

**synthesis  
technology**

**MOTM-320 Voltage-Controlled LFO  
Assembly Instructions & Owner's Manual**

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# MOTM-320 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 12 parts:

2ea 10mfd Electrolytic (16V or 50V)	C1, C2
1ea 0.01mfd film cap (reddish-brown)	C8
2ea 1000pf yellow box (marked 1N or 102)	C5, C10
7ea 0.1mfd (marked 104) ceramic axial	C3, C4, C6, C7, C9, C11, C12

**Resistor** bag, containing the following 80 parts:

11ea 10K (brown, black, orange)	R1, R13, R17, R19, R21, R30, R38, R46, R47, R58, R59
8ea 1K (brown, black, red)	R44, R52, R53, R64, R66, R73-75
6ea 220K (red, red yellow)	R23, R24, R32, R43, R78, R79
5ea 51K (green, brown, orange)	R27, R56, R68, R69, R77
5ea 20K (red, black, orange)	R16, R33, R37, R60, R61
4ea 4K7 (yellow, violet, red)	R12, R31, R45, R51
3ea 1M (brown, black, green)	R22, R42, R67
3ea 33K (orange, orange, orange)	R35, R39, R63
3ea 100K (brown, black, yellow)	R20, R41, R57
2ea 62K (blue, red, orange)	R36, R62
2ea 47 ohms (yellow, violet, black)	R48, R49
2ea 2K (red, black, red)	R50, R55
2ea 13K (brown, orange, orange)	R54, R76
2ea 1K3 (brown, orange, red)	R70, R72
1ea 7K5 (violet, green, red)	R11
1ea 27K (red, violet, orange)	R14
1ea 6K8 (blue, gray, red)	R15
1ea 150K (brown, green, yellow)	R18
1ea 5K1 (green, brown, red)	R25
1ea 510K (green, brown, yellow)	R26
1ea 3K6 (orange, blue, red)	R28
1ea 1K8 (brown, gray, red)	R29
1ea 39K (orange, white, orange)	R34
1ea 300K (orange, black, yellow)	R40
1ea 2K7 (red, violet, red)	R71
5ea 100K 1% (brown, black, black, orange)	R2, R3, R4, R7, R80
2ea 243K 1% (red, yellow, orange, orange)	R5, R6
1ea 54K9 1% (green, yellow, gray, red)	R9
1ea 1M 1% (brown, black, black, yellow)	R10
1ea 412K 1% (yellow, brown, red, orange)	R65
1ea 1K 1% 3W TEMPCO	R8

**IC bag, containing the following 23 parts:**

1ea TL074ACN quad op amp	U1
1ea LM393N dual comparator	U2
3ea TL072 dual op amp	U3, U6, U7
1ea NE5517 dual OTA	U4
1ea OP275GP dual op amp	U5
1ea CA3080AE OTA	U8
5ea BC560C PNP transistor	Q2, Q3, Q7, Q8, Q14
7ea BC550C NPN transistor	Q1, Q4, Q5, Q10-Q13
2ea BF245A JFET	Q6, Q9
4ea 1N4148 signal diodes	D1, D2, D3, D4

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

2ea Axial ferrite beads (plain, gray things)	L1, L2
1ea MTA-156 power connector	JP1
1ea 4x2 header strip w/shunt	{for LED SELECT}
1ea bi-color LED SSI-LXH-387HGW	mounted on panel

**Knobs, 3ea, ALCO PKES90B1/4**

**Jacks, 8ea Switchcraft 112A**

**Pots, 3ea containing the following:**

3ea 100K linear pots	VR1 – VR3
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**Front panel**

**Mounting bracket**

**Wire bag, containing the following 9 wires:**

3ea RG-174 coax, 4 ½ inches  
1ea RG-174 coax, 7 inches  
5ea 2-wire set, 22ga, 6.5 inches (white/orange)  
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)

6ea small tie-wraps

**Organic Solder**

**No-clean Solder**

**PC Board, MOTM-320**

## GENERAL INFORMATION

Thank you for purchasing the MOTM-320 Voltage-Controlled LFO (Low-Frequency Oscillator). If you have any issues concerning the building or use of the kit, please contact us by email: [syntht@yahoo.com](mailto:syntht@yahoo.com)

This kit should take the average builder between 4 and 5 hours. The LFO 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-320:

- 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
- Small amount of silicone heat-sink compound

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

## 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.

If you have Internet access, there are more pictures and hints on our website at:

[www.synthtech.com/motm](http://www.synthtech.com/motm)

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, and there is a boatload!

