



MOTM-485 GX-1 Diode VCF Assembly Instructions & Owner's Manual

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MOTM-485 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:

3ea 10 μ fd, 50V Electrolytic	C1, C2, C3
2ea 22N reddish-brown film cap (marked 223)	C10, C11
1ea 47N reddish-brown film cap (marked 473)	C12
1ea 3M3 50V non-polar electrolytic	C9
1ea 33 μ fd 16V non-polar electrolytic	C6
2ea 10 μ fd, 50V non-polar electrolytic	C7, C8
2ea 0.1 μ fd, axial ceramic cap (marked 104)	C4, C5

Resistor bag, containing the following 50 parts:

9ea 100K 1% (brown, black, black, red)	R1-R6, R14, R28, R35
5ea 4K7 (yellow, violet, red)	R33, R41, R42, R43, R46
4ea 22K1 1% (red, red, brown, red)	R19, R20, R24, R50
4ea 10K (brown, black, orange)	R25, R45, R47, R49
3ea 2K2 (red, red, red)	R18, R21, R22
3ea 18K (brown, gray, orange)	R17, R27, R29
2ea 120K (brown, red, yellow)	R9, R13
2ea 51K1 1% (green, brown, brown, red)	R7, R8
2ea 47K (yellow, violet, orange)	R15, R32
2ea 6K8 (blue, gray, red)	R26, R30
2ea 1K 5% (brown, black, red)	R34, R37
2ea 3K3 (orange, orange, red)	R38, R44
2ea 150K (brown, green, yellow)	R39, R40
1ea 200K (red, black, yellow)	R10
1ea 470K (yellow, violet, yellow)	R12
1ea 54K9 1% (green, yellow, white, red)	R16
1ea 1K2 (brown, red, red)	R23
1ea 470 ohms (yellow, violet, brown)	R31
1ea 15K (brown, green, orange)	R36
1ea 47 ohms (yellow, violet, black)	R48
1ea 1K 1% 3300ppm Tempco resistor (black)	R11 (mounts on Q1, see text)

IC bag, containing the following 11 parts:

3ea BC550C NPN transistor	Q3, Q4, Q9
2ea BC560C PNP transistor	Q2, Q6
2ea CA3086 transistor array IC	Q7, Q10
1ea BF245 FET transistor	Q8
1ea LT1013 op amp	U1
1ea THAT 340P transistor array	Q1
1ea SSM2220P PNP array	Q5

- Misc #1 bag, containing the following 7 parts:**

2ea Axial ferrite beads (plain, gray things)	L1, L2
1ea MTA-156 power connector	JP1
1ea SPDT toggle switch	SW1
1ea DPDT toggle switch	SW2
1ea 2K Bourns 3386P-202 trim pot	TP1
1ea 20K Bourns 3386P-203 trim pot	TP2

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

- Jacks, 6ea Switchcraft 112A**

- Pots, 3ea containing the following (either part will work):**

3ea 100K lin Spectrol 149-71104/148-71104	VR1-3
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- Front panel**

- Printed Circuit Board**

- Mounting bracket**

- Wire bag, containing the following 10 wires:**

1ea long RG-174 coax	J4
2ea short RG-174 coax	J5, J6
1ea 2-wire set 22ga. (white/black) long	J3
1ea 2-wire set 22ga. (orange/white) long	J1
3ea 3-wire set 22ga. (orange/white/gray) short	SW1, SW2
1ea 2-wire set, 22ga. 3½" (red/black)	J2
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" aluminum spacers
 - 4ea #6 KEPS nuts (for pc board)
 - 5ea small tie-wraps

- Organic Solder AND No-Clean solder (1 bag each type)**

GENERAL INFORMATION

Thank you for purchasing the MOTM-485 VCF. If you have any issues concerning the building or use of the kit, please contact us at (817) 498-3782 or by email: synth1@airmail.net.

This kit should take the average builder between 2 to 3 hours. 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-485:

- Soldering iron, 50W max power. Use 700°F tip/temperature setting
- Small amount of heatsink compound (not supplied)
- Needle-nose or chain-nose pliers
- Mouser lead-bending jig for the resistors
- Diagonal cutters
- Allen key set for securing the knobs ($1/16$ " or 1.58mm)
- Magnifying glass to read the markings and to inspect solder joints
- DVM (Digital Volt Meter) to verify resistor values
- #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>.

The 2 trimmers on the board are set "by ear", no special test equipment needed. An oscilloscope is handy (and fun) to look at the output waveform, seeing the effects the VCF has using various settings.

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.

Note that this kit uses 5 different decades of 47-ohm resistors, be careful and don't get them swapped! Also, don't swap the 2 trim pots (they are clearly stamped on the sides in black ink). The 1% resistor color bands can be confusing, so always measure them with the DVM before soldering.

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

- Find the MOTM-485 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).
- We will stuff the resistors by value to make things easier. The resistors are inserted on a 0.4-inch spacing (this is where the Mouser jig makes things nice and fast). 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 100K 1% resistors (9) and solder into R1 to R6 (all near U1), R14 (by J3), R28 (by Q7) and R35 (by VR3).

