MOTM-410 Triple Resonant Filter
Assembly Instructions & Owner's Manual

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MOTM-410 PARTS LIST

Please carefully check that all parts are in your kit. If you have a suspected shortage, please call or email. If you get free extra stuff, keep it for next time.

❐ **Capacitor** bag, containing the following 20 parts:

2ea 10mfd, 50V Electrolytic	C19, C20
2ea 0.047mfd yellow box (marked 47N or 473)	C3, C4
3ea 0.1mfd yellow box (marked 100N or 104)	C6, C7, C8
3ea 1000pf axial polystyrene	C5, C9, C10
1ea 0.47mfd yellow box (marked 470N or 474)	C11
1ea 0.22mfd stacked film (marked 224)	C14
1ea 0.33mfd stacked film (marked 334)	C13
7ea 0.1mfd (marked 104) ceramic axial	C1, C2, C12, C15 – C18

❐ **Resistor** bag, containing the following 65 parts:

8ea 10K (brown, black, orange)	R1, R11-R15, R21, ***R68 {optional}***
8ea 1K (brown, black, red)	R2-3, R6, R9, R17, R52, R55, R58
7ea 100K (brown, black yellow)	R18, R23, R30, R34, R38, R43, R45
6ea 33K (orange, orange, orange)	R31, R33, R35, R37, R47, R51
4ea 1M (brown, black, green)	R16, R48, R49, R50
3ea 150K (brown, green, yellow)	R8, R62, R65
3ea 390K (orange, white, yellow)	R10, R61, R64
3ea 51K (green, brown, orange)	R22, R40, R67
3ea 180K (brown, gray, yellow)	R53, R56, R59
3ea 2K7 (red, violet, red)	R54, R57, R60
3ea 120K (brown, red, yellow)	R42, R63, R66
2ea 47K (yellow, violet, orange)	R19, R41
2ea 220K (red, red, yellow)	R24, R28
2ea 4K7 (yellow, violet, red)	R32, R36
2ea 2K2 (red, red, red)	R44, R46
2ea 22K (red, red, orange)	R26, R39
1ea 6K8 (blue, gray, red)	R25
1ea 3K9 (orange, white, red)	R27
1ea 8K2 (gray, red, red)	R29
1ea 68 ohm (blue, gray, black)	R20

❐ **IC** bag, containing the following 19 parts:

3ea VTL5C4/2 dual Vactrol	D1, D2, D3
1ea TL074 quad op amp	U5
2ea JRC4558 dual op amp	U1, U2
2ea TL072 dual op amp	U3, U4
2ea NE5517 dual OTA	U6, U7
6ea BC560C PNP transistor	Q1, Q2, Q3, Q7, Q8, Q9
3ea BC550C NPN transistor	Q4, Q5, Q6

❒ **Misc** #1 bag, containing the following 4 parts:

2ea Axial ferrite beads (plain, gray things)	L1, L2
1ea MTA-156 power connector	JP1
1ea DPDT (ON-OFF-ON) toggle switch	SW1

❒ **Knobs**, 7ea, ALCO PKES90B1/4

❒ **Jacks**, 8ea Switchcraft 112A

❒ **Pots**, 7ea containing the following:

4ea 100K cermet Spectrol 149	VR1 – VR4
3ea 100K conductive plastic Bourns 95A1	VR5, VR6, VR7

❒ **Front panel**

❒ **Mounting bracket**

❒ **Wire** bag, containing the following 14 wires:

4ea RG-174 coax, 4 ½ inches
1ea RG-174 coax, 7 inches
1ea 2-conductor red/black cable 8 inches
4 ea 2-wire set, 22ga. 3 inches (red/black)
3ea 3-wire set, 22ga, 4 inches (white/orange/gray)
1ea Power Cable, 20"

❒ **Hardware** bag, containing:

4ea #8-32 x 3/8 black screws (for mounting module to rack)
4ea #6-32 x 1/2 zinc screws (for attaching pc board to bracket)
4ea 1/4 inch aluminum spacers
6ea #6 KEPS nuts (2 for attaching bracket to front panel, 4 for pc board)
7ea small tie-wraps

❒ **Organic Solder**
❒ **No-clean Solder**
❒ **PC Board**, MOTM-410

GENERAL INFORMATION

Thank you for purchasing the MOTM-410 Triple Resonant Filter (VCF). If you have any issues concerning the building or use of the kit, please contact us at (817) 281-7776 or by email: synth1@airmail.net.

This kit should take the average builder between 3 to 4 hours. The VCF kit contains many different resistors and special parts. However, please remember this is NOT a speed contest; it is an accuracy contest. There is no rule that you have to complete the entire kit in one day (as long as you wash the flux off!).

Successful kit building relies on having the proper tools. Here is a list of what you will need to build your MOTM-410:

* Soldering iron, 50W max power
* Needle-nose or chain-nose pliers
* Diagonal cutters
* Allen key set for securing the knobs (1/16” or 1.6mm)
* Magnifying glass: to read the capacitor codes and to inspect solder joints
* Lead bending tool (optional, but makes the job go much faster)
* DVM (Digital Volt Meter) or oscilloscope (to check the output)
* #1 Philips screwdriver
* Fingernail brush for washing off the organic flux
* Old towel for blotting dry pc board

For more information of tools used and suggestions, see the MOTM FAQ and Tutorial pages at http://www.synthtech.com.

You also may find it useful to purchase additional heat-shrink tubing (1/8” diameter, 2:1 shrink ratio) and solder. Just be sure it is NOT rosin-based flux!

HOW TO FOLLOW THE DIRECTIONS

Please read the entire instruction before proceeding. There may be valuable information at the end of the instruction. Each instruction has a check box ❒ next to it. After you complete the instruction, check the box. This way you can keep track of where you are in the process.

VERIFY THE PARTS LIST

❒ Verify that all of the parts are in the kit as shown on the parts list.

A WORD ON SOLDERING

There are 2 very different types of solder used in the kit. Most of the soldering uses ‘Organic Flux’ solder. ***This is strictly for use on the pc board, and is NOT to be used on the front panel wiring!***

In order for solder to ‘stick’ to the copper, a chemical called ‘flux’ is embedded in the solder. The flux leaves a residue on the pc board that should be cleaned with warm water. DO NOT USE SOAP OR OTHER CLEANSERS. Most of the parts in the kits are ‘waterproof’ and can be washed in the sink. The flux is OSHA approved for flushing down the drain, so don’t worry about that! A soft brush is used to gently scrub the board. We recommend a ‘fingernail brush’, which is about 1” x 2” and can be found for about $1.

The other type of solder is called ‘No Clean Flux’; because as the name implies it does, not require washing. This solder is used for wiring the pots, switches, jacks, etc. This solder is harder to use on the pc board; because even when melted, it is not very fluid (about the consistency of toothpaste). We will use it VERY SPARINGLY on the pc board.

OK, let’s get started on the board!

PART #1: SOLDERING THE RESISTORS

Since there are more resistors than anything else, we will start here. If you do not know the resistor color code, refer to the parts list. Resistors are not polarity sensitive, but the board will be easier to debug (and look nicer) if you point the first color band in the same direction for all the parts. The color code is also in the README FIRST document that every customer receives with his or her first order.

