

Replacing Transistors in Thomas Organ Vox Amplifiers

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Thomas Organ recommended its own house replacement types, probably because (a) they knew that they'd work, (b) they supported their repair shops and dealers and (c) they got to make the money from selling the repair parts. This was a very common practice in the 1960s, not just grasping commercialism on Thomas Organ's part.

The actual Thomas-stocked parts were almost certainly standard industry parts which were bought with their own "house numbers" printed on them. They may have been specially selected for some parameter or other. With some exceptions there are no Thomas Vox semiconductors available any more. The problem with even Thomas Organ's recommended industry number replacements is that we're now almost fifty years past the time they picked commercial replacements, and those replacements are not easy to find, either. So to fix a Thomas Vox amp, we're often picking replacements for replacements. In general, don't use NTE replacements. They're expensive and very much pot luck whether they'll work.

Here's the list of Vox replacement transistors I compiled from various sources, with the pertinent information listed:

P/N	POL	PKG	Notes	CIRCUIT	Old Repl.	Modern Repl.
86-5042-2	PNP	TO-5/39		Driver		
86-5043-2	PNP	TO-3		Output		
86-5044-2	NPN	TO-98 or 92	2	Preamp/GP amplifier;	2N2925	2N5088*, 2N3392, etc.
86-5049-2	NPN	TO-98				
86-5050-2	NPN	TO-98		Gen. Pur?		
86-5051-2						
86-5052-2	UJT	TO-92	5	Repeat percussion	2N2646	UJT
86-5064-2	PNP	TO-18		Small signal amp	2N2907	2N2907, PN2907
86-5073-2				Revb Driver		
86-5075-2	NPN	TO-39		Driver	2N2219	
86-5082-2						
86-5083-2	PNP	TO-3	1	Output	DTG110 (5)	Replace with Silicon PNP
86-5084-2	NPN	TO-3		Output	2N3055 (5)	
86-5085-2	NPN	TO-66	6	Driver	40250	
86-5088-2	PNP	TO-3	1	Output	DTG 110 (5)	Replace with Silicon PNP
86-5089-2	PNP	TO-3	1	Output	DTG 110 (5)	Replace with Silicon PNP
86-5090-2						
86-5095-2	N FET	TO-92	3	Low Noise Pre-amp.	2N4303	2N5485, others; must rebias
86-5098-2	P FET	TO-92	4	Elect. Sw.	2N4343	2N4343, J176, J175
86-5101-2	NPN			Output	2N5036 (5)	
86-5102-2	NPN	TO-202		Driver	D28D3	
86-5110-2	NPN	TO-92 or 92		Shunt Mod.	2N2925	See 86-5044-2
86-5111-2	NPN	TO-92		Low Noise Pre-amp	2N5089	2N5089
86-5112-2		TO-3		Matched Pair 5084	NA	See "output offset" below
86-5113-2		TO-3		Matched Pair 5083	NA	Replace with Silicon PNP
86-5114-2	NPN	TO-98 or 92		Gen. Purp. GE only	2N2924	2N5088*, 2N3392, etc.
86-5117-2	NPN	TO-98 or 92		Low Noise Amp	2N2925	2N5088*, 2N3392, etc.

1. Germanium. Replace with Silicon PNP and rebias as detailed below.
2. Most common small signal transistor in Thomas Vox. May be either package. Pinout ECB.
3. Low noise JFET for 11*3 series.
4. Used for signal switching, not audio amplification.
5. UJT oscillator in repeat percussion for 1143*6 Beatle
6. TO-66 driver in higher power amplifiers

This is not all inclusive, it's just all I have. If I get more info, I'll update the list.

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Small Signal Bipolars

The small signal bipolars can mostly be replaced with any modern NPN silicon low noise device. Modern replacements should be low-noise NPN with h_{fe} between 200-400.

The 86-5044-2 is the most common device used in these amps. It's an ECB pinout, like the 2N3391, many BCxxx series and Japanese 2SCxxxx. You can use EBC by bending pins. The pins are usually bent funny on the originals, so this is not too worrisome.

It's likely that Thomas Organ used some sorted/selected version of the 2N2925 device for many of its part numbers. You can still find 2N2925s, but it's unknown what they may have specified as a selection (if any) to the maker of the transistor, so even a "real" 2N2925 may not identically match the original device. Use a 2N5088, 2SC1815, BC549, or similar, and note the differences in the pinout, being sure you get the right pin in the right hole. In many ways, the 2SC1815 is ideal. It's got the ECB pinout of the original TO-98 transistors, high gain, and can pull more current than a 2N5088, even if it's a db or so more noisy.

