KWM-2/2A Keying Circuit ~ Functional Description and Issues

Common Problems Encountered

1. *PTT Keys, but then will not drop back out* after release of PTT button or TUNE/LOCK KEY functional Selection (Or drops out very slowly)
2. *PTT will Key the transmitter and then chatter* ~ (Relays drop in and out)
3. Intermittent Keying or no MIC PTT

Before starting to diagnose your radio

It is always good to understand why you are doing something. This tutorial will help you understand how "Keying your KWM-2" actually works. If you do not wat the tutorial, then just jump down to the diagnostics section.

In every case, when you key the KWM-2, you are not just grounding one end of the relays to pull them in as in some equipment. There are three separate ways that an M-2 gets keyed. You can key it when you push a mic button or use the PTT line in the rear at the RCA jack. You can key it by using the TUNE or the LOCK KEY modes during tune-up on the MODE switch, or you can key the M-2 by talking into a "hot" mic with the VOX set up correctly. A hot mic is one that always produces audio, no matter the state of the PTT button on the mic.

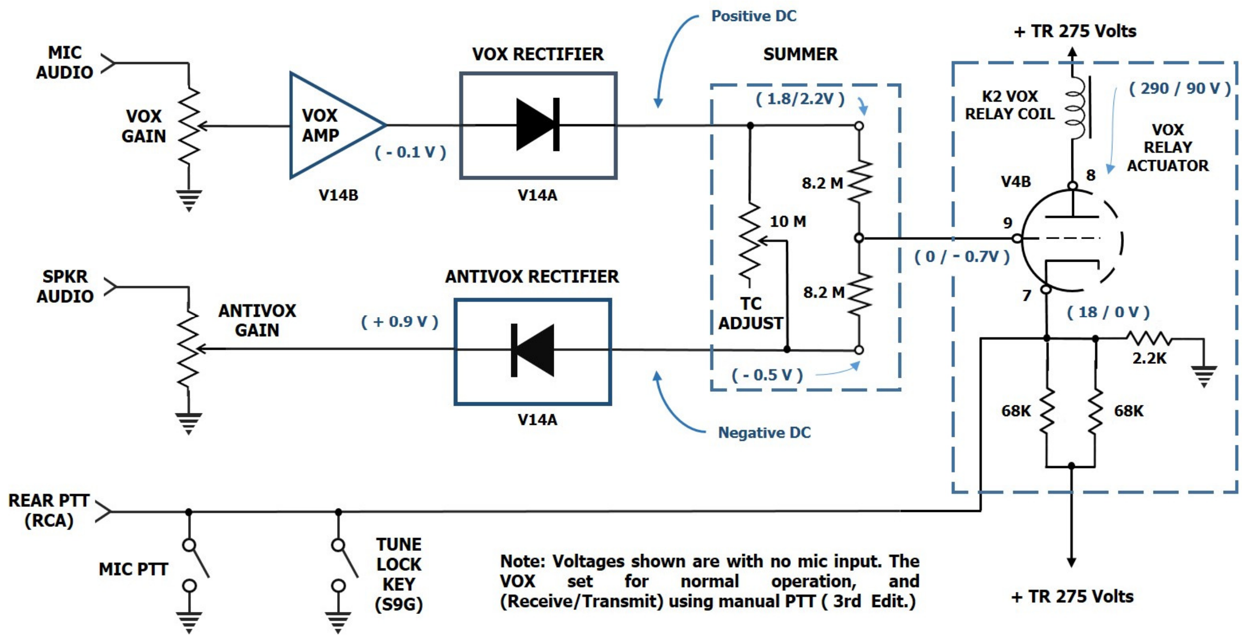
Some Helpful Definitions

VOX stands for Voice Operated Switch and takes audio coming from the 2nd MIC AMP (prior to, and therefore independent of, the MIC GAIN setting) and amplifies it with the triode portion of V14B after the operator sets the VOX level with the VOX GAIN pot. This amplified MIC AUDIO is then capacitor coupled to, and rectified by, the first diode section of V14B (Pins 6, 3) thus setting up an average positive DC level at the cathode of the diode. This DC voltage is applied to one input port of a 2-port voltage summing network consisting of R42 and R48. This is best visualized by looking at the block diagram below.