- Locate the 4K7 resistors (5) and solder into R33 (by C6), R41-43 (by TP2) and R46 (by SW2A).

- Locate the 22K1 1% resistors (4) and solder into R19 (by Q5), R20 (by L2), R24 (next to Q5) and R50 (by C11).
- Locate the 10K resistors (4) and solder into R25 (by Q7), R45 (by Q2/Q3), R47 (by Q8) and R49 (by Q10).
- Locate the 18K resistors (3) and solder into R17 (next to R49 that you just did), R27 (by J1) and R29 (2 over from R27).
- Locate the 2K2 resistors (3) and solder into R21 and R22 (by C3) and R18 (by Q9).
- Locate the 120K resistors (2) and solder into R9 (by TP2) and R13 (by Q8).
- Locate the 51K1 1% resistors (2) and solder into R7 and R8 (by U1).
- Locate the 6K8 resistors (2) and solder into R26 (by Q1) and R30 (close to SW1).
- Locate the 1K 5% resistors (2) and solder into R34 and R37 (by C7/C6).
- Locate the 47K resistor (2) and solder into R15 (by SW2B) and R32 (behind VR2).
- Locate the 3K3 resistors (2) and solder into R38 (by Q9) and R44 (by C11/C12).
- Locate the 150K resistors (2) and solder into R39 and R40 (by C10).
- Locate the 200K resistor and solder into R10 (by TP2).
- Locate the 1K2 resistor and solder into R23 (by J4).
- Locate the 470K resistor and solder into R12 (by C12).
- Locate the 54K9 1% resistor and solder into R16 (by Q1).
- Locate the 470-ohm resistor (look closely!!) and solder into R31 (by VR2).
- Locate the 15K resistor and solder into R36 (by SW1).
- Locate the 47-ohm and solder into R48 (by Q8). **Leave the Tempco resistor for a later step.**

After soldering all the resistors wash and dry the pc board.

PART #2: Soldering the ICs & Misc parts

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.
- 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 LT1013 IC. Solder into U1, with the “dimple” on the top of the package on Pin 1. Pin 1 has a **square** pad (all the others are round),
- Locate the THAT 340P transistor array and solder in Q1. There is a “dimple” by Pin 1.
- Locate the SSM2220P and solder into Q5. The “notch” depression on the top of the package matches the “notch” on the white silkscreen symbol.
- Locate the CA3086s (2) and solder into Q7 and Q10 (match the “notches”).
- Locate the BC550C transistors (3) and solder into Q3, Q4 and Q9. The flat side of the transistor matches the flat side of the white silkscreen symbol.
- Locate the BF245 FET transistor and solder into Q8. Note the center lead is angled backwards slightly.
- Locate the BC560C transistors (2) and solder into Q2 and Q6.
- Apply a small bit of solder to the via holes. These are the small pads (no components go in them) that allow traces to “change sides” of the pc board. **DO NOT SOLDER PADS FOR THE REMAINING COMPONENTS!!** The via holes need a **VERY SMALL AMOUNT** of solder. For example, there is a via hole on the top-side trace that is above TP2, running along the edge of the board (by the “R9” white silkscreen).

PART #3: BOARD WASH #2

- Wash the board in warm water, gently scrubbing *both* sides.
- 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 another break or set the kit aside for later. You are about 75% finished at this point: this is a good stopping-point.

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 #4: CAPACITORS/TEMPCO RESISTOR

Locate the **CAPACITOR** bag. Locate the 1K Tempco resistor, and your heat-sink compound.

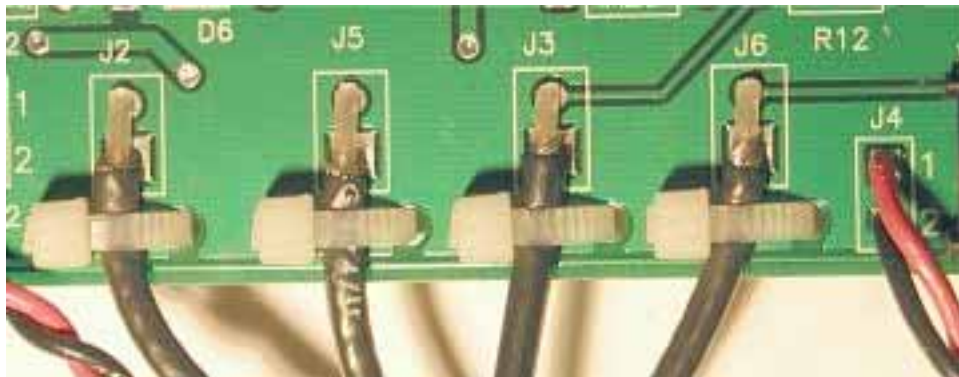
- Locate the 22N caps (2). They will have 223 stamped on the side. They solder into C10 and C11.
- Locate the 47N cap, with 473 stamped on the side. Solder into C12.
- Locate the 0.1 μ f axial ceramic caps. They solder into C4 and C5 (by U1).
- Locate the 3M3 non-polar cap, and solder into C9 (by J2).
- Locate the 33 μ f non-polar cap. Solder into C6.
- Locate the 10 μ f non-polar caps (2). Solder into C7 and C8.
- Locate the 10 μ fd electrolytics (3). 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, C2 and C3 with the stripe **away** from the + pad on the board.
- Locate the black Tempco resistor. This will solder on top of Q1. A small amount of heatsink compound is first applied to the top of Q1 and the Tempco is placed so that the DIP package is in contact with the bottom of the Tempco. Be sure the Tempco is level and flat before soldering.