You will start by soldering in ALL of the resistors.

❒ Find the **RESISTOR** bag.

❒ Find the MOTM-410 blank pc board. There is a copy (larger than actual size) of the silkscreen which shows where the parts go at the end of this document. It will be useful if you locate the part on the print first, put the part in the board, then ‘check off’ the silkscreen. All parts are inserted from the side of the board with the white silkscreen (the “top” side).

NOTE: some reference designators are under the resistor! Be careful.

❒ We will stuff the resistors by value to make things easier. The resistors (and other long-leaded parts) are inserted on a 0.4 inch spacing. The important thing is to be sure that the part is sitting all the way down on the board. Push the leads in the holes, push the part on the board, and then bend the leads on the bottom outwards to a 45 degree angle (roughly!). This is called ‘cinching the leads’: and keeps the part from falling out! From the bottom of the board, solder (using the organic flux), applying heat to the pad for about a half second first, then applying just enough solder to make a small puddle that looks like a tiny pyramid. Enough solder should flow in the hole such that on the top (component) side, a small amount is on the top pad as well

The rule of soldering: don't use too much, you can always add more! Cut the leads flush with the top of the solder joint with your diagonal cutters.

Locate the 10K resistors (8). ***IMPORTANT!*** R68 is optional. If you plan to use your MOTM-410 with MOTM-300 VCOs, then *R68 is installed*. If you plan to use the MOTM-410 for processing external audio (such as the output of other synths) *do not install R68!* R68 is located directly above J1 (lower left corner). The remaining 10K resistors solder into R1 (beside U2), R11 (above J4), R12, R13, R14, R15 (all beside U1) and R21 (above R68).

❐ Locate the 1K resistors (8) and solder into R2 (below U2), R3 (above J2), R6 (above J4), R9 (above J6), R17 (beside VR4), R52 (by Q4), R55 (by Q5), and R58 (above D3).

❐ Locate the 100K resistors (7) and solder into R18 (by U2), R23 (by Q1), R30 and R34 (by U5), R38 (below U7), R43 and U45 (beside U7).

❐ Locate the 33K resistors (6) and solder into R31 (by U6), R33 (by U5), R35 (by JP1), R37 (by U5), R47 and R51 (by U7).

❐ Locate the 1M resistors (4) and solder into R16 (top left corner), R48, R49, and R50 (these are "sideways" below D2).

❐ Locate the 150K resistors (3) and solder into R8 (above VR4), R62 (by VR2) and R65 (by VR3).

❐ Locate the 390K resistors (3) and solder into R10 (by VR4), R61 (by VR2) and R64 (by VR3).

❐ Locate the 51K resistors (3) and solder into R22 (by J1), R40 (above J6) and R67 (by Q9).

❐ Locate the 180K resistors (3) and solder into R53 (by Q7), R56 (by VR3) and R59 (by Q9).

❐ Locate the 2K7 resistors (3) and solder into R54 (by Q7), R57 (by VR3) and R60 (by Q9).

❐ Locate the 120K resistors (3) and solder into R42 (by VR7), R63 (by VR2) and R66 (by VR3).

❐ Locate the 47K resistors (2) and solder into R19 (by U2) and R41 (above Q3).

❒ Locate the 220K resistors (2) and solder into R24 (by Q1) and R28 (below VR1).

❒ Locate the 4K7 resistors (2) and solder into R32 (by U6) and R36 (by JP1).

❒ Locate the 2K2 resistors (2) and solder into R44 and R46 (by U7).

❒ Locate the 22K resistors (2) and solder into R26 (below VR1) and R39 (below U7).

❒ Locate the 6K8 resistor and solder into R25 (by Q1).

❒ Locate the 3K9 resistor and solder into R27 (by Q2).

❒ Locate the 8K2 resistor and solder into R29 (beside U6).

❒ Locate the 68 ohm resistor and solder into R20 (next to C17).

PART #2: BOARD WASH #1

❒ Verify all the resistors are in the correct position.

❒ Verify all the resistors are flat on the board. Correct if needed. Check solder joints.

❒ Wash the board in warm water, gently scrubbing *both* sides. DO NOT USE ANY SOAP! Just water!

❒ Shake the board a couple of times, blot dry with an old towel (the leads will frazzle a good towel). Let dry at least 15 minutes.

❒ Take a little break! You are about 1/3rd of the way finished.

PART #3: CAPACITORS & board wash.

❒ Locate the **CAPACITOR** bag. Set the polystyrene 1000pf caps (the big silvery ones with the long, thin leads) aside. ***THESE CAPS ARE SOLDERED IN AFTER THE ICs!***

❒ Locate the 0.047mfd yellow box caps (2) and solder into C3 and C4.

❒ Locate the 0.1mfd yellow box caps (3) and solder into C6, C7, and C8.

❒ Locate the 0.47mfd yellow box cap and solder into C11.

❒ Locate the 0.22mfd stacked film cap (reddish-brown color) and solder into C14.

❒ Locate the 0.33mfd stacked film cap and solder into C13.

❒ Locate the 0.1 axial caps (7) and solder into C1, C2, C12, C15, C16, C17 and C18.

❒ Locate the 10µfd electrolytics (2). Note that there is a stripe on the NEGATIVE terminal. The pc board has a + on the POSITIVE terminal. Carefully stick the capacitors into C19 and C20 with the stripe ***away*** from the + pad on the board.

❒ Wash the board again, gently scrubbing both sides. Use ONLY warm water!

PART #4: MISC and IC STUFF

Almost done with the parts on the pc board! This will finish up the soldering with the organic flux.

❒ Locate the **MISC #1** bag and the **IC** bag.

❒ Locate the ferrite beads (2). They are axial parts, gray colored with no markings. These are non-polar, and are soldered into L1 and L2 (by JP1).

❒ Locate the MTA-156 power connector. Solder into JP1. Note that the connector has a 'locking tab' on one side. This side is the "inside" facing relative to the pc board. Note the silkscreen symbol for JP1 has a line on one side, indicating this is the side where the locking tab goes.

❒ Locate the TL074 op amp. Solder into U5. Note that all ICs are pointing "down" towards the bottom edge of the pc board. The IC will have a 'notch' or indentation in the top by Pin #1.

❒ Locate the JRC4558 op amps. Solder into U1, U2. Solder the TL072s in U3 & U4.

❒ Locate the NE5517 OTAs (2). Solder into U6 and U7.

❒ Locate the VTL5C4/2 Vactrols. Note that on one side, there is lettering +LED- and CELL. This side faces up. Also, note that by the – lead, the case is slightly notched or cut in. This matches the silkscreen pattern on the pc board. Carefully bend the leads at a 90 degree angle to the part, about 1/8" from the body of the part. Do not pull excessively on the leads, or they will break! Solder the 3 Vactrols into D1, D2, and D3.

❒ Locate the BC560C transistors (6) Match the flat side of the part to the flat side shown on the silkscreen. Place the transistor in the holes, but do NOT press the transistor all the way to the pc board. Leave about 0.1 inch of the leads exposed between the pc board and the underside of the transistor. Solder into Q1, Q2, Q3, Q7, Q8 and Q9.

