
POTS	LOWPASS, BANDPASS, HIGHPASS FREQUENCY, RESONANCE

2 The Original Circuit

The original Revision 1 design dates back to January 1974 when Eμ Systems introduced the module. This was probably a transistor and Op Amp based design. Two years later the module was redesigned to use the SSM2020 chip, and it's this later circuit that has been replicated.

The design is a standard State Variable Filter and therefore has a 12dB/octave response. The unique feature is the use of the SSM2020 as the control chip, which imparts the filter with both precision and warmth.

Here are the specifications:

Noise (10 - 10 KHz)	= 1 - 5mV
Cut-off frequency	= 30 Hz – 15 KHz
Maximum Q without oscillation	= 100

3 The AM Circuit

The AM circuit is a straight copy of the original Eμ Systems Revision 2 design. It uses the same SSM2020 chip and dual audio grade Op Amps for the main filter circuit. The audio mixing Op Amp was originally a 556, which is truly obsolete. The board has been designed to take any dual audio Op Amps, and the prototype was developed with NE5532 and LF353. I use OPA2134's in production modules. A bypass capacitor has been added to this circuit to avoid HF oscillation.

The frequency control used a 741 Op Amp to sum the front panel and a firmware CV input, a trimmer enables voltage control to be calibrated to 1V per octave. There is no temperature compensation. The Q control uses an exponential transistor circuit to drive a CA3080 OTA, as thr VCA in the feedback signal. The original transistor pair was an AD820, which is expensive and hard to find. Provision has been made for a high quality SSM2220 pair on an 8 pin DIL, or manually matched transistor pairs, or the original AD820.

The SSM2020 chip is hard to locate, but some can still be found quite cheaply.

The original circuit has been modified to provide CV control of Frequency and Resonance.

The REV06 board is the production board. There are no errors.

4 PCB

The PCB is double sided with solder mask and silkscreen on the upper surface. The component names are shown in the silk screen but not the component values. The size of the PCB is 80mmx100mm.

The PCB is held to the front panel at 90 degrees by the use of two pot brackets manufactured by Omeg (www.omeg.oc.uk). These brackets (and pots) are centred at 40mm apart. The BANDPASS and HIGHPASS pots hold the PCB to the front panel.

5 PCB Connections

The PCB has a number of connections designed for MTA 0.1" headers, so that the panel components can be connected to the PCB. I use headers and sockets to enable the board to be easily replaced, however you can solder wires straight to the PCB.

PCB Header Name	Pin #	What is it?	Where does it go?
INPUT	Pin 1	Audio Input	Jack Socket SIGNAL INPUT
	Pin 2	Not Used	
QIN	Pin 1	Q CV Input	Jack socket QIN
	Pin 2	Not Used	
CV_INS	Pin 1	CV1 Input	Jack Socket CV IN
	Pin 2	CV2 Input	Keyboard CV bus or optional CV
LOWPASS	Pin 1	Low pass Pot	LOWPASS Pot Pin 1
	Pin 2	Low pass Pot	LOWPASS Pot Pin 2
	Pin 3	Low pass Pot	LOWPASS Pot Pin 3
BANDPASS	Pin 1	Band pass Pot	BANDPASS Pot Pin 1
	Pin 2	Band pass Pot	BANDPASS Pot Pin 2
	Pin 3	Band pass Pot	BANDPASS Pot Pin 3
HIGHPASS	Pin 1	High pass Pot	HIGHPASS Pot Pin 1
	Pin 2	High pass Pot	HIGHPASS Pot Pin 2
	Pin 3	High pass Pot	HIGHPASS Pot Pin 3
FREQ	Pin 1	FREQ Pot	FREQUENCY Pot Pin 1
	Pin 2	FREQ Pot	FREQUENCY Pot Pin 2
	Pin 3	FREQ Pot	FREQUENCY Pot Pin 3
RESO	Pin 1	RESO Pot	RESONANCE Pot Pin 1
	Pin 2	RESO Pot	RESONANCE Pot Pin 2
	Pin 3	RESO Pot	RESONANCE Pot Pin 3

OUTS	Pin 1	Signal Output	Jack socket OUTPUT
	Pin 2	Signal Output	Not Used
PAD	Pin 1	Panel Earth	Jack socket earth bus

6 Pots

The PCB is designed to be used with Spectrol 248J conductive plastic pots; they are a reasonable price and very high quality. The PCB will work with either 3.18mm or 6.35mm spindle diameter models. The PCB can be used with other pots such as sliders provided they are all mounted off the PCB.

7 Power

The module should be powered from a well regulated +15V and -15V power supply, current consumption is around 25mA. The power connector is the standard two ground MOTM/Oakley 4-pin Molex connector. One ground is for the circuit, the other is for the panel ground (PAD).

8 Front Panel

The AM2140 is a standard AM format module which can be built into a number of panel formats. You can use your own format or choose from the following:

AM High Density
This panel format enables a higher density of controls on each panel, and panels are usually 90mm wide. All the pots have a small spindle diameter of 3.18mm which enables the control knobs to be located closer together. Both 19mm and 13mm control knobs can be used. The "look and feel" is similar to the ARP 2500.