PART #5: FINISHING THE PCB (Trimmers, pots and wire)

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 2K blue trim pot. It will have “P 202” marked on one side. Solder into TP1 (labeled Q TRIM).
- Locate the 20K trim pot. It will have “P 203” marked on one side. Solder into TP2 (labeled CV OFFSET).
- Locate the Spectrol pots (3). **IMPORTANT:** in order for the pc board to properly align with the front panel, each pot must be **absolutely flat** on the pc board, with the shafts pointing away from the pc board. These are marked on the top side as 71104. Solder these pots into VR1, VR2 and VR3. Remove the outer pot nut and the flat washer. The rear pot nut should be tightened all the way back, then rotated $\frac{1}{4}$ turn **looser**. This allows the stress of mounting to be on the threads of the bushing, not pressing against the pot body itself.
- Locate the **WIRE** bag. The MOTM-485 has lots of wires: be very careful when soldering to the pc board in order that the wire colors are correctly into the proper holes.
- The long coax wire solders into J4. A tie-wrap is used on each wire to secure the coax flat onto the pc board. Note that the coax wires have one end stripped back shorter than the other: the short end solders to the pc board. See the photo below for details (**this is a generic photo!**)



- Solder the 2 short coax cables into locations J5 and J6. Secure with tie-wrap.
- Solder the long white/black twisted wire into J3. White into 1, Black into 2.
- Solder the orange/white twisted wire into J1. White into 1 and Orange into 2.

- Solder the 3 white/gray/orange wires into SW1 and SW2A/SW2B. In all cases, the White goes to 1, the Gray into 2 and the Orange into 3.
- Solder the red/black twisted wires into J2. The Red is in 1 and the Black solders into 2.

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

PART #6: 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 6 Switchcraft jacks. Notice that from the rear, there is a beveled corner. This corner is **ALWAYS CONNECTED TO GROUND**. 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 6 jacks/lockwashers, with the beveled corner in the **upper-right** corner, into the 6 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 #7: ATTACH PC BOARD TO BRACKET/PANEL

- In the **HARDWARE** bag, locate 4 #6-32 x ½" screws, 4 #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 nuts attach on the bottom of the bracket. Note the bracket has 2 notches; these are for the 2 switches to mount in-between the pots.

Attach the pc board to the bracket using the 4 screws, spacers and nuts (the nuts go on the bottom of the pc bracket). Do **not** tighten the nuts all the way, so the pcb can "slide" in the bracket. Next, place the 3 pot bushings/shafts through the 3 holes in the panel. With the 4 pcb nuts still partially tightened, put the 3 flat washers and 3 nuts on VR1-V3 (on the front of the panel) and tighten. This will "pull" the pcb up against the panel, resting on the 3 rear pot nuts. **NOW** you tighten the 4 nuts on the bottom of the pcb bracket.

PART #8: 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. You may find, in some cases, it is easier to first remove a jack from the panel and solder the wires, then reattach it to the panel.

- Mount the 2 switches in the panel. The larger DPDT switch goes in the top hole (marked HP/LP) and the SPDT switch (3 lugs) goes in the lower hole (marked F/H). In both cases, the rear nut needs to be tightened all the way, then “backed out” $\frac{1}{4}$ turn. Put on the toothed lockwasher, insert the switch so the handle toggles up/down in a straight line, then place a nut on the front and tighten. The lockwasher always goes on the **back side** of the panel. There is no top/bottom orientation for the switches, just be sure they are straight.
- Solder the white/gray/orange wire SW1 to the SPDT switch. The Orange wire goes on the Top lug, the Gray wire to the middle lug and the White wire to the bottom lug (hopefully the same order they are in the 3 holes on the pcb!)
- Solder the white/gray/orange wire in SW2B to the lower set of 3 lugs of the DPDT switch (the set nearest the pcb). Orange on the top, Gray on the center and White on the bottom lug. Now repeat with the 3 wires in SW2A, soldering to the upper set of 3 lugs. Use a tie-wrap to bundle the 6 wires together in the middle of the wires.
- Solder the short coax in J5 to the IN 1 jack. The braid goes to the beveled (ground) lug and the inner conductor goes to the right lug (the top lug is not connected). Use just enough solder so that the hole in the lug is filled with solder. All 3 coax wires attach in this manner.
- Solder the short coax in J6 to the IN 2 jack.
- Solder the red/black wire in J2 to the FM IN jack. The black wire goes to the beveled lug, the red wire to the left lug.
- Solder the orange/white wire in J1 to the 1V/OCT jack. The orange wire goes to the beveled lug, and the white wire goes to the left lug.
- Solder the white/black wire in J3 to the RES CV jack. The black wire goes to the beveled lug, and the white wire goes to the left jack.
- Solder the long coax in J4 to the OUT jack (braid to beveled, inner wire to left lug).
- Use the remaining tie-wrap to bundle the wires to the jacks.
- 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.