- Find the **RESISTOR** bag. Set aside the large black 1K Tempco resistor. **DON'T LOSE IT!** It is soldered at the end of construction.
- Find the MOTM-320 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 (11) and solder into R1 (above VR2), R13 (top & center of board), R17 (above C6), R19 (right of U2), R21 (above R19), R30 (beside U3), R38 (beside L2), R46 (beside C3), R47 (right above), R58 and R59 (both above J8).
- Locate the 1K resistors (8) and solder into R44 (above J5), R52 and R53 (both above Q10), R64 (above J7), R66 (besides R8), R73 (above LED SELECT), R74 (below JP2), and R75 (above J6).
- Locate the 220K resistors (6) and solder into R23 and R24 (either side of C5), R32 (beside U4), R43 (above J4), R78 (above VR3) and R79 (beside Q12).
- Locate the 51K resistors (5) and solder into R27 (below Q6), R56 (beside U6), R68 and R69 (above R63) and R77 (beside Q12).
- Locate the 20K resistors (5) and solder into R16 (beside VR1), R33 (above Q7), R37 (beside L2), R60 and R61 (below VR3).
- Locate the 4K7 resistors (4) and solder into R12 (beside Q5), R31 (below C8), R45 (beside Q13) and R51 (above R45).
- Locate the 1M 5% resistors (3) and solder into R22 (beside U2), R42 (above J3) and R67 (beside R8).
- Locate the 33K resistors (3) and solder into R35 (above C8), R39 (below Q6) and R63 (above C10).
- Locate the 100K 5% resistors (3) and solder into R20 (below J1), R41 (above J4) and R57 (below VR2).

## **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 stuffing resistors.

### **PART #3: RESISTOR STUFFING #2**

- Locate the 62K resistors (2) and solder into R36 (beside L2) and R62 (beside U5).
- Locate the 47 ohm resistors (2) and solder into R48 and R49 (below Q11).
- Locate the 2K resistors (2) and solder into R50 (beside Q13) and R55 (beside Q12).
- Locate the 13K resistors (2) and solder into R54 (below L1) and R76 (beside C12).
- Locate the 1K3 resistors (2) and solder into R70 (above J8) and R72 (below JP2).
- Locate the 7K5 resistor and solder into R11 (above Q9).
- Locate the 27K resistor and solder into R14 (beside Q4).
- Locate the 6K8 resistor and solder into R15 (beside VR1).
- Locate the 150K resistor and solder into R18 (beside D4).
- Locate the 5K1 resistor and solder into R25 (above J6).
- Locate the 510K resistor and solder into R26 (beside U2).
- Locate the 3K6 resistor and solder into R28 (left of U7).
- Locate the 1K8 resistor and solder into R29 (above R28!).

### **PART #4: BOARD WASH #2**

- 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.
- Take a little break! You are about 3/4ths of the way finished stuffing resistors.

### **PART #5: RESISTOR STUFFING #3**

- Locate the 39K resistor and solder into R34 (above Q7).
- Locate the 300K resistor and solder into R40 (left of U1).
- Locate the 2K7 resistor and solder into R71 (above J8).
- Locate the 100K, 1% resistors (5) and solder into R2 and R3 (above VR2), R4, R7 and R80 (left of U1).
- Locate the 243K 1% resistors (2) and solder into R5 and R6 (left of U1).
- Locate the 54K9 1% resistor and solder into R9 (below J4).
- Locate the 1M 1% resistor and solder into R10 (below J4).
- Locate the 412K 1% resistor and solder into R65 (below VR2).

### **PART #6: CAPACITORS & board wash.**

- Locate the **CAPACITOR** bag.
- Locate the 0.01mfd PPS film cap and solder into C8.
- Locate the 1000pf (1nf) yellow box caps (2) and solder into C5 and C10.
- Locate the 0.1mfd axial caps and solder into C3, C4, C6, C7, C9, C11 and C12.
- 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 C1 and C2 with the stripe ***away*** from the + pad on the board.
- Wash the board again, gently scrubbing both sides. Use **ONLY** warm water!