For the 86-5111-2, most small signal low noise NPNs will work if you get the pinout correct. I like the 2N5088 and use it everywhere. You can also use the BC107/108/109, and many others. Likewise for the other low signal NPN silicons.

Driver Transistors

The three driver transistors listed are the 86-5042-2, 86-573-2, 86-5075, the 86-5085, and the 86-5102. Drivers are medium power devices, intended for more current than small signal amplification, but less than driving speakers. They have been called "uniwatt" devices by some makers, to indicate that they're typically capable of one to a few watts of power. In the 60's, these were generally TO-39 package; this is superseded by the TO-126 or TO-202.

On the drivers, I'd use a Toshiba 2SC4793 or 2SC5171. They're made for audio drivers, and are fast, high gain, and tough. They can replace all of the listed drivers. These are probably my first choice.

Some other guesses are: BD175/177/179, BD233/235/237, BD439/441 in the TO-126 uniwatt package, although these are a bit low gain, and slower (lower f_t) than the 2219. They'll probably work. In a pinch I'd try the MJE340.

In the TO220 package, try the KSD880 (Fairchild), BD243B/C, BD239B/C or the KSC2073.

The 86-5102-2 is a problem. The original is quite a high gain device, and the other replacements may not give good results. Still working on this one.

JFETs

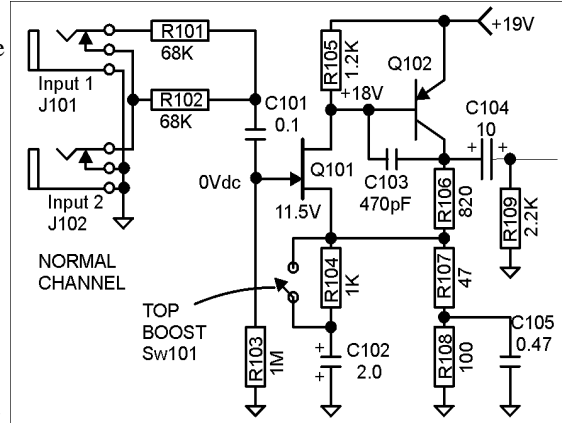
The JFETs from Thomas are what motivated me to write this. JFETs are kind of a bad dream for E.E.s. They're so variable that it's really hard to design well with them.

The 86-5095-2 N-channel is used as a low noise input device in the V11x3*6 models. Thomas suggests the 2N4303, which is still available, but not all that common. Some commercial cross references for that part number are 2N4416, 2N5245, 2N5362, 2N5458, and 2N5459.

Almost all commercial JFETs have high enough voltage ratings. But you do need to know a JFET's I_{dss} , V_{gsoff} , and transconductance. I_{dss} is the largest current a JFET will conduct. V_{gsoff} is the voltage which turns it completely off, and transconductance is the current that flows in the channel per volt of change on the gate.

I found that the JFETs I had did not work well in the Thomas preamps. In fact, a 2N4303 that I came up with did not work. So I ran some simulation models so I could diddle with the JFET parameters. What seems to be important in the low-noise preamp spot for the 86-5095-2 is that I_{dss} has to be over 5ma and V_{gsoff} is over 3V. There are many JFETs that do this. However, the other thing that matters is transconductance, and all my JFETs were biasing the bipolar PNP that followed them incorrectly. They were pulling too much current through the base of the transistor.

The DC feedback in the circuit is supposed to fix this, but does not in all cases. I found that I had to tune the circuit to match the JFET I put in, even if it's a recommended replacement type. In the Thomas Vox amps, this means varying the value of the resistor from base to emitter of the PNP that the N-JFET drives in the preamps of the 11x3*6 preamp series. In the example schematic at right, the normal channel from the 1143*6, this would be R105. This is nominally 1.2K. Using values from 220 ohms to 4.7K, I could tune in most of the JFETs I tried. The trick is to measure the voltage from the PNP collector to ground and change the base-emitter resistor so the collector is roughly in the middle of the power supply, or alternately that the source of the JFET is about 1.5-2.0V. You have to get the DC voltage on the PNP transistor collector away from ground enough to not distort the signal; it's only a couple of volts here, so this is not hard.