ANTIVOX relates to the use of speaker audio which is, in the case of the KWM-2, coupled in from the plate of the speaker amp V16 by C235. This picked-off audio sample is gain controlled by the ANTIVOX (GAIN) CONTROL and then rectified by the second diode section (Pins 1, 2) of that very busy 6BN8. The result is a negative voltage proportional to speaker audio at the anode of its rectifier diode. This negative DC voltage is applied to the second port of the voltage summing network. The output of the summing network is applied to the grid of the VOX Relay Actuator, V4B. When VOX GAIN and ANTIVOX GAIN are properly adjusted, the positive DC voltage from the MIC audio sums approximately to zero with the negative DC voltage from the speaker audio. The result is that the relay K2 is not activated.

The Anti-VOX circuitry simply attempts to cancel the VOX control signal to the VOX Relay Actuator. Also note that the VOX Time Constant pot has, in theory, little impact on the voltage summing function.

You can refer to the following block diagram as we walk through the function of the various keying modes.



KWM-2/2A KEYING CIRCUIT BLOCK DIAGRAM circa 1962

Now, let's back off and look at the components of this entire keying circuit shown using Figures 1 & 2.

On the right is the VOX RELAY AMPLIFIER/Switch (V4B) and on the left is the VOX amplifier (1/3 of a 6BN8) followed by the VOX RECTIFIER (another 1/3 of a 6BN8) and then the ANTIVOX RECTIFIER (the last 1/3 of that 6BN8).

Figure 1. (Below) VOX/ANTIVOX KEYING CIRCUIT ~ Early KWM-2 circa 1962, 3rd Edition