## PART #7: 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 1N4148 diodes (4). Note one end has a black band around it. This is the cathode end. Look at the pc board: the 4 diode locations (D1-D4) show this banded end. Insert the 4 diodes in the board, with the cathode end over the band on the silkscreen. Note that all 4 diodes point in the same direction.
- Locate the TL074 op amp. Solder into U1. 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 LM393 comparator. Solder into U2.
- Locate the NE5517 OTA. Solder into U4.
- Locate the TL072s (3). Solder into U3, U6 and U7.
- Locate the CA3080AE and solder into U8.
- Locate the OP275. It solders into U5. Note: Revision A pc boards show this part on the silkscreen as a ‘4556’. *This is a typo: the OP275 is the correct part!!*
- Locate the BC550C transistors (7). Remove transistors from the tape carrier, and any residue from the holding tape. 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, Q4, Q5, Q10, Q11, Q12 and Q13.
- Locate the BC560C transistors (5). Solder into Q2, Q3, Q7, Q8 and Q14.
- Locate the BF245A JFETS (2) and solder into Q6 and Q9.
- 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.

- In the JP2 position, solder an orange/white wire. Now, the silkscreen will say RED and BLACK, this was from the original LED that is no longer available. Solder the WHITE into RED and the ORANGE into BLACK. The holes are also a bit large, be sure to fill them with solder.
- 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 #8: 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 #9: 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 (3). These solder into VR1, VR2 and VR3. It is important that the pots side absolutely flat on the pc board, with the shafts sticking straight out over the edge of the board.
- Locate the 4 pieces of RG-174 black coax cable. Note that one end has longer wires stripped than the other. The short ends will go in the pc board in locations J5, J6, J7 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 J5.** The 3 SHORT coax cables go into J6, J7 and J8. 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 4 orange/white twisted wires. These go into locations J1, J2, J3 and J4. In all cases, the **WHITE** wire goes into the '1' hole and the **ORANGE** wire goes in the '2' hole. Note carefully, the wire is stripped with one long end and one short end. Be sure the short end goes into the pc board.
- Solder the 2x4 header strip into the LED SELECT location. The short ends go into the pc board. Don't lose the blue jumper!
- Find the 1K Tempco resistor. This solders into R8, and **must also be so that it touches both Q1 and Q2**. Bend the leads and put the resistor in but about 1 inch off the board. Now apply a **tiny** bit of heat-sink compound to the flat sides of Q1 and Q2. Then, gently press the Tempco flat on the pc board, with the 2 transistors contacting the body of R8. You may need to slightly bend the transistors forward to touch R8. Solder R8 in position, **all the way flat on the pc board surface**.

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 1/2 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 3 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 3 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 3 pot nuts are all pressing against the panel. By hand, put hex nuts on the outside threads of VR1 and VR3 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 & VR3. 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.

- 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 is inserted. In all cases, this lug is left **unconnected**. IN ALL CASES the coax braid goes to the beveled lug and the inner wire to the right lug.
- Solder the coax in J8 to the PULSE jack. Route the coax in-between the SHAPE and PULSE jacks. Solder the braid to the BEVELED lug and the inner wire to the LEFT lug.
- Solder the wire in J4 to the SHAPE jack. Orange wire to BEVELED, white wire to LEFT. This connection is the same for J1 – J4.
- Solder the coax in J7 to SAW jack.
- Solder the wire in J3 to the FM jack.
- Solder the coax in J6 to the TRI jack.
- Solder the wire in J2 to the 1V/OCT jack.
- Solder the coax in J5 to the SINE jack.
- Solder the wire in J1 to the SYNC IN jack.
- Insert the panel LED wires through the panel hole from the front. The LED has 1 lead longer than the other. Solder this to the WHITE wire in J2 and the shorter lead to the ORANGE wire in J2. Be sure the leads do not touch each other.
- Attach the 1 ty-wrap around the coax wires, and another around the orange/white and LED wires. Trim off the excess.
- Decide on the jumper setting for the LED. You can always change it later. The TRI setting will not show effects of the SHAPE setting, because the TRI output is a constant 50% duty cycle. The other 3 settings will show, in different patterns on the LED, the output waveform as it goes from positive to negative.
- 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-320!**

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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-320 uses a “discrete” approach to a LFO design. Instead of the cheesy and simple Tri/Square LFOs found on most synths, the MOTM-320 has full waveshaping that is voltage-controlled. Also, very careful design and component selection allows the MOTM-320 to cover a very wide range of frequencies: from 1 cycle in 20 minutes (.0008Hz) to about 1200Hz. That's a span of over 20 octaves!

And to top it off, the MOTM-320 has full temperature compensation, the first in **any** dedicated LFO.