The P-channel JFET is only used for signal routing/switching in the 11*3 series of amps. Thomas lists 2N4343, and the commercial replacement I found listed was BFT11. However, a J175/176 worked fine in my boards. Not being used in analog mode for amplifying means that all you have to do is make it switch fully on and off, and the circuits can do this easily enough. Use the J176 if you have a choice, the J175 if you have to. I got a J174 to work, too.

Output Transistors

Thomas only used germanium parts for outputs in the early amps, not in the signal circuits. The only commercial replacement listed is the DTG110, probably the "B" suffix. You can still get these from Germanium Power Devices, I think. They are quite expensive, not stocked anywhere, and probably only available in large quantity. If you find them, they'll cost \$20 each or more, and you may or may not find matched pairs.

Fortunately, they're not necessary. I very much recommend replacing all instances of the 86-5083, 86-5088, and 86-5089 with silicon PNP power devices. There is really nothing to lose with this. The silicon power devices are tougher, more reliable, and dramatically cheaper. All this costs you is that you have to re-bias the output stage that they're in. This is simple, and I'll tell you how to do that below.

First go look at http://geofex.com/Article_Folders/voxamp/voxprot.htm for the advice on output devices. I'll shorten that up considerably here.

For the 86-5084-2, Thomas said you could use a 2N3055, with a note. I suspect that if I had that note, it would talk about testing for breakdown voltage or a specific manufacturer. The breakdown voltage of the 2N3055 is marginal in the Thomas Vox amps. I highly recommend using other replacement devices with much larger $B_{v_{ce0}}$ and higher second breakdown rating. Suitable transistors are either the TO-3 Japanese audio parts if you can find them, or Motorola/On Semi devices. This probably means the MJ15001, MJ15015, MJ15024, MJ21194 or MJ21196.

The real choice of replacement output devices comes down to (a) the amplifier model you're working on and (b) what you're doing with the heat sinks. If you are doing the quickest possible repair, order TO-3 output devices and cram them into the existing heat sinks, possibly using new sockets and being sure you do a competent job of mounting them on new/fresh mica washers and a thin layer of heat sink goo, getting the mounting screws snugged well down.

If you're working on a Beatle, Super Beatle, or one of the high power Westminster chassis, the existing heat sink and ventilation setup is marginal. That's one reason they got the reputation for failing.

I've seen TV amps with the screws about to fall out, and this is seriously bad for getting heat out of the transistors. Don't fall back on the 2N3055 unless you have no other options on the Beatle. You can use the 3055 on the Royal Guardsman, Buckingham, and Viscount, but I don't recommend it because of the second breakdown rating.

If you are (a) willing to do the work to replace the TO-3s with plastic devices, or (b) replacing the heat sinks to

make flat plastic devices easier to do, you have a much wider range of output devices. The NJW0281, MJL21194, MJL21196, MJW21194, MJW21196, and many devices from Toshiba or Sanken work fine. You want a device rated for over 100V, 15A, 100W and over 3MHz per device. Toshiba no longer makes the 2SC3281, but its successor will be fine.

A third possibility is to use plastic devices on the existing sinks by using more of them. A third pair on the Beatle should help with keeping the device temperatures down a lot.

Note that Toshiba devices and now On Semi devices are widely counterfeited, so if you buy devices from anybody except a major distributor, it's likely they're fakes. That includes especially ebay.

As far as matched pairs of 86-5083-2 (germanium): don't do this. Change over to silicon PNP and fix the biasing.

Instead of looking for matched pairs of 86-5084-2 silicon NPN, get extra replacements for the devices you're replacing, and swap them around, testing for a DC voltage under 100mV on the amplifier output. Stop when you get a good match. The whole point of matched pairs on these amps is that the DC offset on the speaker output is totally dependent on the matching of the output transistors at their no-signal bias point. Note that any mismatches in the biasing resistors will cause offsets too. It's best to measure and match the bias resistors, then swap transistors until you get a low offset.