❐ Locate the BC550C transistors (3). Solder into Q4, Q5 and Q6.

❐ Locate the 3ea 1000pf polystyrene caps. Solder into C5, C9 and C10.

❐ Apply a small bit of solder to the via holes. These are the small pads that allow traces to “change sides” of the pc board. DO NOT SOLDER PADS FOR THE REMAINING COMPONENTS!!

PART #5: FINAL BOARD WASH & INSPECTION

❐ Verify all the parts are in the correct locations. Make sure all of the ICs are pointing the same direction. Make sure all of the transistors are facing the same direction.

❐ Inspect the solder joints. Any solder shorts? Too much solder? Missing joints?

❐ Wash the board under warm water. Scrub gently. Dry.

THIS IS A GOOD STOPPING PLACE TO REST OR PUT THE KIT AWAY UNTIL LATER.

You are now finished with the Organic flux solder. All soldering past this point is using the No-Clean solder. You do not have to wash the board anymore.

PART #6: FINISHING THE PCB

You will now solder in the remaining parts on the pcb in preparation for wiring to the front panel. USE THE NO-CLEAN SOLDER. BE CAREFUL!

❐ Locate the Spectrol 149 pots (4). These solder into VR1, 2, 3 and VR4. It is important that the pots side absolutely flat on the pc board, with the shafts sticking straight out.

❐ Locate the 5 pieces of RG-174 black coax cable. Again, note that one end has longer wires stripped than the other. The short ends will go in the pc board in locations J1, J2, J4, J6 and J8. Look at the pc board. Notice that in the coax positions, there is a large hole pad (lower pad) and a smaller pad (top hole). The braided wire is soldered into the larger hole. The smaller, inner conductor goes in the top hole. BE SURE THE SHORTER BRAIDED END GOES INTO THE PC BOARD.

The 1 LONG coax cable solders into J1 (IN). The 4 SHORT coax cables go into the other locations. Solder each coax cable into the holes. Attach a tie-wrap to secure the coax cable flush to the board. The tie-wrap goes down, into the left hole and up through the right hole. Secure and trim off any excess.

❒ Find the 3 orange/white/gray twisted wires. They are soldered into VR5, VR6, and VR7. Look at the pcb silkscreen, and note that there are the numbers 1, 2 and 3 beside the box around the 3 pads, ***and note carefully that for VR7, the numbers are in reversed order***. Solder the White wire into the #3 pad, the Gray wire into the #2 pad, and the Orange wire into the #1 pad. Again, for VR7, the White and Orange wires are "backwards" from the other 2.

Now, locate one of the blue Bourns pots. In order to ease soldering of the jacks, you will solder it to the lead wires first. This pot attaches to the VR7 wires. Look at the back of the pot, and notice there are 3 tiny numbers stamped above the 3 lugs. The leftmost lug is #3, the middle lug #2, and the right lug #1. These correspond to the #1, #2 and #3 pads for the orange/gray/white wires. Solder the White wire in VR7, pad #3 to the left lug, the Gray wire to the middle lug, and the Orange wire to the right lug (#1 pad to #1 lug, etc).

❒ Find the long red/black cable (has a gray outer jacket). This solders into J5 (right beside VR5). The Red wire goes into the #1 pad, and the Black wire into the #2 pad.

❒ Find the 4 red/black twisted wires. They go into SW1A, SW1B, J3 and J7. In all cases, solder the Red wire into the #1 hole and the Black wire into the #2 hole.

YOU ARE NOW FINISHED WITH THE PC BOARD WORK! BREAK TIME.

PART #7: FRONT PANEL PREPARATION

You will now attach components to the front panel. It is HIGHLY recommended that you use a set of hollow shaft nut drivers, NOT PLIERS, to tighten the nuts. This prevents scratching. NOTE: all references to part orientation is from the REAR of the panel.

❒ Locate the 8 Switchcraft jacks. Notice that from the rear, there is a beveled corner. This corner is ALWAYS CONNECTED TO GROUND, USUALLY WITH THE BRAIDED CONDUCTOR. Each jack has a flat washer, a lockwasher, and a ½" hex nut. Remove the nuts and washers from each jack. Place aside. Keep the lockwasher on the jacks.

❒ Insert the 8 jacks/lockwashers, with the beveled corner in the ***upper right*** corner, into the 8 holes. Place the flat washer on the jack, then the hex nut. Hold the jack with one hand on the backside, keeping it 'square'. Tighten the hex nut with a nut driver. NOTE: when tight, not much of the exposed threads of the jack are exposed.

You are now ready to attach the pc board to the bracket and then wire up to the panel.

PART #8: ATTACH PC BOARD TO BRACKET/PANEL

❒ In the **HARDWARE** bag, locate 4 #6-32 x 3/8 screws, 6 #6 KEPS nuts, and 4 spacers.

❒ Locate the mounting bracket. The pc board attaches to the bracket, with the 4 screws threading from the top of the board, through the spacers, through the bracket, and then out the bottom of the bracket. The #6 KEPS nut attaches on the bottom of the bracket. Note the bracket has 2 long mounting flanges with a hole in each. These attach to the 2 threaded studs sticking out of the rear of the panel. The 4 pots each stick in its panel hole when the bracket is screwed down on the 2 threaded posts.

Attach the pc board to the bracket. The flanges will point upwards when the pc board is sitting on the bracket. Note that the bracket holes for the pc board are actually oblong. This is to allow adjustment for the pc board to firmly press up against the back of the panel. As a start, set the 4 screws ALL THE WAY TO THE LEFT of the oblong holes. ***Loosely*** tighten the 4 KEPS nuts on the bottom.

❒ THIS IS A VERY IMPORTANT STEP, SO PAY ATTENTION AND READ ALL OF IT BEFORE PROCEEDING!

Note that each of the 4 pots on the pc board have 2 hex nuts and a flat washer. Remove the first hex nut and the washer. Set aside.

What you will do now is adjust the remaining hex nuts so that when the bracket is all the way down on the panel's threaded studs, all the pot hex nuts touch the rear of the panel.

Screw (by hand) each hex nut on the pots so that it is all the way on (touching the face of the pot). Now, pick up the pc board/bracket assembly and carefully slide it over the 2 threaded studs, making sure the pots are aligned in the holes. Use 2 #6 KEPS nuts and tighten the bracket to the panel.

❒ Loosen the 4 KEPS nuts on the bottom of the bracket. Slide the pcb ALL THE WAY TO THE RIGHT AS FAR AS IT WILL GO, so that the 4 pot nuts are all pressing against the panel. By hand, put hex nuts on the outside threads of VR1 and VR4 to keep the pc board in place. Now, tighten the 4 KEPS nuts on the bracket. The pcb and bracket should be secure, with no gaps visible between the panel and the pot nuts. You may need to loosen the nuts on the pots, so that they are touching the back of the panel. Again, make sure each pot's nut is touching the back of the panel (no gaps!). There will be a gap from the edge of the *pc board* to the panel.