CONGRATULATIONS! YOU HAVE FINISHED BUILDING THE MOTM-485!

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

THEORY OF OPERATION – by Scott Rider, Chief MOTM-485 Designer

The MOTM-485 is a 2nd-order Sallen-Key switchable highpass/lowpass filter that is based on the same circuit configuration as that discovered to be used in the Yamaha “NE” submodule set that Yamaha developed in the early 1970s for their GX-1 stage synthesizer. The filters represented by the MOTM-485 are the NE10400 lowpass and NE10500 highpass filter “potted” submodules; that is, the NE modules were small circuit boards composed of standard parts and placed in shallow plastic “potting” boxes with connection pins facing up, then an epoxy resin/catalyst was poured into the boxes and allowed to harden. This is similar to the way ARP modules for machines like the 2600 and Odyssey was made. The Yamaha NE submodule set was used in their SY-1 and SY-2 preset solo synthesizers and their Electone CSY-1 & CSY-2 organs in addition to the GX-1.

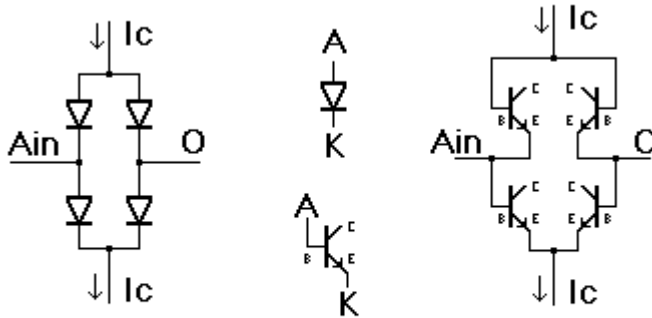
Since the NE10400 and NE10500 are nearly identical circuits, with the use of a DPDT switch it is possible to route the signal path such that both filter modes can be provided in one module. For the purposes of adapting the filter core to patchable modular use, the original circuit has been updated to a MOTM voltage control front end for 1V/Octave frequency as well as reversing FM input. Aside from that and the passive audio mixer circuit to provide three signal inputs, the core filter circuit remains the same as that used in the original submodules.

Diode rings as Voltage-Controlled Elements

Referring to the schematic, note there are two diode rings, or “bridges” that are made from the base-emitter junctions of four transistors of Q7 as well as Q10. In each ring, the transistors (connected as diodes) form an “equivalent impedance” circuit: a control current enters the “top” of the ring (pins 6 and 9 of the Q7 or Q10 array) while the same amount of control current leaves through the “bottom” (pin 3). These control currents are supplied from the CV front end for resonance (Q7) and filter frequency (Q10). As current flows through either “side” of the diode ring, a corresponding forward voltage is developed across each diode. The voltage-current aka “V-I” characteristic of diodes being nonlinear, on paper it typically appears as an exponential curve upward. The math starts to get a little complex here is things head toward AC systems analysis and we discover we’re talking about impedance and not simple resistance, but for simplicity just consider that for each value of control current “I” there is a resultant voltage “V” on the curve. Taking the basic electrical formula $V=I \times R$ (voltage = current times resistance), rewriting it as $V/I=R$ the “apparent”

resistance of the diode ring changes with the control current. Q7 is the resonance amount control element and Q10 is the filter frequency voltage control element.

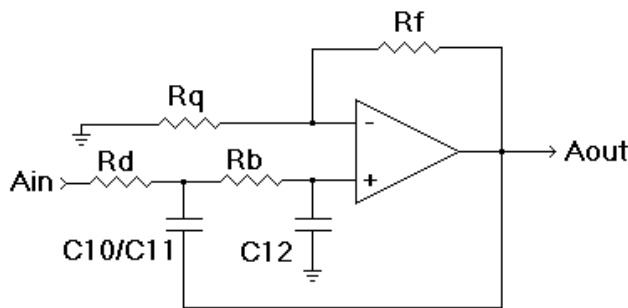
If it is difficult understanding how a transistor can be a diode, look at it the following image:



The canonical diode ring is illustrated on the on the left, where “Ain” is the signal input, “O” is the signal output and “Ic” are the control current source input (top) and output sink (bottom). Since a diode is a P-N junction device, with the P material called an anode and the N material called the cathode for their natures of harboring “positive” (an)ions or “negative” (cat)ions, it should then be apparent that a bipolar transistor, in this case N-P-N junction devices, can act as diodes if one junction is left unused (traditionally the collector). Thus, the “bases” of our NPNs become anodes and the “emitters” become cathodes, and we get the diode ring made from transistors as shown on the right.