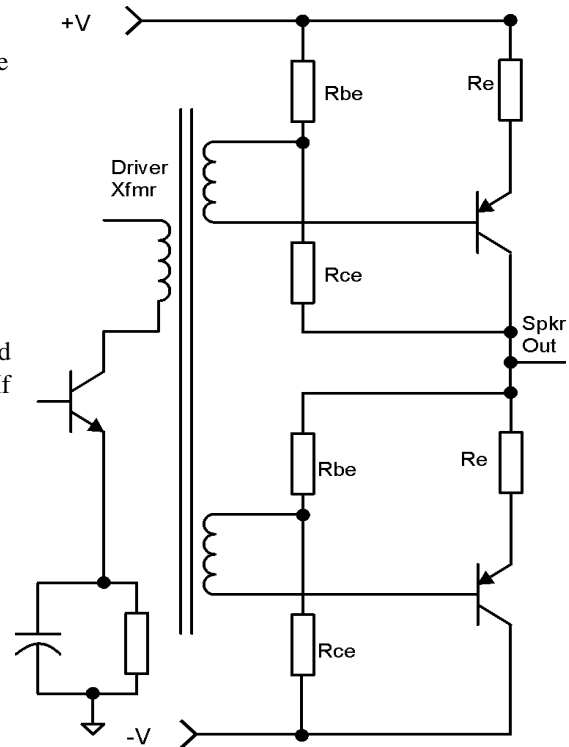
Never replace one of any set of outputs in an audio amp. Get a fresh set of both top and bottom side outputs. Modern output transistors are relatively cheap, being in the \$0.50 to \$3.00 range mostly.

On the right is a generalized schematic of the germanium PNP type output stages. You will not find these in Royal Guardsman or Beatle/Super Beatle amps, even the earliest ones. But they are common in the Viscount/Buckingham, Essex bass, Berkeley, Cambridge and some others. It's expensive or impossible to get matched pairs of the germanium output transistors.

Use a Silicon PNP replacement instead. Germanium is so slow that any silicon device you find that will withstand the voltage / current / power on the output stage will be fast enough. I recommend a silicon PNP with $B_{vce0} > 100V$, $I_c > 8A$, and $P_{diss} > 40W$. If it's a TO-3 package, the MJ15016 works fine, and is massive overkill. Those are \$2.16 at the time of this writing. If you can make your peace with subbing in a flat plastic device, especially a TO-220, it gets cheaper. Suitable devices are the TIP42C, BD244, MJE15029, MJE15031, BD912. They'll cost \$0.50 to \$1.50 or so. You may be able to find a TO-3P package device as well. These packages can be formed to fit into the same space as a TO-3 metal can, even into a socket for a TO-3.

The rebiasing is easy enough. The values of R_{ce} and R_{be} are designed to just barely turn on the outputs. For germanium, this is about 100-200mV. For silicon, it's 400-500mV. All you do is increase the resistance of R_{be} by about 3-4X, then test for crossover distortion by listening, and make sure it does not overheat either sitting idle or at half-power with a test signal and load. If you get the resistor too small (as it will be with the stock value) you'll hear gross crossover distortion, a kind of fizzy distortion as the note decays. When you just get it right, the crossover distortion disappears. When you get it too large, the distortion is fine, but the transistors get too hot and go into thermal runaway. So you have to test for both distortion and overheating.

DC offset at the speaker output is a matter of how well matched the output device idle currents are. If the top and



bottom devices each allow through the same amount of current, the DC voltage at the output is zero because the bottom device pulls out of the output exactly what the top device lets in. If one idles at a higher current than the other, the difference is made up through the speakers, and there will be a DC offset. This difference in current comes from two places: mismatched output devices and mismatched bias voltages. You can correct it either place. A perfect setup would measure and match the R_{ce} and R_{be} , then substitute in output devices to get 0Vdc on the output under load. Perfection is usually not required, though. If the offset is under 100mV, you're probably fine. 100mV in the 6 ohms DC of an 8 ohm speaker dissipates a couple of milliwatts and is probably OK.