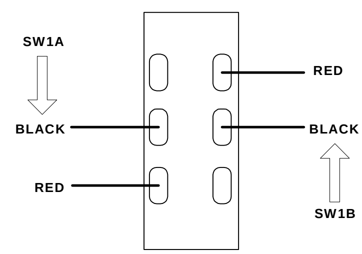
❒ Remove the hex nuts on VR1 & VR4. For all of the pots, first put on the flat washer, then the hex nut. Tighten with a ½" nut driver.

PART #9: FINISH WIRING TO THE PANEL

Please read the following instructions carefully. In order to neatly attach the many wires to the front panel components, the wires are soldered in a specific order.

❒ Find the DPDT toggle switch. Note there switch has 6 lugs, in 2 columns of 3 lugs (this is with respect to the actuation of the toggle lever on the switch). Insert the switch into the panel hole labeled SINGLE/DUAL/DUAL REV. Tighten the outside hex nut, but DO NOT OVERTIGHTEN!! Be sure the switch is oriented so the lever operates "up and down" and not "side-to-side"!

The 2 pairs of red/black wires in the SW1 holes solder to 4 lugs of the switch (2 of the lugs are not connected). Solder the Red wire in SW1A to the Bottom lug (the one closest to the jacks) of the switch, to the inside column (closest to the pcb). Solder the Black wire in SW1A to the Center lug of the same section. Solder the Black wire in SW1B to the other Center lug (towards the outside panel edge). Solder the Red wire in SW1B to the Top lug of the outside section. See the illustration below.



❒ Locate the 2 blue Bourns 91A panel pots. These solder to the 3 wires in VR5 and VR6. In both cases, solder the White wire to the Left lug, the Gray wire to the Center lug, and the Orange wire to the Right lug. Attach the VR5 pot in the RATE hole. Attach the VR6 pot to the DEPTH hole. The wires on VR5 are a little long: just form a backwards 'S' with the wire. Use a tie-wrap to bundle and secure the VR6 wire to the 2 wires on the switch. Attach the tie-wrap about 1 inch (2.5cm) behind the switch.

❒ For the time being, leave the VR7 pot unattached to the panel. This is after the jacks are soldered.

❒ Now you will solder to the 8 jacks. Each jack has 3 lugs: from the rear we will refer to them as LEFT, TOP, and BEVELED. The TOP lug is for the switched contact: this is a NC (normally closed) contact that is opened when a plug in inserted. For 2 of the jacks (RATE and DEPTH), you must solder a small wire from the TOP lug to the BEVELED lug. This will short the input to the pcb to ground with no plug inserted. The circuitry depends on this ground connection in order to operate properly. Refer to the schematic, and see that for J5 and J7, the jack indicates a shorting connection. Use a scrap lead of resistor wire, and solder the wire across the 2 lugs for these 2 jacks. It may be easier to first remove the jacks from the panel.

❒ We will start with the bottom row. Solder the coax in J8 to the MIX OUT jack. The braid goes to the BEVELED lug. The inner conductor goes to the LEFT lug.

❒ Solder coax in J6 to the OUT 3 jack.

❒ Solder the coax in J4 to the OUT 2 jack.

❒ Solder the coax in J2 to the OUT 1 jack. This is a "stretch fit", but the wire will reach.

❒ Solder the coax in J1 to the IN jack. Use a tie-wrap and bundle the coax wires together.

❒ Solder the red/black wire in J7 to the DEPTH jack. The Black wire goes on the BEVELED (ground) lug. The Red wire goes to the LEFT lug. There is a jumper on this jack from TOP to BEVELED.

❒ Solder the long red/black cable to the RATE jack. The Black wire goes to the BEVELED lug. The Red wire goes to the LEFT lug. There is a jumper from TOP to BEVELED on this jack.

❒ Solder the red/black wire in J3 to the SWEEP jack. The Black wire goes to the BEVELED lug. The Red wire goes to the LEFT lug. There is NO JUMPER on this jack!

❒ Attach the VR7 pot to the panel, in the SWEEP hole.

❒ Rotate all of the front panel pots fully counter-clockwise. Locate the **KNOBS**. Notice each knob has a white line on it. Place the knob on the pot shaft, align the white line to the '0' tick mark, and tighten the hex screw. The silver part of the knob has a protective clear plastic overlay that can be removed if desired. Gently rub with your fingernail across it and it will peel off.

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CONGRATULATIONS! YOU HAVE FINISHED BUILDING THE MOTM-410!

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All that's left to do is test it! But before we do, please read the following Theory of Operation.

THEORY OF OPERATION

The MOTM-410 contains 3 bandpass filters and 2 voltage-controlled LFOs. Since this filter is used primarily as an effects device, there is no "traditional" 1V/Oct control network.

In order save front panel space, the controls and jacks work differently than on other MOTM modules. Please read the following sections carefully to understand how the controls interact with the 3 filters.

AUDIO PROCESSING SECTION : Page 1 of the Schematic

The audio input is buffered by U2B. Adding optional pad resistor R68 will attenuate the input by half (-6dB). This is necessary for processing 10V Pk-Pk signals found in the MOTM system. If you are using the typical 1V pk-pk signals in a studio (like the outputs of other synths) this resistor should be not used.

U2A forms a 65Hz high-pass filter. This is found in the original Korg PS-3100 design, and was probably for filtering out AC hum in the bandpass filters. It is included in the '410 because it does factor into the overall "sound" of the module (as does using 4558 op amps as opposed to a more modern design). The '410 tries to achieve as close as possible the sound of the PS-3100.

The filters have high gain, so resistors R2 and R20 divide the audio signal. If you ever want to modify the overall gain of the '410 module, adjust R20 (smaller value is less gain). Due to tolerances in the capacitors and the Vactrol resistive elements, the overall gain will vary +-20% unit-to-unit. The "factory stock" 68 ohm resistor is just a compromise.

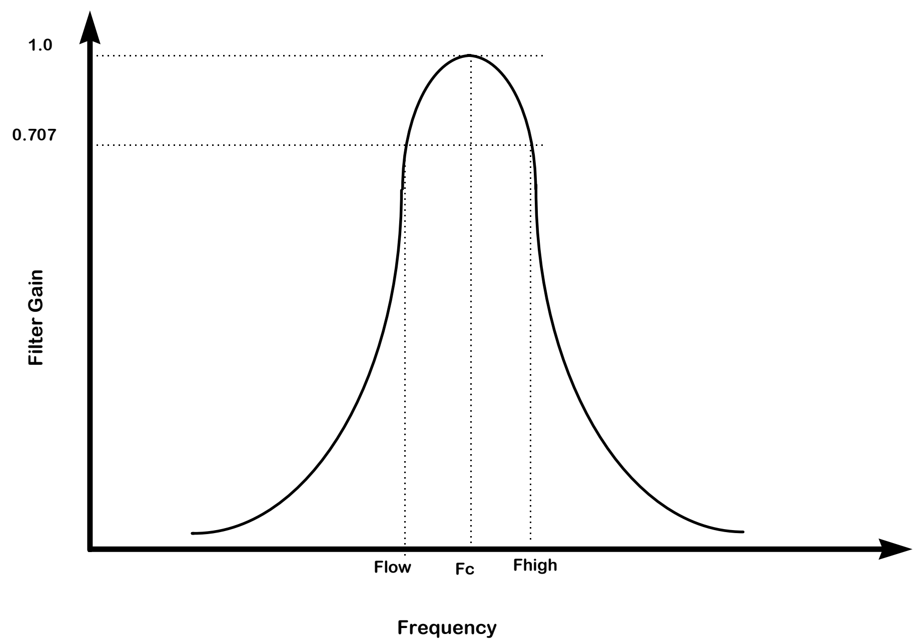
The audio signal is split into the 3 identical bandpass filter stages. The center frequency of a bandpass filter is controlled by the 2 resistors inside each Vactrol. These resistors vary their resistance as a function of the amount of light the internal LED shines on them. The amount of light, is in turn, a function of the LED current. The more current in the LED, the more light and the lower the resistance. Vactrols are sometimes referred to as LDRs (Light-Dependent Resistor).