### **LFO CORE : Page 1 of the Schematic**

The “heart” of the LFO is a triangle VCO built by charging/discharging capacitor C8. Since we are concerned with running at low frequencies, the physical properties of C8 are critical to LFO operation. It may not look special on the outside, but inside the cap is wound with a film material called PPS (polyphenylene sulfide). PPS film is used for 2 reasons in this application:

- a) extremely temperature stable from -40 to +180F (not that we even see that range!)
- b) very low leakage currents, for operating at very low frequencies

The “bad” new is that PPS is not so great at higher frequencies (say 5Khz and above), but this is a LFO, not a musical VCO (although certain users will attempt to use it as such).

The cap is controlled by an OTA U4B, and is buffered by FET Q9. The FET is again for operating at very low frequency, as it keeps current from leaking back into the buffer stage (pin 10) of U4B.

The frequency of the LFO is controlled by the current flowing into pin 16 (labeled ICNTRL), set by exponential converter Q1/Q2. This configuration is ‘different’ from others in that it uses a NPN/PNP pair. These are discrete TO-92 transistors, which are in physical contact with Tempco (temperature-compensating) resistor R8. The reference current (the current applied to the OTA with control voltage set to zero) is set by 1M resistor R10. Scaling to nearly 1V/Oct is by the divider ratio R9/R8.

The input summing network is straightforward: U1A/B form a “reversing attenuator” for the FM IN jack. The LFO's initial rate is set by panel pot VR1. U1C sums all the control voltages together.

To get the triangle wave, we switch OTA U4B from source to sink with a discrete Schmitt trigger Q3/Q4/Q5. This is a diff amp with one side set as a latch (Q3). The trip point is the R13/R16 ratio or at +-5V. The output signal (called BUFIN because it is buffered by U4A) is a square wave at the triangle wave's frequency. The square wave does two things: it

reverses the output of the triangle, and it drives the tri-to-saw converter U4A. The saw converter is a crude but effective “slope-changer”: when the triangle reverses slope, the square wave then reverses the slope at the SAW output. This forms a saw from the triangle, but there will be a “glitch” in the middle of the transition due to finite switching speeds of the OTA and current source Q7/Q8. Later on, this sawtooth is “deglitched”.

Op amp U1D is a simple summing amp for the voltage-controlled waveshaper. The initial shape is set by panel pot VR3. Modulating voltages at SHAPE IN jack are added/subtracted from the pot setting.

The MOTM-320 can be sync'd to an external oscillator. The sync waveform at SYNC IN jack is compared to a trigger threshold set by R18/R19 (about 1V). The SYNC waveform can be any zero-crossing waveform greater than 3V pk-pk.

The output of comparator U2A is +-15V “squared” version of the input. This is passed through a pulse-shaping network (C5, R23, and D1) to generate a narrow trigger pulse into U2B. This then shorts FET Q6, which causes C8 to be yanked to the +15V supply.

Generally speaking, the frequency of the wave at SYNC should be **lower** than the LFO frequency. If you try to sync to a higher frequency, the output of the LFO becomes distorted. Some users will find this amusing and to their advantage.

## **WAVESHAPING SECTION : Page 2 of the Schematic**

There are 3 separate waveshapers, all driven in parallel by the LFO core. Each one is discussed in detail below.

The SINE shaper uses the Moog modular “degenerative emitter” circuit. This circuit uses a little known fact that you can bias a differential amplifier to a certain point on the  $I_c/V_{be}$  curve to approximate a sine function. Sweeping the  $V_{be}$  with a triangle generates a “curved triangle” that is close to a ‘true’ sine wave.

The diff amp Q12/Q13 is biased by temperature-compensated constant-current source Q10/Q11. The 2 47 ohm resistors R48 and R49 in the emitter leads cause the operating point of the diff amp to shift into the desired region.

The key to getting the “correct” output is the  $V_{be}$  voltage across R55. Normally, resistor R77 (with R55) sets the  $V_{be}$  range of Q12. But what we do is feed in a DC offset voltage via R79 into the base of Q12. This will “warp” the sine wave to bow more upwards or downwards (see the scope printouts in the USE OF THE MOTM-320 section).

The differential output is fed into diff amp U3B to form the output waveform.

The PULSE output is easily done: op amp U6B is a comparator that is fed the SAW output from the LFO core and ½ of the SHAPE voltage (via divider R68/R69). This generates a variable-width pulse out of U6B. The large swing (about +-13V) is divided by R70/R71 to a +-5V level.