The Sallen-Key Filter Model Using Diode Rings

The classic 12dB/octave (or decade) Sallen-Key lowpass model can be drawn as:



For the MOTM-485 circuit, think of Rd as the diode bridge Q10, Rb as R48, Rf as R47 and Rq as the R23+R37+TP1+C9+Q7 chain. Yes, there is a capacitor in there (never mind a transimpedance diode cell made from Q7) but we’re dealing with AC impedance so think of it as a resistor. It is much easier that way. The op-amp? We’ll get to that.

An incoming audio signal applied to inputs J5, J6 is AC-coupled by C8 into the emitter-follower buffer circuit around transistor Q9. The buffer output is well suited to driving signals into variable impedances such as the impedance cell diode ring built from array Q10. In the LP mode, this is precisely what happens. Remembering that the control current flowing top-to-bottom in the ring changes the impedance for the signal flowing across the ring, we effectively have a variable series resistor connected to a tuning capacitor (C12). This "R" C circuit forms the first order of our filter.

As the control current increases, the apparent resistance decreases, and the corner frequency of the filter goes up. Now, the output of this "R" C circuit is buffered by the high-impedance gate of the FET Q8 into the amplifier made from the circuit surrounding Q2 & Q3. This amplifier is the "active element" (op-amp!) of our active filter. (The "R" C circuit alone is a passive filter). The output of this amplifier is emitter-coupled back to the filter input through C10 and C11. Think of C10+C11 as one capacitor, just split up to cover both sides of the diode bridge. The effect of this feedback is the diode bridge now acts as the impedance element for a second order filter, convolving both the original "R" C12 and the feedback "R" (C10+C11). The math sucks, trust me.

If an audio signal enters the filter with a frequency much higher than the cutoff frequency, the filter operates as a second-order lowpass filter. If, however, an audio signal enters which is close to the cutoff frequency, the circuit behaves as an active bandpass filter with emphasis "Q". What is interesting is how the Q of this circuit is manipulated. The filter output is taken from the source-side of the amplifier buffer FET, and a variable impedance diode bridge Q7 in combination with C9, TP1, R23, R37 and R47 form a negative-feedback circuit. Strictly speaking, R47 alone provides negative feedback; it is the rest of the parts that attenuate the signal that R47 couples back into the filter from the source (negative) side. If negative feedback decreases, the emphasis (Q) increases. This Q is voltage-controlled given that there is the variable-impedance element Q7, which is controlled by the simple voltage-to-current circuit made from Q1C and R26 to R30. Resistors R12 to R15 set the range of control seen by Q1C from the panel knob and input jack, which "sweeps" Q7.

The final output of the filter is a buffered/amplified signal taken from the "Q negative feedback attenuator" at the junction of R23 and R37. The signal is tapped here so that, with increasing Q, the overall amplitude decreases to avoid clipping of the resonant peak by the final amplifier made from the gain-of-10 Q4/Q6 circuit. The filter output is then AC-coupled to remove any DC offset imposed by the variable Q and provided on output jack J4.

Voltage-Control Front End

The 1V/OCT and reversing-input FM jacks are MOTM-standards employed here. They are not of course part of an original NE10400 or NE10500. The original filters used discrete transistors instead of the matched array Q1, which is one reason why they potted them (for temperature stability), and no active-summing front end was employed. The operation of the reversing circuit built around U1 has been noted elsewhere, but in short the 1V/OCT input is given a gain of 1 or ½ depending on the setting of the tracking switch. This is a Yamaha thing, used on their highpass filters. Since this is a patchable module, the switch is provided so the half-tracking mode is available but not mandatory. Similarly, the FM input is given a knob-variable gain from -1.33 to +1.33. The sum of the FM and 1V/OCT voltages goes into a traditional exponential V-I converter made from Q1. Note that this is slightly different than the servo-feedback type of expo converter (see the MOTM-300/310) in that 1) it does not use a servo loop and 2) it uses a PNP-NPN configuration as

opposed to dual PNP or Dual NPN). This was done because the converter is really a PNP-NPN-NPN: Q1B and Q1D are both driven off Q1A. Why two exponential current outputs? Well, remember the diode bridge likes to be balanced, specifically, it likes having the same amount of current injected at the top as pulled out of the bottom. So, Q1D provides the current sink at the bottom, whereas Q1B operates a current mirror made from Q5, which provides a current source at the top. These identical source and sink currents are of course the “control current” for the filter frequency. The “left over” transistor Q1C is used for the Q control circuit as described previously.