The filter structures used are not "standard" topology as seen in the textbooks. The textbooks will show equal capacitor values and unequal resistors. In our case, we want the opposite: equal resistors (inside the Vactrol) and really don't care what the cap values need to be.

The center frequency of the bandpass stage is given by: 1/(20)(pi)RC where R is the resistance of the Vactrol resistor and C is 1000pf in our design.

What about the other C (the 0.1mfd)?. Well, it is chosen to be 100 times bigger than the other C on purpose! This makes the math easy! In fact, is also makes this bandpass filter have a constant Q of 5.

This brings up a point: the typical synth filter has Q or resonance at the cutoff frequency. Resonance causes a “peaking” of the gain before the filters starts to attenuate the signal. A bandpass filter by design always “peaks”. So, the Q number has a different meaning.
The Q of our bandpass filter (which is fixed at 5) is given by: Fc/(Fhigh-Flow)
Where Fc is the center frequency, and Fhigh and Flow are the frequencies where the audio signal is attenuated 3dB from the value at Fc. See the illustration below.

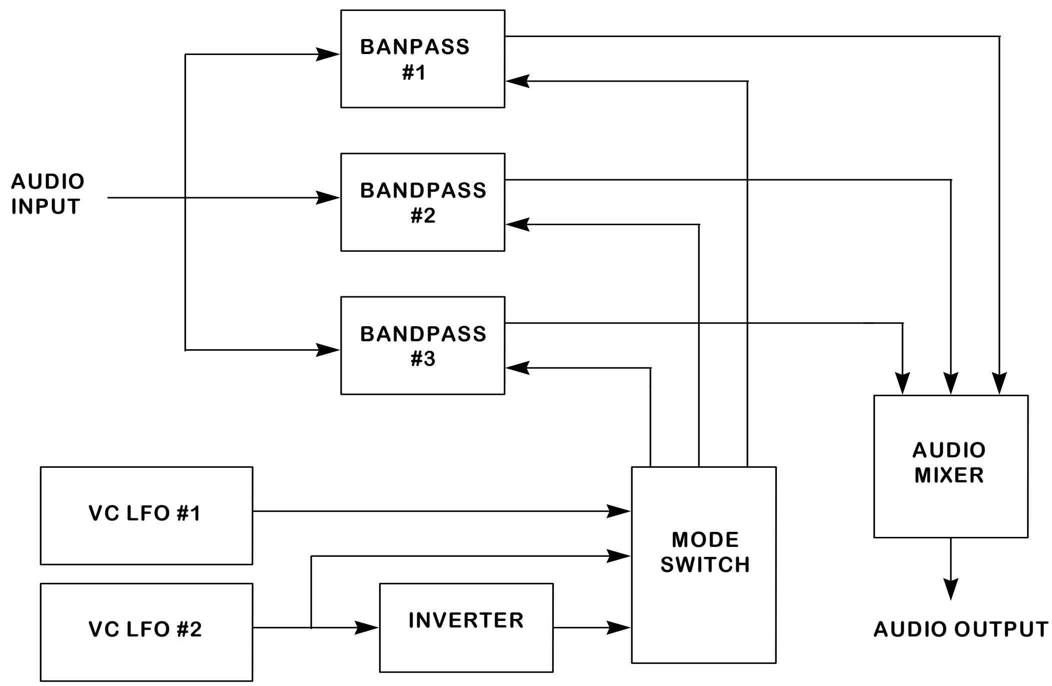


For example: if our filter is tuned to 1000Hz, the input audio is attenuated by 3dB (a factor of 0.7) at 900Hz and 1100Hz. Bandpass filters do not have a “slope” associated with LP and HP filters.

The 3 filters are summed together by U1A. Panel control VR1 is a “balance” control between the original audio (called the ‘dry’ signal) and the filtered audio signal (called the ‘wet’ signal). Since the Q of our filters is fixed at 5, the ‘410 uses this balance function to emulate the “RESONANCE” control on other VCFs.

Dual VC LFO and Filter Control Section : Page 2 of the Schematic

The ‘410 contains 2 VC LFOs, that are controlled in parallel. The LFOs are set, by capacitors C13 and C14, to run at slightly different rates. The LFO outputs sweep the 3 filters back and forth across the audio spectrum. A 3-position toggle switch selects how the filters are swept. See the block diagram below:



The 2 LFOs use the same basic circuitry (just the integration capacitor is a different value). The OTA U6 controls the frequency (I like to call sub-audio frequencies “rate” instead) of the integrator U5C and U5D. The capacitor is charged, then discharged to produce a triangle output. The rate is set by how much current is available to the integration cap. This current is controlled by the 2 transistors Q1 and Q2. Q2 is an exponential converter whose control current into the OTA is set by the Vbe voltage on Q1. The Vbe is generated by summing the voltage set by the RATE pot VR5 and the RATE input CV applied to J5. Note that J5 is a shorting jack to ground: with nothing plugged in the RATE is set by the RATE pot only. R23 biases the RATE jack so that “standard” –5V to +5V control voltages can be used.

Ignoring SW1 for the moment, the 2 triangle waveforms then go to another OTA, U7. This OTA performs 2 functions: a sine shaper and a VCA. Sweeping the bandpass filters with a sine wave is more pleasing to the ear, so we purposely overdrive the input differential amplifier stage of the OTA to “distort” the triangle into a sine (this same technique is used on the MOTM-300 VCO).

The OTAs are set up as VCAs. The DEPTH input is set up like the RATE input: if no CV is plugged into the jack, the DEPTH panel pot sets the “width” of frequencies the filters sweep over. If a CV is plugged in, the pot sets the ‘initial DEPTH’ and the CV increases the depth (+ control voltages) or decreases it (- control voltages). The RATE and DEPTH controls **are not input attenuators** for the CVs! Rather, think of them *as offsets* if the CV inputs are used.