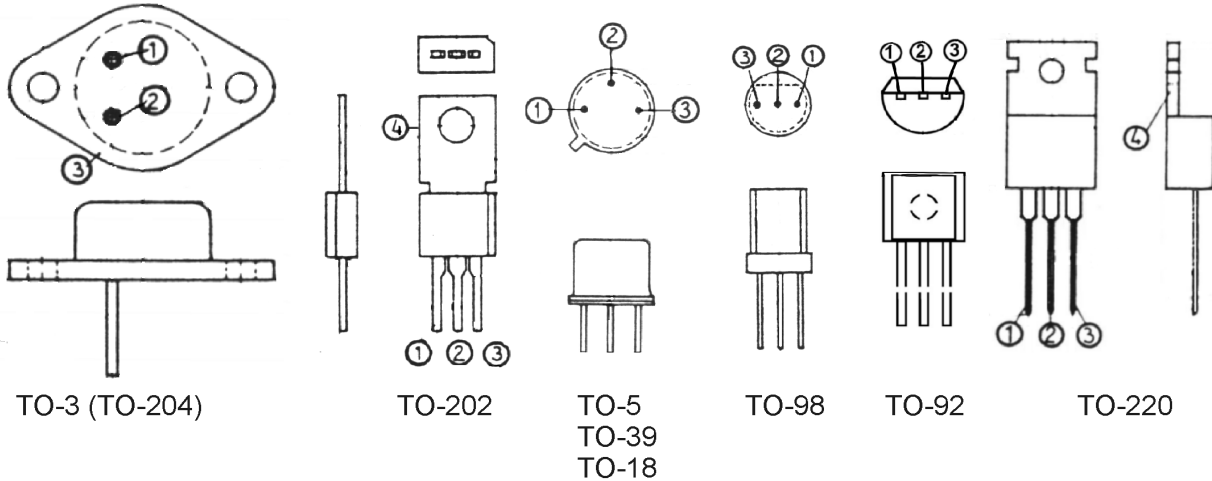
Where Used:

The following tables list the transistor types used in the Thomas Organ amplifier model numbers. The type number on the left leaves off the "86-" at the first and the "-2" at the end; an 86-5074-2 is listed as "5073". The model numbers are across the top, leaving off the "V" in front of them. A "1011" is a "V1011" model.

	104	112	113	114	115	116	117	118	119	1011	1021	1031	1042
5042	104												
5043	104												
5044	104	112	113		115	116	117	118	119	1011	1021	1031	1042
5049	104												1042
5050		112	113		115	116		118	119	1011	1021	1031	
5051									119				
5064		112	113		115		117	118					
5073		112			115							1031	
5075		112	113		115	116			119	1011	1021	1031	
5082													1042
5083		112			115								
5084			113			116	117	118	119				
5085			113			116	117	118	119				1042
5088													
5089											1021	1031	
5090										1011			
5114					116								

	1081	1083	1121	1123	1131	1141	1151	1181	1133	1143	1154	1241	836
5042		1083											
5044	1081		1121	1123		1141	1151	1181	1133	1143	1154		
5049													
5050	1081		1121			1141	1151	1181					836
5051			1123						1133	1143	1154		
5052										1143			
5064			1121	1123		1141	1151	1181	1133	1143	1154		
5073	1081		1121	1123			1151				1154		
5075	1081	1083	1121	1123		1141	1151		1133	1143	1154		
5082													
5083			1121	1123			1151			1143	1154		
5084						1141		1181	1133				836
5085						1141		1181	1133	1143			836
5089	1081												
5095				1123					1133	1143	1154		
5098				1123					1133	1143	1154		
5101		1083											
5102		1083											

Package and Pinout Diagrams



TYPE #	OUT-LINE	P1=	P2=	P3=	V _{ceo} (V)	I _c (mA)	H _{fe} min/max *typical	P _{dis} (W)	F _t (MHz)	Sugg. Replacement	Notes
2N2219	TO-39	E	B	C	30	800	100-300	3	>3	2N5320/21	Can use KSC/2SC3503E in TO-126
2N2646	TO-92										UJT
2N2907	TO-18				40	600	40-200	0.6 – 1.8		PN2907	2N2907 available; Use PN2907 only for preamp Xstr; Most Si PNP Small signal devices work OK, prefer low noise. If needed, try 2N3906.
2N2924	TO-98	E	C	B	25		150-300				Also found in TO-92; 2SC1815 has same pinout, works. Use any NPN small signal, high gain device, watch the pinouts.
2N2925	TO-98	E	C	B	25		250-470				
2N3055	TO-3	E	B	C	60	15A	20-70	115		MJ15015G	2N3055 is marginal!
2N4303	TO-92										
2N4343	TO-92										
2N5036	TO-219				60	8A		83	0.8		Output in Berk-III, plastic fake TO-3 You can use the 2N3055 here.
2N5088	TO-92	E	B	C							Great replacement for small signal, with EBC pinout
2N5089	TO-92	E	B	C							Very high gain, low noise
2SC1815	TO-92	E	C	B							Great replacement for small signal, with original pinout (ECB)
40250	TO-66				50	>2A	25/100	29	1.2	KSC2073, 2SC2073	1181/1141/1143*6/836
D28D3	TO-202					>1A	>230	6.5W			ACK!!!
DTG110	TO-3										Don't even try. Replace with Si PNP.