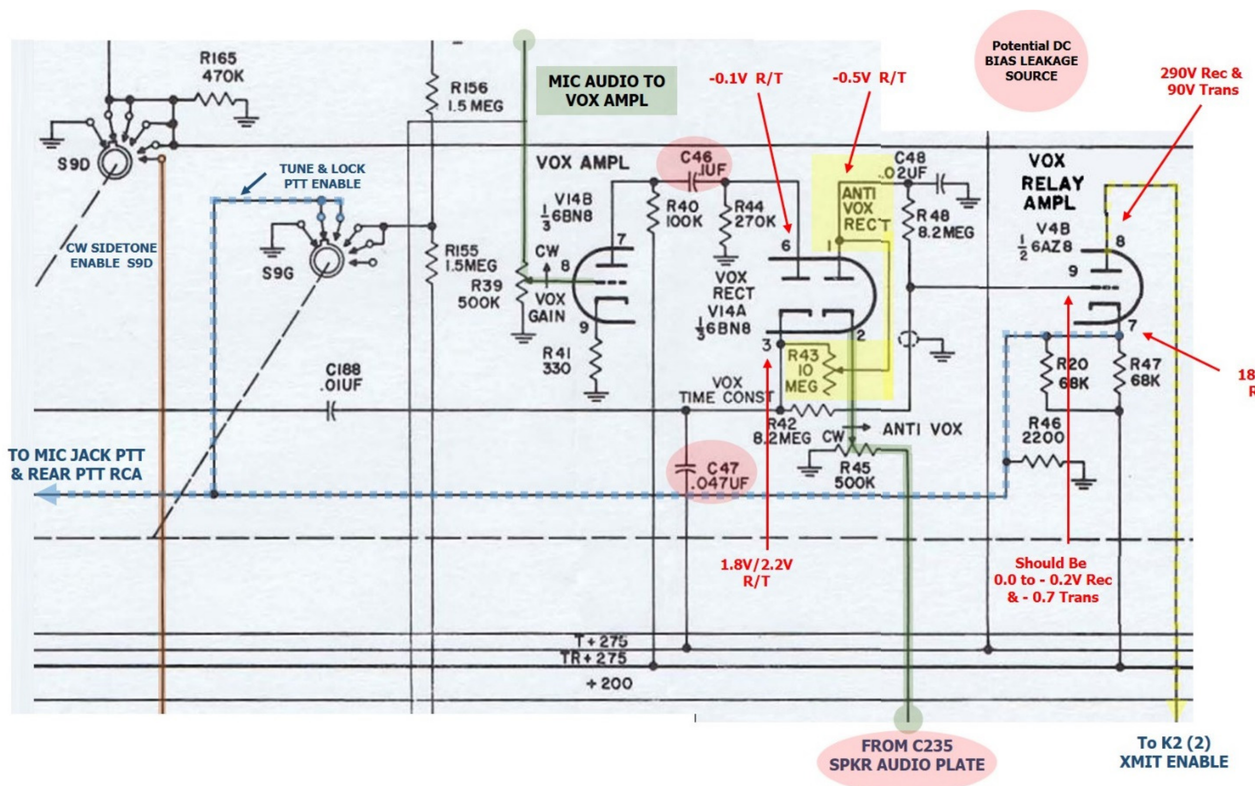
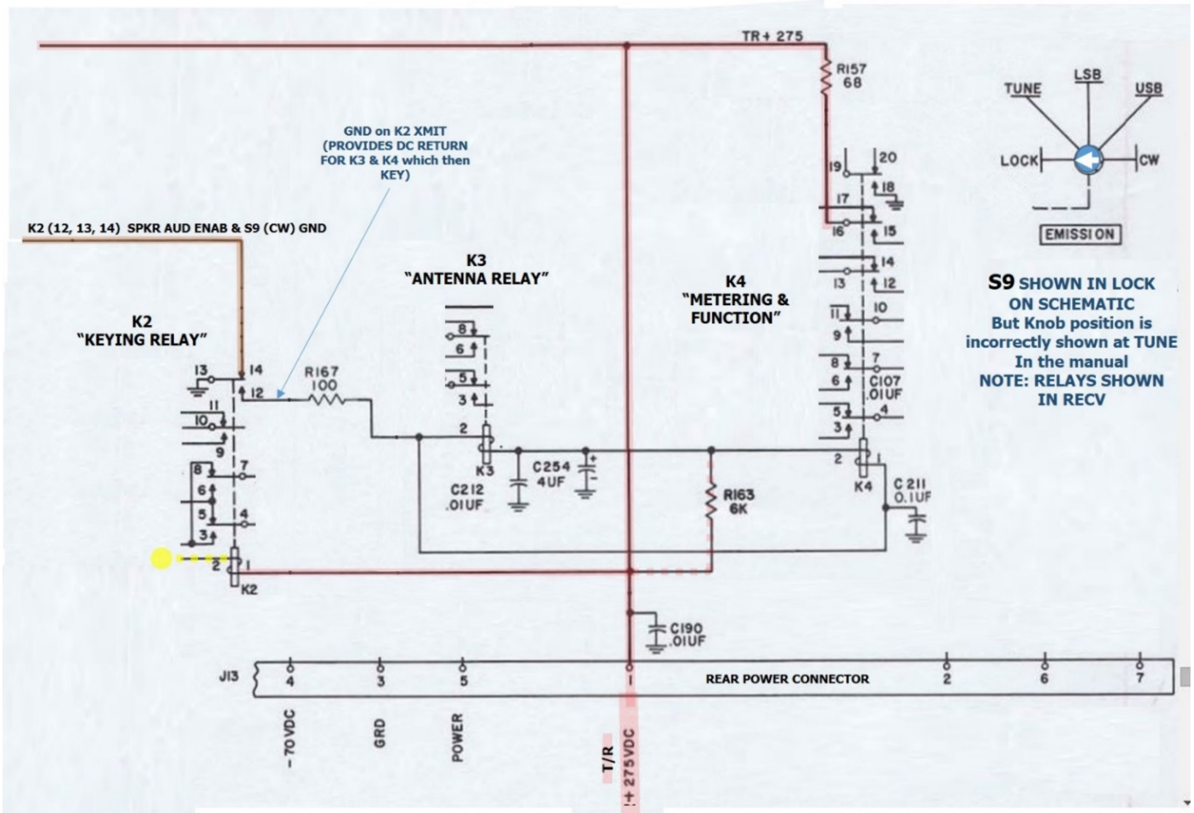