Highpass Mode

The operation of the filter in highpass mode is essentially the same as for lowpass, save that the input signal is introduced into the now series-capacitor (SW2 switches C12 from being grounded to being used for series input) and the impedance element Q10 has the left side fixed at a DC constant (again by SW2) of half the power supply voltage in order to most efficiently use the bridge as a parallel (to AC ground) resistor. Series R with parallel (to ground) C being the simplest lowpass model, it is reasonable to assume Series C with parallel R is the simple highpass model. And such is the case: the filter now behaves as a second-order highpass filter save for that region where the input signal is close to the cutoff frequency, at which point it assumes a bandpass within the bounds of Q.

PRELIMINARY CHECKOUT & TROUBLESHOOTING

The first thing to remember: this filter *will not self-oscillate* — Blame Yamaha :)

The most common mistakes when building this filter are:

- a) Make sure the 3 film caps are in the correct place. C10 and C11 have caps marked “223” and C12 has one marked “473”.
- b) Verify the 2 trim pots are correct. TP2 must have a mark of “P 203” and TP1 must have the “P 202” mark.
- c) Make sure C9 is the 3M3 non-polar cap

To verify operation of the filter, an oscilloscope is most helpful. But I’ll assume you don’t have one for now (start saving, there are many good ones on eBay for \$100). But you will need a signal source, such as a MOTM VCO (you cannot plug a mic or guitar into the ‘485 directly, you first must amplify the signal).

- a) Set both trim pots to the center positions (use a small flat screwdriver).
- b) Set the top switch to LP, the bottom switch to F, RES to 0 and FREQ to 0.
- c) Apply power, and apply an audio signal to IN 1. A VCO Saw at ~A440 is a good starting place.
- d) Monitor the OUT jack with an audio amp: turn the volume down and do NOT use headphones!
- e) Slowly rotate the FREQ knob towards 10. At first, the volume should be very low because the VCF (if it is working) will be attenuating most of the signal. As you rotate the FREQ knob, more and more of the signal should pass through.

- f) If this is properly operating, switch to HP mode and rotate FREQ back and forth. Now you should hear the “opposite” effect: only the higher harmonics are passing through the filter.
- g) Put the filter back into LP mode and play with both RES and FREQ. You should be able to hear the effects of increasing resonance (the volume will drop some, but the filter will “squeal” more).

Limitations, Hacks and General Weirdness of the MOTM-485

The MOTM-485 is unlike any other MOTM VCF because it uses a pair of diode “rings” to act as the variable element. The diode ring topology has several issues: they have smaller dynamic ranges for the control current (the VCF cannot sweep as broadly), the diodes introduce lots of IM distortion (especially in HP mode) and in this particular implementation, the resonance characteristics are based in part on the harmonic content of the audio output (this will be evident when using narrow pulses in HP mode).

So, why use diodes at all? Because, Yamaha needed to build a very inexpensive filter for the GX-1, which is an organ and so has 1 pair (a HP/LP set) for every note! Of course, the MOTM version uses matched pair transistor arrays and has temperature-compensation for the control voltage. Also, the OTA in chip form was very expensive in the mid-1980s compared to the diode version.

Even though the MOTM-485 is “faithful” to the original Yamaha overall design and topology, the GX-1 was a “controlled” environment. The waveforms were limited; the amplitudes under tight control and many hours were spent in trimming (remember, this thing cost like \$50,000 when it came out, as much as a large house). In updated modular format (as open-ended as it gets), the, how shall we say, “quirks” of the design can be seen. So, what I’m saying is, don’t be surprised if the MOTM-485 “doesn’t sound like my other filters” or “puts out all sorts of strange, distorted sounds” because that’s part of its charm.

Quirk #1: HP mode has all sorts of IM (intermodulation) distortion at high resonance

This is will be based on the input level (see Quirk #2) and the setting of the Q PEAK trimmer. But in general, once the RES pot is past 4 or so in HP mode, all hell can break loose. It’s not broken, OK? It can almost sound like an overdriven ring-mod at times. If you look with a ‘scope, you will think something is terribly wrong with the output (sine wave turns into odd ramps, etc).

Quirk #2: the filter is sensitive to input levels

You will be tempted to jam 2 full-level VCO waveforms into the 2 IN jacks. Prepare for all sorts of messed-up tones. If you want “tamer” outputs, run a mixer before the inputs (like a MOTM-890). Again, HP mode will be more wacky than LP mode with large inputs.

Quirk #3: limited sweep range

The filter cannot sweep 20Hz-24Khz like say a MOTM-440. The MOTM-485 is more on the order of 80Hz to 6Khz. Again, this is a function of the diode control currents.

Quirk #4: setting Q PEAK will alter the tone

There is no “correct” setting for this. It’s like adding Tabasco sauce to your soup. Some people will crank this all the way up, others all the way down. Start in the middle and tweak to taste. Use several waveforms/amplitudes to hear what difference it makes. If you can’t decide, leave it in the middle.