The RAMP output circuitry is the most complicated. Working our way from output to input: the original sawtooth is “deglitched” by the slew limiter U8/C10/U5A. This circuitry is essentially a linear lag circuit that ‘smooths’ the RAMP output and gets rid of the glitch (we want to get rid of it because if you were to feed it into a VCO, the “hiccup” in output frequency of the modulated VCO would be audible).

The circuitry around U6A and Q14 form a DC summer/rectifier. The LFO sawtooth voltage is added to the SHAPE voltage by U6A with a fixed offset set by R56/R65 of 1.85V. The emitter of Q14 is at +7.5V. Based on the total output voltage of U6A, Q14 turns off and on. This generates the RAMP waveform as shown in the scope shots.

The panel LED is driven by op amp U5B, which acts as a switch. The selected waveform, via jumper block LED SELECT, is fed into U5B which at first looks like a buffer. What happens is that for positive waveform cycles, current flows through 1 LED and then is steered to ground by D4. R73 sets the brightness level. For negative cycles, D4 is reversed-biased (off) and current flow out of the op amp, through the panel LED, and then through R72 (which of course sets the LED brightness).

The LED SELECT allows different visual indications of the waveforms. Note that jumpering TRI will not show any SHAPE effects, as *the TRI output is a fixed duty cycle (50%)*.

Note that you can’t make the panel LED really bright due to the available current provided by U5B.

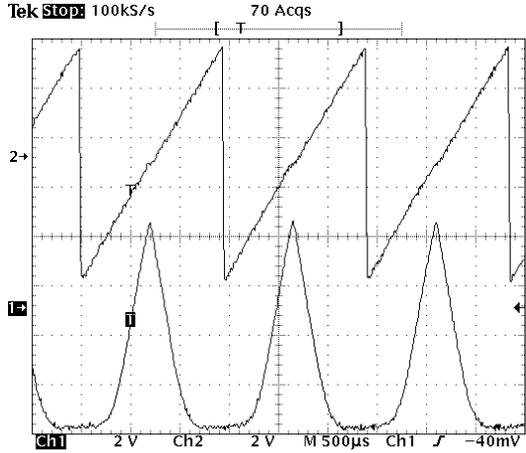
## TROUBLESHOOTING

If your MOTM-320 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.

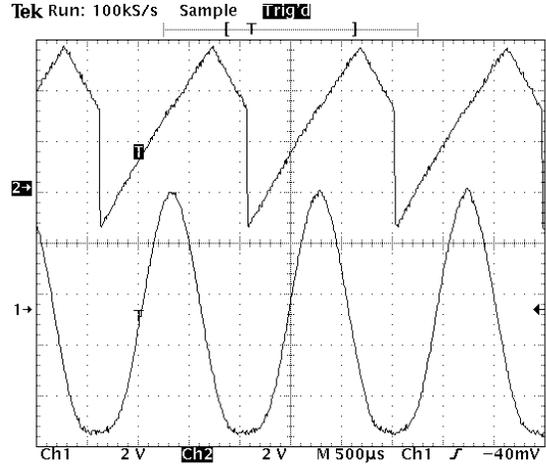
- All of the ICs are pointing the same way and all notches are ‘down’.
- The braided wire on the coax goes to the beveled side of the jacks. All of the orange wires go to ground on the jacks (beveled side). All of the white wires go to the left (signal) lug.
- The parts are in the right places, and all the transistors “face to the right” (flat side facing the front panel). Make sure you didn’t swap the transistors around with each other!
- No solder shorts or missing joints.
- If you have a scope, set the RATE control to 10 and check for a triangle wave at pin 9 of U4, a sawtooth at pin 1 of U3, and a square wave at pin 8 of U4. If these are not present, check the circuitry around U4 for errors in stuffing.

# EFFECTS OF SHAPE VOLTAGE

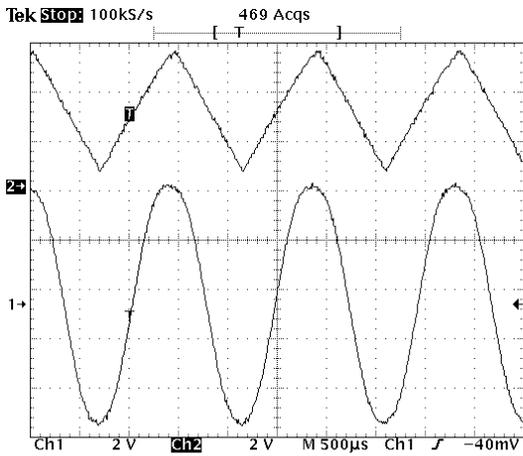
The following scope shots show the SINE and SAW outputs as the SHAPE pot is rotated from 0 to 10. The pictures appear "jaggie" due to the 8-bit sample resolution of the scope.