Figure 2. VOX & PTT RELAY KEYING SIMPLIFIED & ANNOTATED



In reality, there are just two keying modes to understand. The fact is that, when you turn the MODE switch to TUNE or KEY LOCK, the mode switch S9G just grounds the PTT line internally. This is the same line that comes from the MIC jack, or from the PTT RCA jack on the back. The two modes we are left with for keying are very different and it is important that you understand how. When you cause the KWM-2 to be keyed (using any of the techniques above), what you are really doing is causing K2 to close. K2 is known as the VOX relay and it is one of the relays located under the shield can under the chassis. It also provides the receiver antenna grounding during transmit. When K2 keys, contacts K2 (12, 13) close and provide the ground return path to in turn close K3 and K4.

K3 is located in the PA cage (and is basically the Antenna Relay) and K4 is located under the chassis right next to K2 and serves to provide the T/R function change and the metering change over.

Now, back to the two keying modes. No matter which of the three actions is taken to key the M-2, K2 is driven closed by the VOX RELAY AMPLIFIER (V4B). You can think of V4B as a remote switch that keys K2 - which in turn causes K3 and K4 to close by providing a ground return path through K2 (12, 13).

The circuit involved at V4B (½ of a 6AZ8) is a very interesting, and at first potentially confusing. In reality it is pretty straight forward if you look at it right. Fun little circuit! If you trace from the plate of V4B, back through the relay K2, you will come immediately to the B+ rail, TR +275. And, if you trace from the Cathode of V4B (Pin 7) down through those parallel 68K 2 watt resistors R20 & R47, you will also come to the TR +275 rail. Hmmmmm It is almost like they drew it funny on the schematic to trick us. Closer scrutiny will reveal that R46 (2.2K) goes to ground off that same cathode, and some more staring turns the 68K parallel resistors and that 2.2K ohm cathode return resistor into a voltage divider circuit that sets the cathode up at a hard 18 Volts. If you do the math on the divider and use 275V, you get 16.7 Volts - but that B+ rail is usually closer to +295 to +300V and that comes out 18 Volts – sure enough.

OK, so we have the cathode sitting at 18 volts and that is where that PTT line is connected. Pushing the MIC PTT button will hard ground that cathode to 0.0 Volts. But, let's leave it un-pushed for now and look back at the plate. Let's assume that V4B is turned off, or that it has a low enough grid voltage (<< zero) to cut it off. Note, that that would be (<< zero) *relative to the cathode* which is at 18 volts. Make note of this because that is what the tube sees. Now, with the tube off and no current flowing, that plate of V4B (Pin 8) is looking right through the K2 relay coil (with no current flowing there is no voltage drop) and it sees the +295 Volts - or there abouts. So we have the V4B "switch" turned off and floating at zero current with the cathode 18 Volts above ground and the plate at +290V.

Now let's look back at the grid (Pin 9) of V4B. As a result of there not being any audio coming in from the MIC, and if there is no speaker audio to be applied, that grid is fixed at about – 0.1 volts (essentially zero and again note that is with respect to ground).

Now, push down the MIC button and bring the PTT line to ground (0.0 V) - or we could have moved the MODE switch to TUNE or to LOCK KEY for tuning. The cathode of V4B, the VOX switch, goes to ground and now, what was a grid bias that was 18.1 Volts negative with respect to the cathode, is only 0.1 volts negative (as impressed).

If you look at the data sheet characteristics (See references at the end of this article) for a 6AZ8 triode half, you will see (pre- PTT) that - with a plate voltage of +278V (that is +290 – 18V) and with an Ec (Grid to cathode voltage) of – 18 Volts, the tube is cut off. Then with a grid voltage still of 0.0 to – 0.1 Volts, and after we key PTT and ground the cathode, the tube characteristics show it is approaching saturation (or turned on) . . . and the relay will now be conducting. Now you understand how PTT keys the K2 relay.