Each bandpass filter has it's own initial frequency control. This control sets the Fc of the filter with 0 volts from the LFOs (ie DEPTH at minimum) and 0 volts from the SWEEP circuit. The LED current in the Vactrols are set by a simple exponential converter using 2 transistors and a reference resistor (ie Q7 + Q4 + R53). The resistor to +15 sets the "idle reference current" in the LEDs. The current is then modulated by changing the Vbe voltage. The current in the LED (and hence the resistance in the filter circuit) is summed from 3 sources:

a) the setting of the FREQ pot
b) the setting of the SWEEP pot and any CV plugged into J3
c) the LFO output voltage

The SWEEP panel control is unique. If nothing is plugged in to J3 (note it is NOT shorting to ground!) the pots generates 0 to +5V to the LED drive circuitry. However, if a CV is plugged in, the SWEEP pot **does act as an input attenuator** for the SWEEP CV. This works only if the source impedance of the SWEEP CV is much lower than the 51K of resistor R67 (which will be the case). Negative CVs cause the 3 filters to move to lower Fc values, while positive CVs move the filters to higher frequencies. Another way to look at it is that the SWEEP pot is a manual version of the LFOs!

Now let's closely examine how the LFOs and the 3 filters are connected. The '410 has 3 unique "sweep modes", each with a different sound. These 3 modes are selected by switch SW1. However, it is not obvious what is going on, so let's take a look.

First see that VCF #1 is always connected to the output of LFO #1. Filters #2, and #3 are connected to LFO #2, and to programmable inverter U4B.

Let's examine each mode and see how they work.

SINGLE MODE

Upon first glance, this looks like a mistake. The output of LFO #1 is shorted to the output of LFO #2 via resistor R11. What's going on??!? Well, by doing this LFO #2 is 'jammed' into running at the rate of LFO#1. Therefore, all 3 filters are swept in unison by LFO #1.

DUAL MODE

The switch is disconnected entirely, and LFO #1 drives filter #1, and LFO #2 drives filters #2 and #3. Since LFO #1 runs slightly faster than LFO #2, filter #1 scurries about quicker.

DUAL REVERSE MODE

SW1 now grounds the + input of U4B, causing the output of LFO #2 to be inverted for filter #3. So now, LFO #1 controls filter #1, and filters #2 and #3 are moving in opposite directions at the LFO #2 rate.

The operations are summarized in a table in the USE OF THE MOTM-410 section.

TROUBLESHOOTING

If your MOTM-410 does not work, please verify ALL of the following before contacting us. The following reference directions assume that you are looking at the pc board with the panel to the right and the power connector to the left.

- ❐ All of the ICs are pointing the same way and all notches are 'down'.
- ❐ The braided wire on the coax goes to the beveled side of the jacks.
- ❐ The parts are in the right places, and the panel pots/switch is wired correctly.
- ❐ No solder shorts or missing joints.

USE OF THE MOTM-410 VCF

The MOTM-410 is a "stand alone" module that can be used for filtering just about any audio source (you can't plug a guitar or mic directly into it, but use a 'direct box' or preamp first!).

In order to get the widest range of sounds, you first must understand what is going on inside the module. There are really 2 separate sections: the filter section with the 3 bandpass filters and the modulation section with the VC LFOs and external CVs.

What exactly is a bandpass filter? This is a filter that passes frequencies in a narrow range (called the "passband") and attenuates all others, both above and below the passband. A good example of a bandpass function is a slider on a "graphic equalizer".

But, there is a ***VERY IMPORTANT DIFFERENCE*** with the MOTM-410! The '410 is set to "cut out" all frequencies except those in the passband. ***Therefore, you will get no audio out of the MOTM-410 unless there are frequencies present in the passbands of the filters.*** Please take the time to understand this concept: if you don't have the passbands set properly, it is possible to conclude the module is "broken" because nothing is coming out.

For example, if we have a bandpass filter set for A440 on a keyboard, then the volume of the notes would get softer as you played *below* A440 or *above* A440. For the notes right around A440, the volume would be normal. The farther away from A440 you played, the softer the notes would get. Eventually, you would not be able to hear the lowest and highest notes at all!

The "loundness" changes because the filter is removing both upper and lower harmonics at the same time, which *drastically* reduces the overall amplitude.

SETUP #1: Exploring the filters

Since the best way to explain is by audio example, please take the time to go through the following exercises.

a) Set RATE and DEPTH pots to 0.
b) Set SWEEP to 10
c) Set MIX to DRY (all the way CCW)
d) Set FREQ1, FREQ2, and FREQ3 to 10
e) Plug an audio source (VCA output, synth output, etc) into IN jack
f) Connect your amplifier to MIX OUT

Play something. You should here whatever the input is (Congratulations! You programmed a wire! ☺). Now set MIX to WET (all the way CW). You should notice a dramatic reduction in volume. In fact, you may hear nothing at all!

Why? By setting the FREQ pots and SWEEP to maximum, the 3 filters are sitting at about 30Khz so not much energy is in the passbands!

Now turn SWEEP all the way back to 0. The volume will rise slightly, but the filters are now at about 19Khz, so still not much energy is present and the volume is still very soft.

Next, set play and hold a note around A440 and slow turn FREQ 1 towards 0.

As the pot is turned, the volume will rise to near full strength. This demonstrates how moving the Fc (center frequency) of the filter towards the note allows more harmonics to pass through. Don't blow your speakers! Turn the volume down first!!

But wait! I bet you also noticed that the timbre of the note has changed! It is more "hollow" or "nasal" sounding. Sure! We are filtering out about 75% of the harmonic content! So the bandpass filter is altering the volume AND the timbre at the same time. It's also altering the *phase* of the signal, but we'll get to that shortly.

SETUP #2: Setting the SWEEP control

The SWEEP pot moves all the filters, in unison, up and down the frequency spectrum. Normally, this pot is set to 0 and the LFOs sweep the filters. But you can use the SWEEP pot to move the filters as a group to a new "spot" on the frequency map.

a) Set Freq 1 to 1
b) Set Freq 2 to 3
c) Set Freq 3 to 5
d) Set SWEEP, RATE and DEPTH to 0.
e) Set MIX to WET.

Play up and down the keyboard. Note the overall volume changes as you play up and down the keyboard. Hold a cord around middle C and turn the SWEEP knob slowly towards 10. You will hear the 3 filters glide up the scale. This is what the LFOs do internally.

Now, set SWEEP to 5 and plug a LFO sine or triangle into the SWEEP jack. You should hear the filters sweep up and down (all 3 are going together at the same rate). The depth of the sweep can be adjusted by the SWEEP pot (which is acting as an attenuator for the CV input).

SETUP #3: Setting up the LFOs

a) Remove any SWEEP CV input and set SWEEP to 0.
b) Set RATE to 5
c) Set DEPTH to 10
d) Set FREQ 1 to 2, FREQ 2 to 5, FREQ 3 to 7.
e) Set the switch to SINGLE
f) Set MIX to WET

Now play. You should hear the internal LFOs sweeping the 3 filters back and forth. Twiddle the RATE and DEPTH knobs and hear the differences. Twiddle the MIX to hear how the effect can be altered.

The 'notches' in the response are also caused by phase cancellation of the audio signal as the filters move past each other. This is how a phaser works: the '410 filter has a more dramatic effect due to both filtering and phase cancellation.

Now play and hold a cord, and set the switch to DUAL, then DUAL REVerse and listen to the differences. You may have to adjust SWEEP to hear the most dramatic effect.

Hopefully at this point you are familiar with the controls on the '410. Here is a chart that relates the 3 filters to the LFOs.