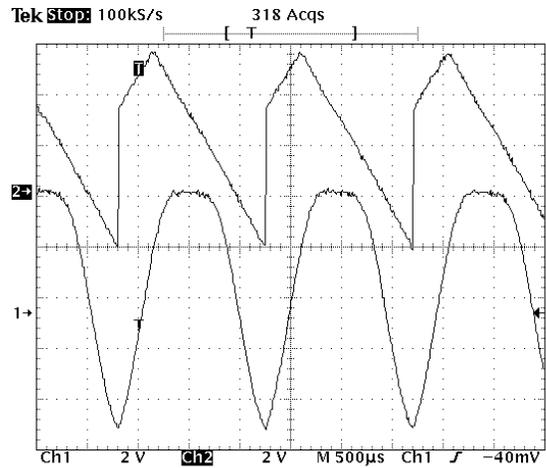
2 Dec 1999  
16:16:58



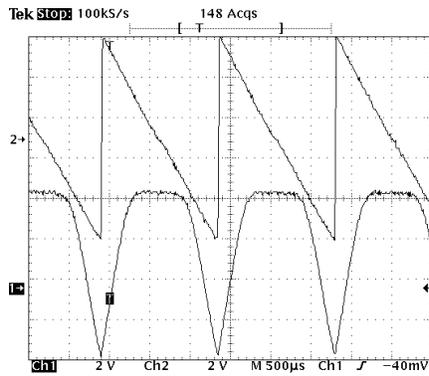
2 Dec 1999  
16:19:27



2 Dec 1999  
16:21:21



2 Dec 1999  
16:23:04



2 Dec 1999  
16:25:00

## USE OF THE MOTM-320 LFO

LFOs are used to modulate VCOs (vibrato), VCAs (tremelo), and filters. In a MOTM system, you can use your MOTM-320 to trigger the MOTM-700 mux, to use as one input of a MOTM-110 Ring Mod, or a host of other uses.

The unique SHAPE feature can add another dimension to your audio palette. The following scope screens show the effect of the SHAPE control as it is rotated throughout it's range.

Remember, the SHAPE pot is like the “initial shape”, as any external control voltage plugged into the SHAPE jack is treated as an **offset** to the pot. In other words, a negative voltage is like turning the pot *lower*, and a positive voltage is like turning the pot *higher*. There is no input attenuator, so any applied SHAPE voltage is “full strength” into the summer circuit.

Also, note that the SHAPE modifies *all 4 outputs simultaneously*. And, it is possible to cause the PULSE output to go to the extremes (0% and 100% duty cycle) which is a constant DC voltage.

To sync the LFO, apply a minimum 3V pk-pk, zero-crossing signal into the sync jack. Any pulses applied must be at least 5ms in duration. It is possible to sync the LFO to pulses that are 0 to +5V, such as outputs of 74HC logic devices.

Since the sync is a “hard reset” of the triangle integrator, applying sync pulses at a faster rate than the triangle oscillator is running will cause severe distortion of the output waveform.

## 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](http://www.mouser.com)) and Digikey ([www.digikey.com](http://www.digikey.com))

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

A – Change capacitor C8. A larger value (say 0.022mfd) will make the total overall range scale accordingly. A smaller cap (say. 0.0047mfd) will speed up the overall rate. Note that too large of a cap may cause erratic performance at the lowest RATE settings. The suggested cap is a PPS film from Digikey: the Panasonic ECHS series. A polystyrene cap can be used, but they tend to be larger in physical size.

Q2) How do I increase the LED brightness?

A – Not much you can do. The LED is on the “dim” side because of the current limit set by the op amp. Also, excessive LED brightness can easily double current consumption of the module. You can lower R72 and R73 slightly.