The Full/Half switch is for the 1V/Oct input jack. Full means “Full tracking” or standard 1V/Oct. The Half position is for emulating a GX-1 MOTM-485 *pair* of filters. The GX-1 has 2 filters in series: HP at Half tracking followed by a LP at Full tracking. So, if you really want a GX-1 sound, you need 2 MOTM-485s. The OUT of the first goes to the IN 1 of the second: the first VCF is a HP response with Half-track. The second VCF is LP mode with Full tracking. The keyboard CV feeds both 1V/OCT jacks (via MOTM-910 mult) at once.

The trimmer TP1 CV OFFSET is like the FREQ panel knob in parallel. It allows you to set the “default center frequency” of the module for a given FREQ pot setting. For example, you may prefer bass sounds, so you can set the FREQ pot tick to “5” to be 220Hz by adjusting TP1. Or, set the “5” tick to be as high as 3Khz with the trimmer at the other extreme. If you can’t decide, leave it in the middle and this makes the “5” tick around 800Hz.

The advantage of using 2 MOTM-485s in series is that now you have independent control of resonance and “bandpass frequency” (just like in the MOTM-480 CS-80 VCF).

MOTM-485 Hacks

- R15 sets how far external voltages sweep the resonance. Lower it for a wider range.
- You can adjust R37 and R23 to alter the feedback for resonance.
- You can play with the filter caps. C10 and C11 must be the same, and C12 has to be 2 times C10/C11.

If you still cannot get the module to perform correctly, please contact us by phone at (817) 498-3782 or by email to synth1@airmail.net



SPECIFICATIONS

MOTM-485 GX-1 Diode VCF

Audio Input Range	10V pk-pk nom. combined both inputs
Control Voltage Range	-7V/+7V
Output impedance	1000 ohms, nom.
Frequency Range	80Hz – 6Khz nom.