Panels are 4U high and 90mm wide. Panels are fitted to horizontal 12mm angled aluminium strip using 4mm diameter machine screws in each corner of the panel. The strip is mounted into a standard 19" rack unit with small wooden end strips.

AM Low Density
This panel format has a lower density of controls on each panel, and panels sometimes have to be 135mm wide to accommodate all the controls. All the pots have a spindle diameter of 6.35mm which means 19mm control knobs can be used, such as those used in the Eμ Systems Modular. The "look and feel" is similar to the Eμ Systems Modular.

Panels are 4U high and 90mm or 135mm wide. Panels are fitted to horizontal 12mm angled aluminium strip using 4mm diameter machine

screws in each corner of the panel. The strip is mounted into a standard 19" rack unit with small wooden end strips.

MOTM Panels
This established panel format has pot spacing very close in dimensions to the AM PCB's, MOTM is 41.275mm compared with 40mm of the AM format. This means you can design MOTM style front panels but with 40mm spacing and this won't look significantly different. Alternatively you maybe be able to mount the AM PCB on 41.275mm hole centres by slightly bend the pot brackets to fit.

9 Building the Module

This module is simple to build. The recommended build order is:

- Resistors
- Inductors
- IC Sockets
- Capacitors
- Trimmers
- Connectors
- Transistors
- Pot Brackets and Potentiometers

Check all the electrolytic capacitors and transistors are fitted the right way round. Before fitting the IC's its worth connecting up the module to a power supply and checking that the power rail voltages are as expected at each IC socket, then power down, and fit the IC's ensuring correct orientation.

Power up and try out the filter. Then proceed to trimming.

10 Trimming

This module is simple to set-up, but there are a few trimmers to be adjusted.

HP OFFSET Connect the High Pass output to a DC meter. Adjust the trimmer to give zero volts at the High Pass output when there is no signal input.

BP OFFSET Connect the Band Pass output to a DC meter. Adjust the trimmer to give zero volts at the Band Pass output when there is no signal input.

Q REJECTION Connect the Low Pass output to a DC meter. Adjust the trimmer so that the front panel Q control has minimal effect of the Low Pass Output.

V/OCT This trimmer adjusts the CV input response, so that the filter accurately tracks the keyboard and oscillators. The 2140 does not oscillate; therefore it is not possible to accurately calibrate the CV response.

However it can be roughly calibrated as follows; Monitor the Band Pass output with a 'scope. Patch the keyboard CV into the CV_IN socket on the PCB. Press C4 on the keyboard and tune a reference oscillator so that the filter is attenuating the signal by a factor of two. Be sure the reference oscillator is not controlled by the keyboard. Now, press C5 on the keyboard and trim V/OCT so that the output from the filter does not vary from the previous level. Repeat as necessary. The adjustment is not terribly critical.

11 Special Components

The AM2140 makes use of a small number of specialist components:

SSM2020

The SSM2020 chip is hard to locate, but it be found especially on eBay.

ECO/Omeg Pot Brackets

These can be obtained from Omeg in the UK. http://www.omeg.co.uk/. Oakley have them again, and I have stock them too.

12 Parts Listing

Part Number	Value	Quantity	Comments
Capacitors			
C1, C2	100nF 100V	2	Multi-layer Polyester
C3, C4	22uF 25V	2	Radial Electrolytic
C5	10pF 100V	1	Low-K Ceramic
C6, C8	330pF 100V	2	1% Polystyrene
C7	100pF 100V	1	Low-K Ceramic
C9	10nF 100V	1	Multi-layer Polyester
Resistors			
R1, R2, R5, R15, R20, R21, R22, R23, R24, R25, R26, R30, R31	100K	10	1% Metal Film
R3, R13, R19	270K	3	1% Metal Film
R4, R12, R14	47K	3	1% Metal Film
R6	1M	1	1% Metal Film
R7, R8, R16, R28	1K	4	1% Metal Film
R9	4K7	1	1% Metal Film
R10	130K	1	1% Metal Film
R11	10K	1	1% Metal Film
R17	370K	1	1% Metal Film
R18	1K8	1	1% Metal Film
R27	22K	1	1% Metal Film
R29	680K	1	1% Metal Film
Potentiometers			
LOWPASS, HIGHPASS, BANDPASS, FREQUENCY, RESONANCE	100K LIN	5	SPECTROL 248
Trimmers			
LPOFFSET, BPOFFSET, HPOFFSET, V/OCT	1M	4	25 turn cermet trimmer
Semiconductors			
IC1, IC2	TL082 or OPA2134	2	Dual Op Amp, audio quality
IC3	CA3080	1	OTA
IC4	SSM2020	1	SSM2020
IC5	OP177G	1	Single Op Amp, Low Offset
IC6	SSM2210	1	Dual Matched Transistors
IC7	OPA134	1	Single Op Amp, audio quality
Passives			
L1, L2		2	Inductor
Hardware			MTA 0.1” 4-pin header
INPUTS, QIN, CV_INS, OUTS		4	MTA 0.1” 2-pin header
POWER		1	MTA 0.156” 4-pin header