# SPECIFICATIONS

## MOTM-320 Voltage-Controlled LFO

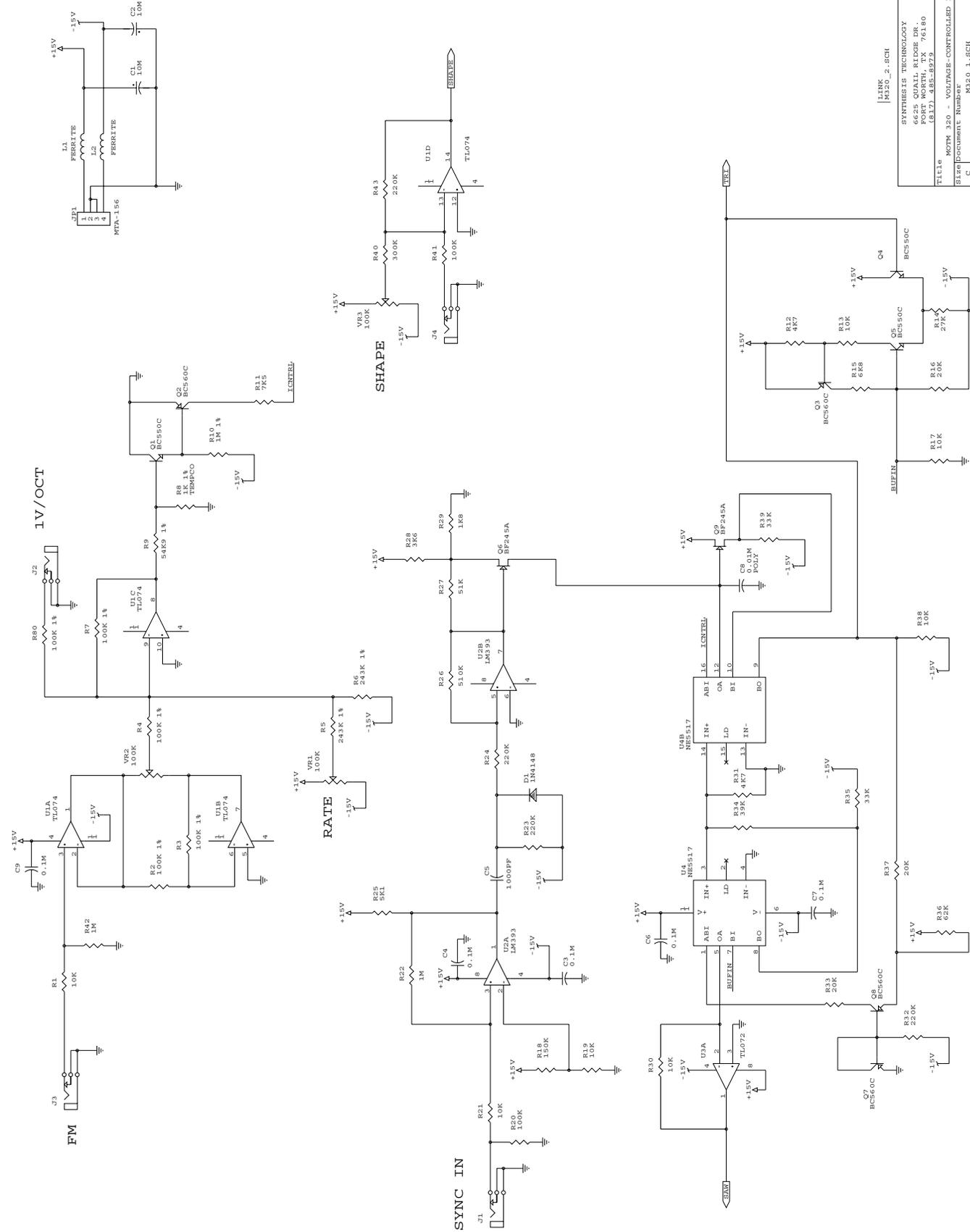
Control Voltage input levels	-7V to +7V
Frequency range	0.002Hz to 1400Hz (typical)
Output impedance	1000 ohms, nom.
Output amplitude	-5V to +5V, +-5%
SYNC input level	+2.8V, min.

### CONTROLS

RATE	sets LFO initial frequency
FM	reversing attenuator from -1 to +1 gain range
SHAPE	sets the initial duty cycle of all the outputs