Now, let's leave PTT open (cathode at 18 V) and set the VOX gain up so we are able to speak in the mic and trigger the VOX mode. We have already turned up the ANTIVOX gain until the speaker audio from the receiver was NOT triggering the VOX. Now, speak in the mic. The rectified mic audio drives the DC level on the GRID of V4B more positive up from 0.1 Volts with respect to ground (which you remember was negative 18.1 Volts with respect to the cathode - which is what the tube cares about). Now we are talking comfortably with the VOX GAIN set at a level that, when rectified, will produce an additional approximately 18 Volts of positive DC grid swing. The cathode is at +18 V and the Grid is at about 18 Volts and the tube turns on and K2 closes.

So, now you see that this "floating triode" can be turned on by jerking its cathode down to ground (PTT), or by talking up the VOX audio and bringing up the grid to an equivalent level. Collins Magic.

OK - Now let's get back to the diagnosis

Obviously, with either of the common faults, 1 or 2 referred to at the top of this article, the first thing to do is sub in, or test a few key tubes. Just the two for now. V4 and V14. You should have a couple of these just in case. They are a little more prone to degradation and they are also getting harder to come by.

Let's assume that they are good and that **you still have fault 1**. You key the MIC with PTT and it keys, but then does not like to come out of transmit. Sometimes it just comes out real slowly. This is a common fault particularly on early radios and ones that have seen a lot of use. You will notice that the two 68K resistors (R20 and R47) that are in parallel on the V4B cathode are rated at two watts each and the combo makes a 34K ohm resistor rated at four watts. Think about that "PTT keyed" mode. When you ground that cathode, those resistors are then right between the B+ rail and ground. While it may seem that the 4 watt rating is plenty hefty, the reality is that with today's higher AC line voltages, and realizing that the "TR + 275" B+ rail is quoted by Collins even in the earlier 1962 and 1964 manuals as being +290 Volts, those resistors are dissipating 3 watts any time you are key down (using the PTT) - - and those resistors are getting HOT. And, the rest of the time, when acting as a voltage divider they are still soaking up 2.2 watts of heat. That is not conservative design.

If the radio has seen a lot of use for the last 55 years and has been key-down a lot, those resistors have seen a lot of heat aging and are typically going up in value. So, lesson learned. It is a good idea to look at those 68K ohm resistors any time you are in there under the hood and if they are more than 10% out of spec, change them. Also, if you have an earlier rig, and it has seen a lot of use (or even a younger one with a lot of use) and you notice the VOX gain creeping up or down in use, you may have a PTT failure coming. The parallel combination that should read about 34K ohms when out of the circuit, is usually getting up around 50-70K ohms when the rig starts to lock the key down. This means the individual resistors are over 100K ohms. Peter, K2LRC says that he uses the *in-circuit* guideline that, if he measure across that pair of resistors and it measure more than 10K ohms, it is time to pull and check them. **Replace R20 & R47.**

Here above the parallel 68K ohm 2 watts are shown cut loose for evaluation

If testing the two tubes involved, and checking out the voltage divider network R20/R47/R46, does not yield the culprit, then this fault can also be caused by a very leaky C200 or C225 bypass capacitors. Note that C225 is used in earlier sets and is a 0.1 uF capacitor. It is shown on the schematic as bypassing the PTT line and the V4B cathode at the MIC jack, but it is actually located back by the PTT RCA jack in some sets. When this change from two bypass caps to one occurred is unclear, but be aware there may be just one bypass cap, or there may be another one hiding around the MIC jack or the rear PTT RCA jack.