SWITCH SETTING	FILTER #1	FILTER #2	FILTER #3
Single	LFO #1	LFO #1	LFO #1
Dual	LFO #1	LFO #2	LFO #2
Dual Reverse	LFO #1	LFO #2	Inverted LFO #2

Experiment! You can spend hour and hours playing with all the possible setting and audio inputs.

Another thing you should play with (if you have a stereo mixer) is to use the 3 individual outs. Run each OUT into a mixer input. Pan #1 to Left, #2 to the center, and #3 to the Right. By adjusting the frequencies, this will generate a "pseudo stereo" effect.

MODIFICATIONS

The following FAQ is a list of possible modifications to suit user taste. Note that Synthesis Technology does not offer the parts needed. Good sources of parts for modifications are Mouser Electronics (www.mouser.com) and Digikey (www.digikey.com)

Q1) How can I speed up/slow down the internal LFOs?

A – Change capacitors C13 and C14. Larger values (0.47 or 0.68mfd) slow down the LFOs. Smaller values (0.15 or 0.1mfd) speed up the LFOs. Make sure the caps have 5mm lead spacing and are stacked film types (do NOT use Mylar caps in this application).

Q2) How do I increase/decrease the overall gain of the module?

A – Make R20 smaller (56, 51, or 47 ohms) to decrease the gain. BUT make R13 larger (12K to 20K) to make the gain larger. DO NOT make R20 larger than 68 ohms or you may clip the audio.

Q3) Can I make the LFOs sweep the filters wider/narrower at maximum DEPTH?

A – Change resistors R42, R66 and R63. Larger values reduce the sweep range of the LFOs. Smaller values increase the sweep range. Note that these resistor are for the LFOs only, and have no effect on the SWEEP pot or SWEEP CV range.

SPECIFICATIONS
MOTM-410 Triple Resonant Filter

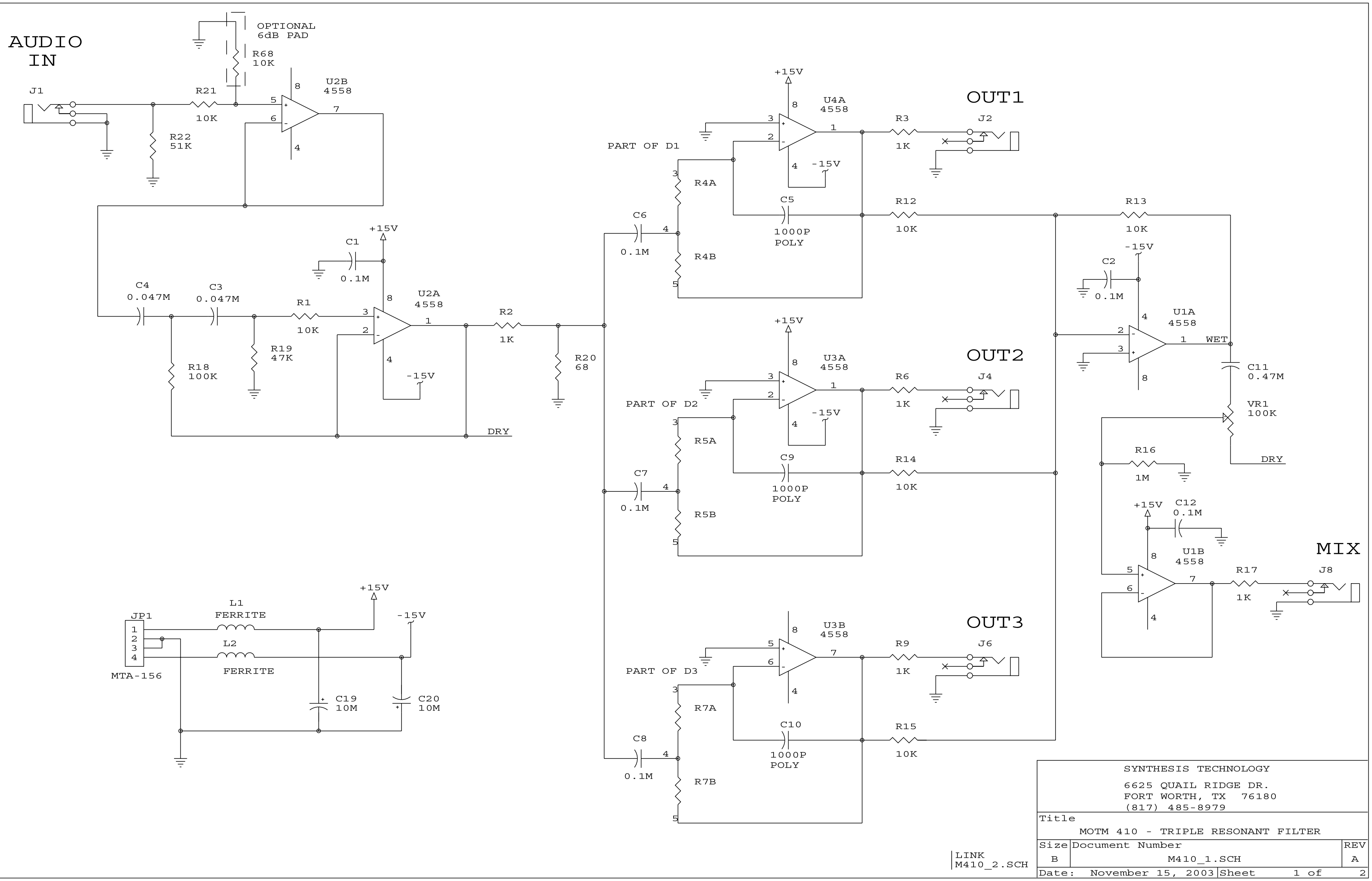
Control Voltage input levels	-7V to +7V
Bandpass frequency range	50Hz to 31Khz
Output impedance	1000 ohms, nom.
LFO Rate	0.05Hz to 100Hz
Audio input level	50mv pk-pk min, 12V pk-pk max (requires installing R68)
Filter gain	1.0 nominal at MIX set to WET, in passband

CONTROLS

RATE	sets internal LFO initial frequency
DEPTH	sets internal LFO sweep depth
MIX	fader between audio input and filtered output
FREQ 1, 2, 3	initial center frequency for filter 1, 2 and 3
MODE	selects SINGLE, DUAL or DUAL REVerse sweeps

GENERAL

Power Supply	-15VDC @ 55 ma nominal +15VDC @ 40 ma nominal
Size	2U x 5U 3.47" x 8.72" 88.1mm x 221.5mm
Depth behind panel	4.375 inches (111mm)