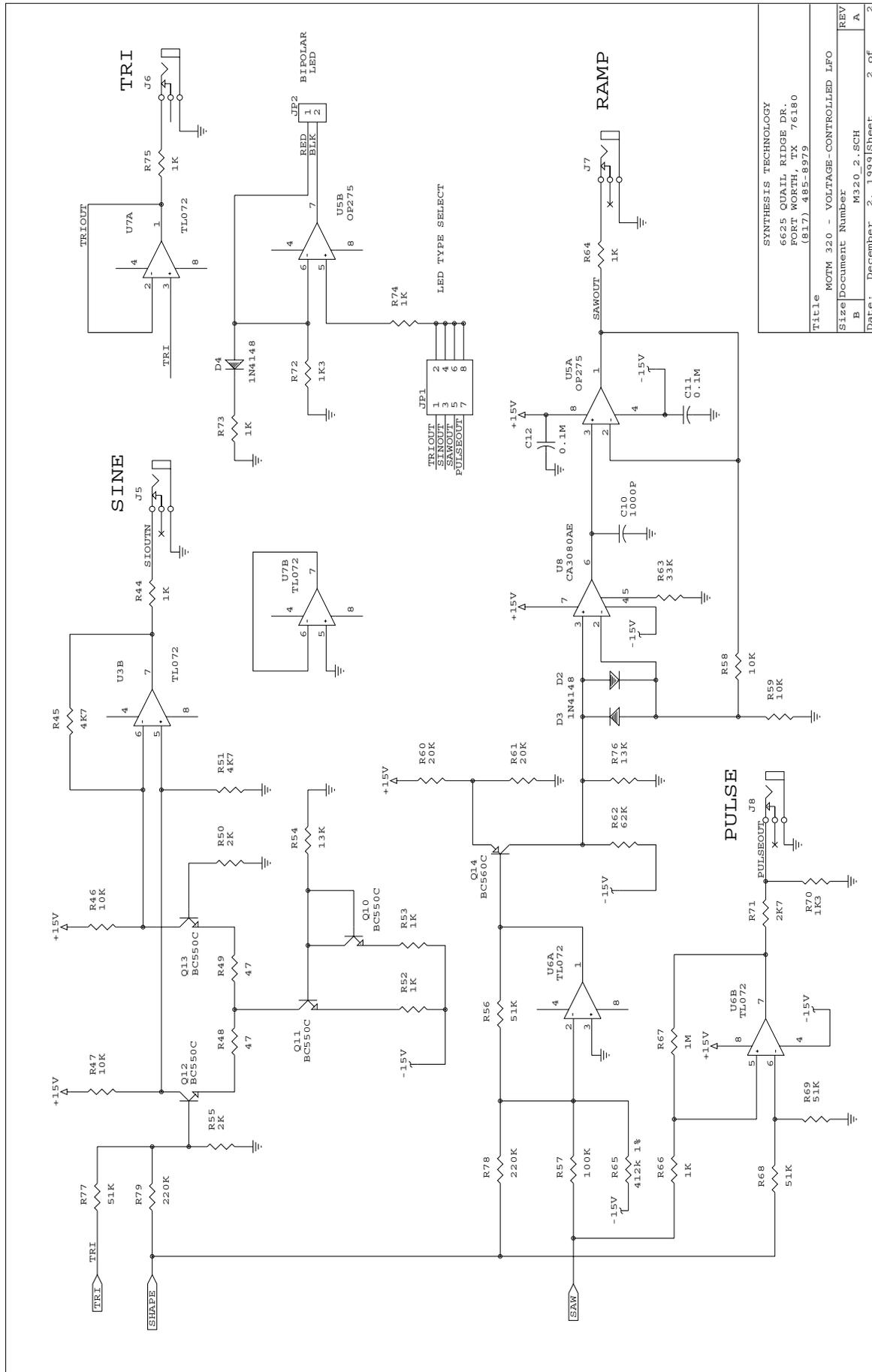
### GENERAL

Power Supply	-15VDC @ 43 ma nominal +15VDC @ 44 ma nominal
Size	2U x 5U 3.47" x 8.72" 88.1mm x 221.5mm
Depth behind panel	4.375 inches (111mm)



SYNTHESIS TECHNOLOGY  
 4000 WOODBINE ROAD  
 PORT NORTON, VIC 3208  
 (817) 485-8973

Title: M320 - VOICED-CONTROLLED JFO  
 C  
 Date: December 2, 1997 Sheet 1 of 3



SYNTHESIS TECHNOLOGY  
 6625 QUAIL RIDGE DR.  
 FORT WORTH, TX 76180  
 (817) 485-8979

Title MOTM 320 - VOLTAGE-CONTROLLED LFO  
 Size Document Number M320\_2.SCH  
 B REV A  
 Date: December 2, 1999 Sheet 2 of 2

SYNTHESIS TECHNOLOGY  
MOTM-320 VC LFO  
SEPT. 1999 REV A