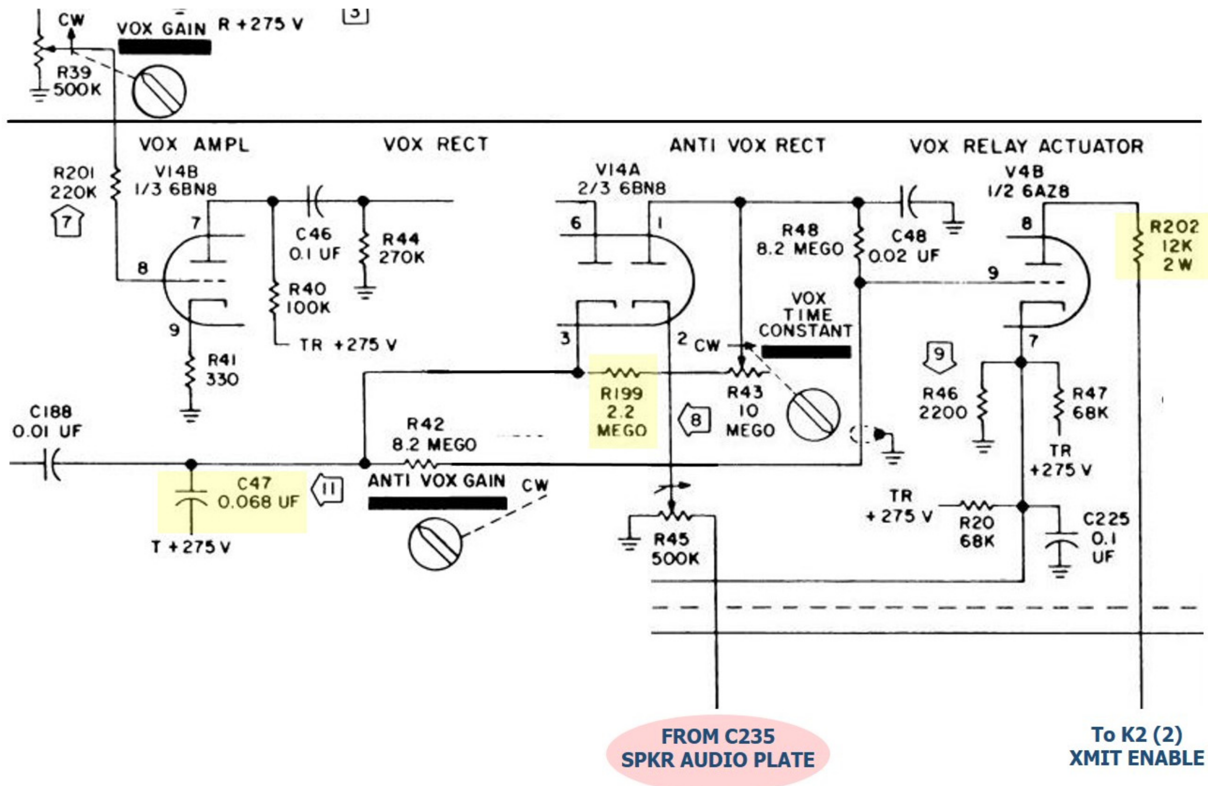
Now, let's look at fault two – Clattering relays when you hit PTT
(or possibly you have unreliable VOX operation)

There is some history behind this one. It is a bit complicated but worth the read. If you look at the manuals and then KWM-2/2A service bulletin SB 2, you will see a parade of changes (highlighted below - Figure 3 - in yellow) spanning about 10 years.

> Looking at Figure 3. You will see the schematic for the VOX AMP/RECTIFIER AND RELAY DRIVER circuitry as it existed in 1978. You can see some important differences between the 1962 and the '78 version.
>
> First (as per SB 2.) they added the entire VOX TIME CONSTANT ADJUST – the new R43. That happened in August of 1960 and they revised that SB 2 again in October. This TC Adjust does

show in Figure 1 (1962) above. Then, still referring to Figure 3, they added R199, a 2.2 megohm resistor between the cathode (Pin 3) of V14B(a) and the R43 10 megohm pot leg that then runs through the wiper to the plate of the ANTIVOX RECTIFIER.

Figure 3. LATER VOX AND PTT (Including TUNE/LOCK) CIRCUIT - circa 1978 9th Edition



The addition of R199 was apparently done to prevent the VOX Time Constant adjustment from getting all the way to the cathode of the VOX rectifier. This had the effect of pulling the grid of V4B so far negative that it was tempted to come out of hard PTT keying by shorting out the inputs to the Summing Network. They may have been trying to deal with the listed fault two (above reference) of the clattering K2 relay.