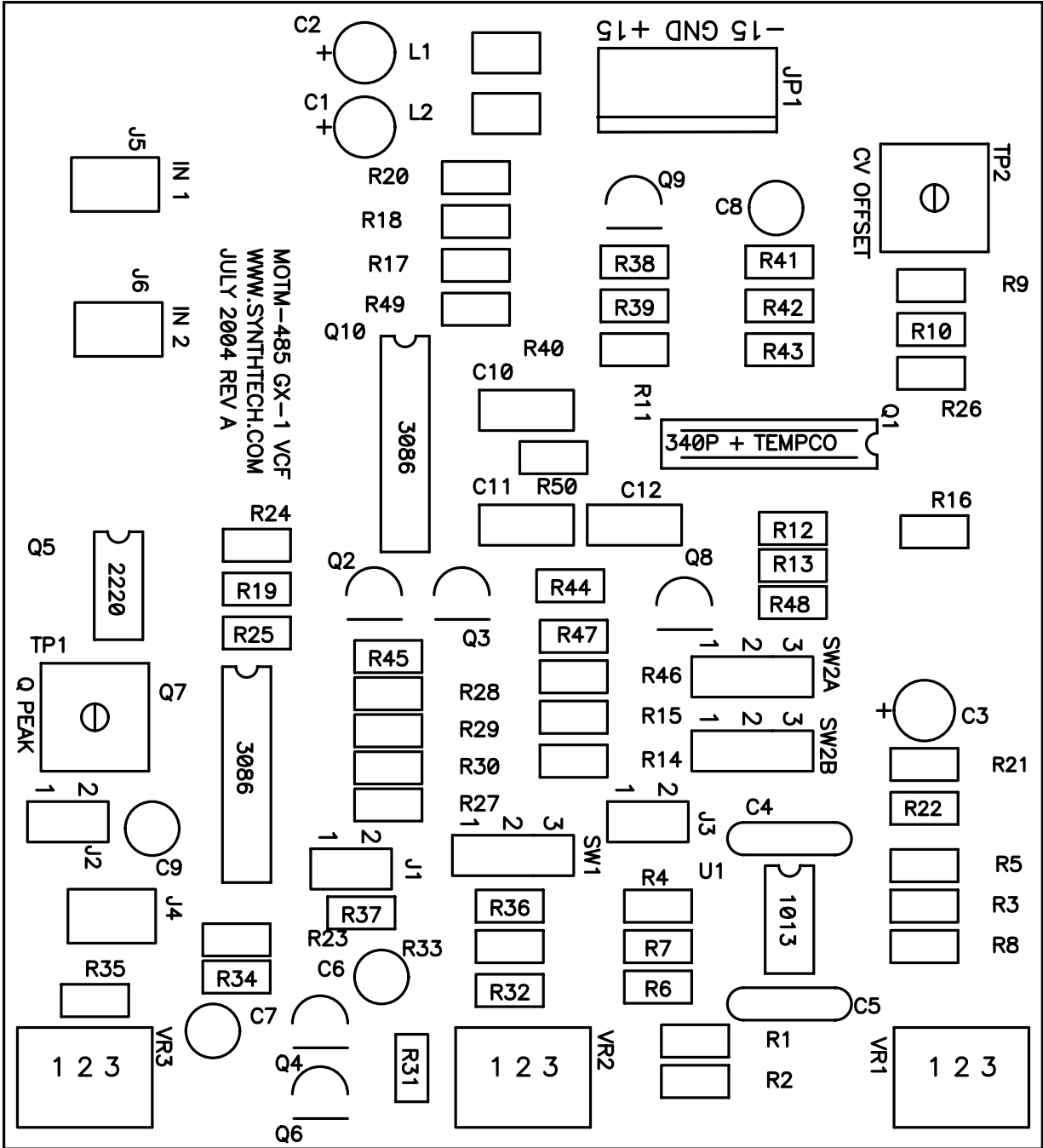
CONTROLS

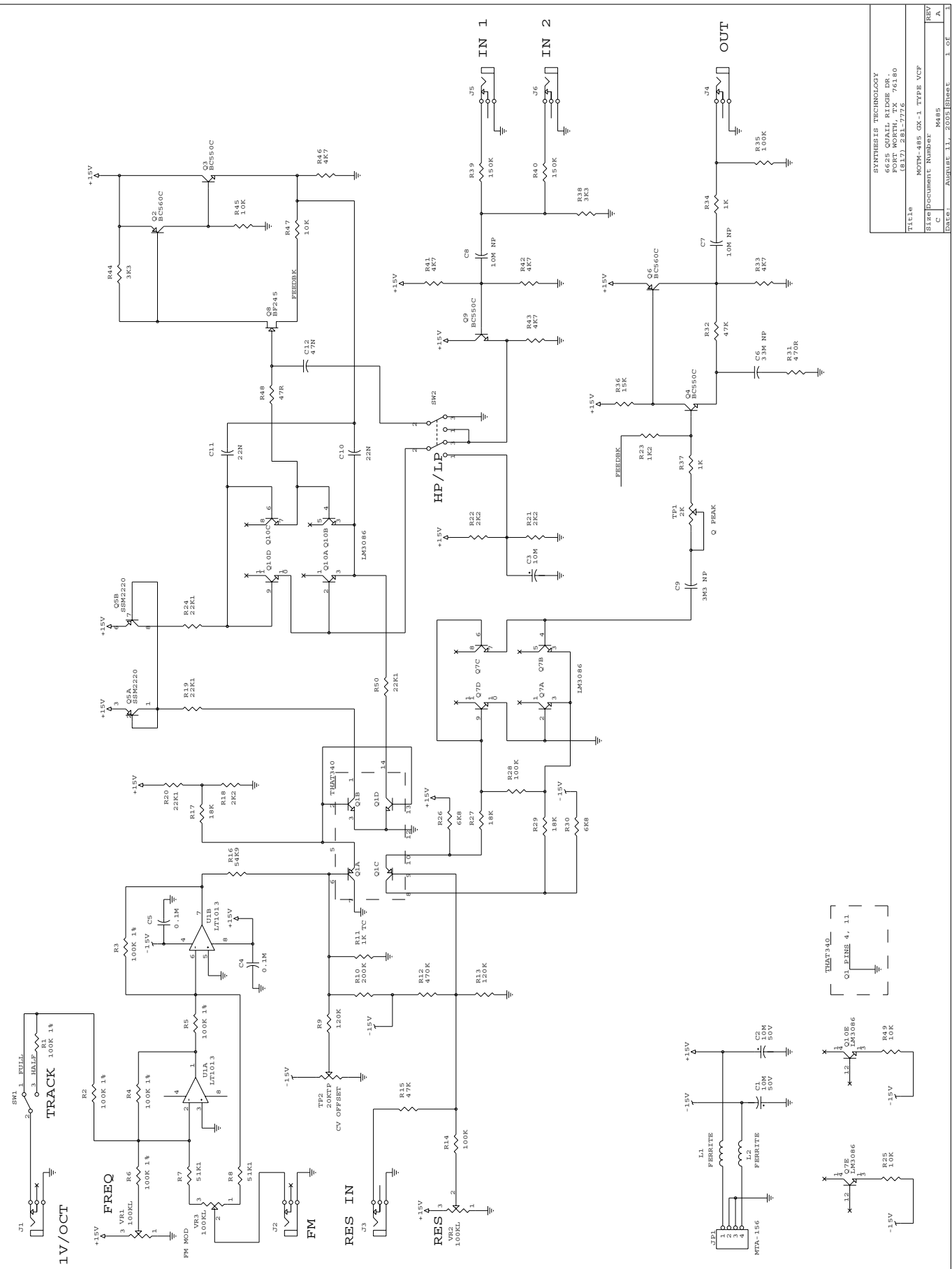
FREQ	sets filter cutoff frequency
RES	sets resonance
CV MOD	reversing attenuator for filter cutoff

GENERAL

Power Supply	-15VDC @ 8ma +15VDC @ 15 ma
Size	1U x 5U 1.72" x 8.72" 44mm x 221.5mm
Depth behind panel	4.5" (114mm)







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