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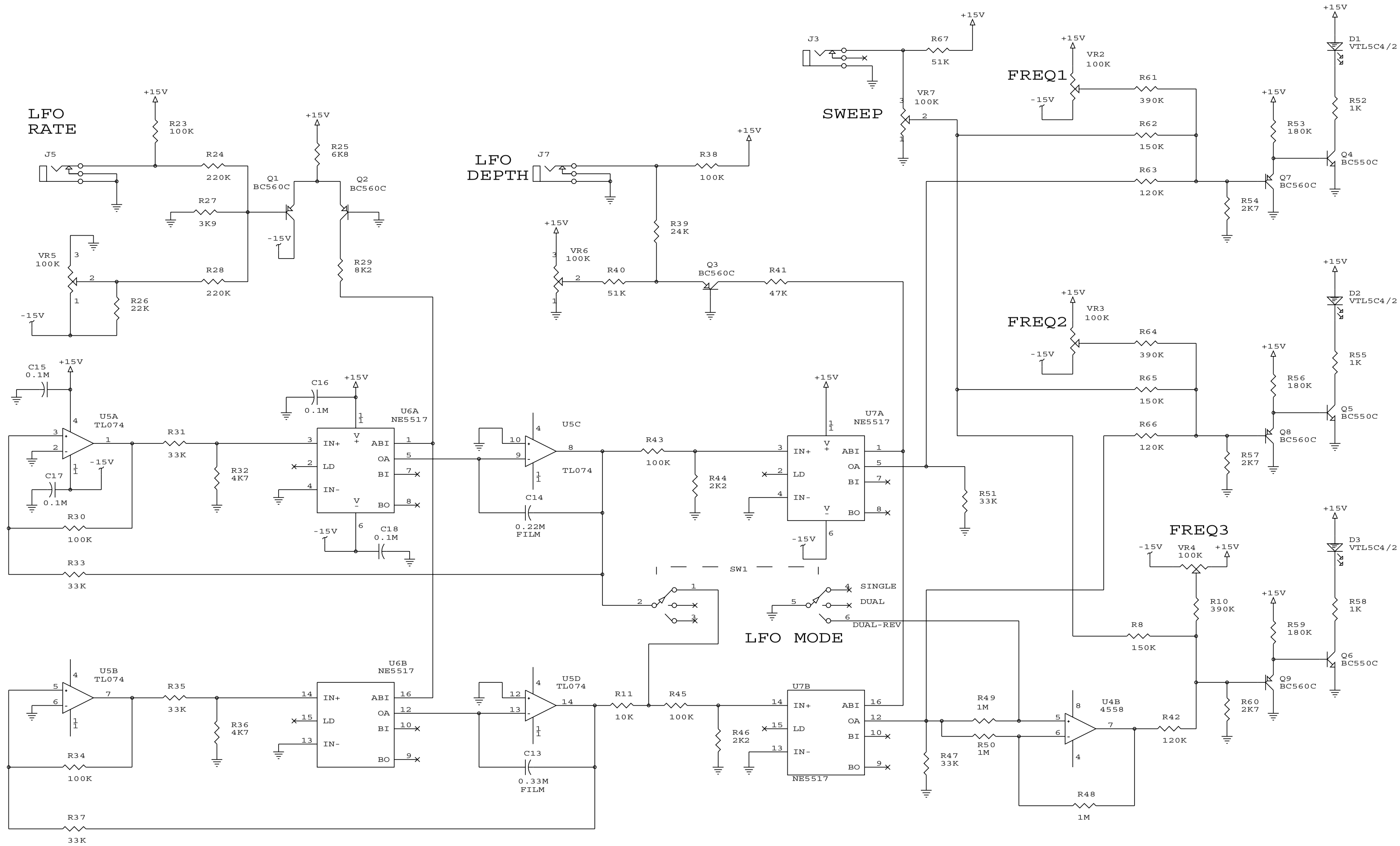

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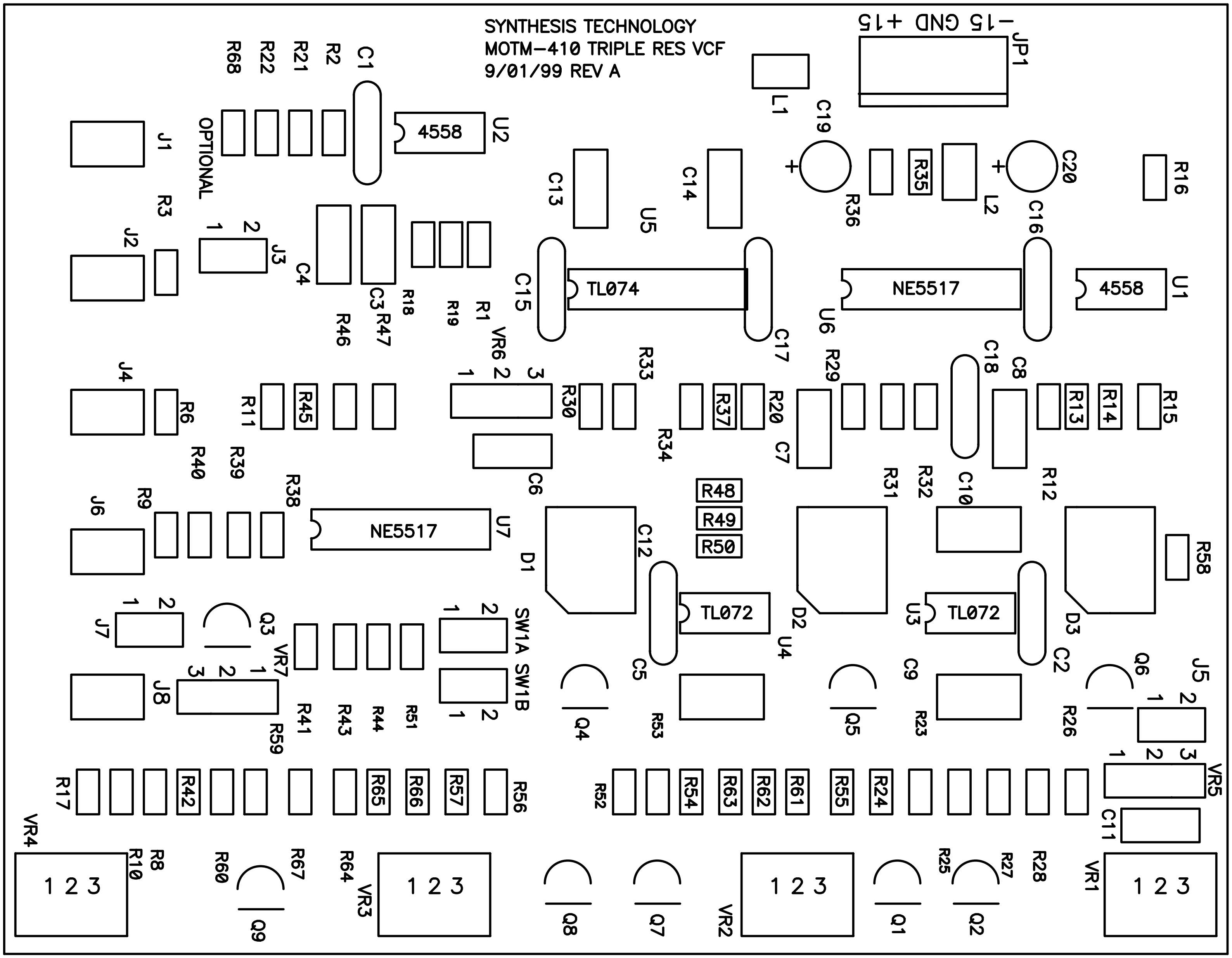
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