Following this addition, they also changed the VOX time constant capacitor C47 from 0.047 ufd to 0.068 ufd. Note that C47 does not become active until keying starts - since it is returned to T +275 (which is floating until K4 closes) and not to ground or TR +275. This capacitor then serves two functions. It provides a fast attack/slow release function the way that it is wired, and it also – upon keying – provides a "goose" for the positive grid bias in order to combat the potential clattering.

Following this, and I have not pinned down the time period yet, they also added a resistor in the plate lead of the V4B plate that runs to K2. That addition appears to coincide with the change to plug in relays and the use of a K2 relay that had a much lower coil resistance.

Just recently, and what triggered this tutorial, I was involved with helping a friend (Mark, K7WXK) resolve a clattering K2 relay when he pushed PTT. It would pull in and then oscillate in and out. He had already observed that adjusting the ANTIVOX GAIN CW would stop the oscillations and raise the V4B grid voltage a little - but not all the way to -0.1 Volts.

Some testing and probing on the problem rig found that the V4B grid was resting at – 0.4 to -0.5 Volts (too low) above ground. The cathode (and therefore R20 and R47) were right where they belonged. . . e.g. the combo 34K ohms was OK and cathode voltage right at 18 volts. But the grid, Pin 9 was too far negative and the result was that K2 pulled in but then came the oscillation.

We shot all the obvious suspects. All the caps (C235 coupling from the speaker amp, C46 coupling from the VOX amp to the Summing Network, as well as the time constant caps C47 and C48) were all OK. The tubes were multiply subbed and tested OK. But, all the pin voltages on the rectifiers and going to the grid of V4B were way out of kilter. Way out in this case, because there is no supply in there, is just a matter of a volt or two at the most.

Mystery. What was shifting the bias developed on those tubes? Then more testing revealed that when the relay was clattering, the plate voltage of V4B (which should have been down at 90 Volts) was unstable and hard to read - but it was averaging way too high. This led me to suspect that the relay driver stage V4B was actually part of a larger oscillation loop involving the B+ line and the mechanical delays of K2 and K3/K4. I got curious and, even though the TR +275 rail is well filtered in the 516F-2 Power Supply, I suggested we add a 20 ufd +350V electrolytic filter cap on the B+ side of K2… Basically right on the back power plug line but located at the hot side of the K2 coil. That solved the problem. The oscillation stopped.

This rig did not have the 2.2 meg ohm resistor in-between the R43 10 meg pot and the V14A cathode at the time. Suspecting that this fix was also related to the oscillation or adjustment of the internal DC voltage of those diodes, we pulled the 20 ufd filter off of the hot side of the relay coil and installed the 2.2 meg R199 cathode resistor. That also fixed the problem, although it did not entirely return the V4B Grid to - 0.1 volts. What it did do was shift the practical range of the R43 center wiper to a place where the diddled grid voltage on V4B stopped the problem "on that rig". Kind of a Band-Aid in my mind.

Final Solution to Fault 2.

It is obvious from this analysis, that the B+ rail internal to the chassis is not stiff enough when the rig goes from receive to transmit and the B+ sags during the keying spike and then stays down during transmit. This issue may be aggravated – by the way – if the 516F-2 P.S. has had the solid state conversion and the dropping resistor is improperly placed. This leads to the oscillation (clacking) and this can be totally eliminated by adding this 20 ufd +350 Vdc rated filter cap at the hot side or K2. In addition we found that just adding the 2.2 meg resistor (R199) marginally eliminated the problem with nominal VOX time constant settings and that is not well understood at this point. **Bottom line, adding R199 and the 20 ufd filter cap on the B+ rail will resolve the problem.**

> Note: SB 2. Adds VOX time constant - Very early M-2s did not even have the VOX TIME CONSTANT POT or variable timing. Be aware there is an error in SB 2, Figure 1. This SB 2 figure labels the V4 VOX RELAY AMPLIER improperly as the ANTIVOX AMPLIFER (which doesn't exist).

Some further observations regarding this chattering relay problem. We did observe, and so have others I have talked to about this work, that the voltages on the cathodes of the two VOX and ANTIVOX rectifiers wander around based upon the position of the various VOX control settings. This is one of the things that makes analysis of this circuit difficult and also makes the performance difficult to control. This is predictable though since there are technically no DC voltage bias inputs into the circuit area other than the internal biasing effect of the thermionic voltages of the diodes. This is complicated by the tendency of a triode (V4B) high impedance grid to self-bias with current flow in the tube when given just a very high impedance grid termination to ground – the situation here.

There are of course the more easily understood average DC levels that result from the two rectified signals from the MIC and the SPKR AMP. This high impedance summing and grid circuit inside the coupling capacitors is VERY susceptible to leaky caps at any of the three coupling points (MIC Audio, Speaker Audio and to a lesser degree, the C188 path). Leakage in any of the audio caps will tend to turn the VOX keying on and add to the Fault 1 difficulties.

I talked with Dennis Day, retired Collins Radio Group head for the HF Commercial and Amateur Radio HF Communication Group about this issue and his memories of the design. Prior to him becoming the Group Head, Dennis was an Engineer in the group under Gene Senti, and he immediately had been assigned the factory sustaining engineering responsibility for the KWM-2 after its introduction by Ed Andrade. Ed was the Project Lead during the design. Dennis' memories were a big help in dating some of the changes. Dennis was (Collins called it the Collateral Engineer) sustaining production engineer on the M-2 for just two years, and then he went on to do the 75S-3 and the 75S-3B/C as the Project Lead.

He made a very interesting last comment that caught my interest and really educated me (and now "you"). I had been looking at tables from the 1962, 1964, 1969 and 1978 manuals. When I observed that the voltage levels for those tube pins that are listed in the Voltage and Resistance table in the manual(s) for that VOX and ANTIVOX area of the circuit (particularly V14B) had changed a lot over the years and then gone almost right back where they started, he laughed and told me what really happened in the factory. Remember that these voltages are all less than a couple of volts and often 0.1 to 0.7 negative.

He said that the Rev 0 manual, which was issued by the engineering group when any radio was introduced, had a Voltage and Resistance table that was developed from data taken by engineering on one of the engineering radios. Just one! Not on production radios, nor any statistical sample. Then, and here is the education, when they later revised a manual based on changes that engineering had been red lining in the current one, the "Publications" Department guy would go down to the factory inventory cage and pull a *hopefully* current radio out of the cage and take it back to his office with a VTVM and make new measurements on his own. Then he would "Update" the manual tables/numbers to *hopefully* the typical current configuration. This data then - for the next almost 20 years for the KWM-2 - came each time from a single factory radio from the period, and it was done by the department that updated the manuals – not engineering. In all fairness, those pubs guys were usually engineers, but notice the "hopefully" comments.

Also, there were no guarantees that the VOX controls were in any particular configuration when that data was taken. Dennis and I think that this is why that sensitive data on the rectifiers (V14A) for instance varied so much from revision to revision. Different guy, different time, different control positions etc. So, buyer beware on those tube/stage Voltage and Resistance tables on any of our equipment. They are just a guide and should be taken with a small dose of salt. When in doubt, look at the Rev 0 manual and, even then, look out for changes.

Fault three – Intermittent or no PTT or intermittent audio

I just had to throw this in, because it has gotten me and I have helped others "fix" this several times. The PL-068 plugs that are used on many pieces of Collins gear are made of brass. Brass oxidizes and takes on a tarnished look and if it get too bad, and you happen to have nice smooth contacts on those high quality Collins mic jacks, then – walla – no contact. Take a very fine 000 or finer steel wool, or a fine abrasive micro pad like the 3M purple (green is too abrasive) stuff and polish those plugs once in a while. Things will work much better. I hope that was not too technical ☺

So, if you waded through all of that, you now have a better understanding of how that little VOX and Keying circuit works and what to look for regarding a few very common faults.

Have fun,

Bill Carns, N7OTQ/K0CXX
Past President and CCA Board Member
Retired Editor, CCA Signal Magazine
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Credits:

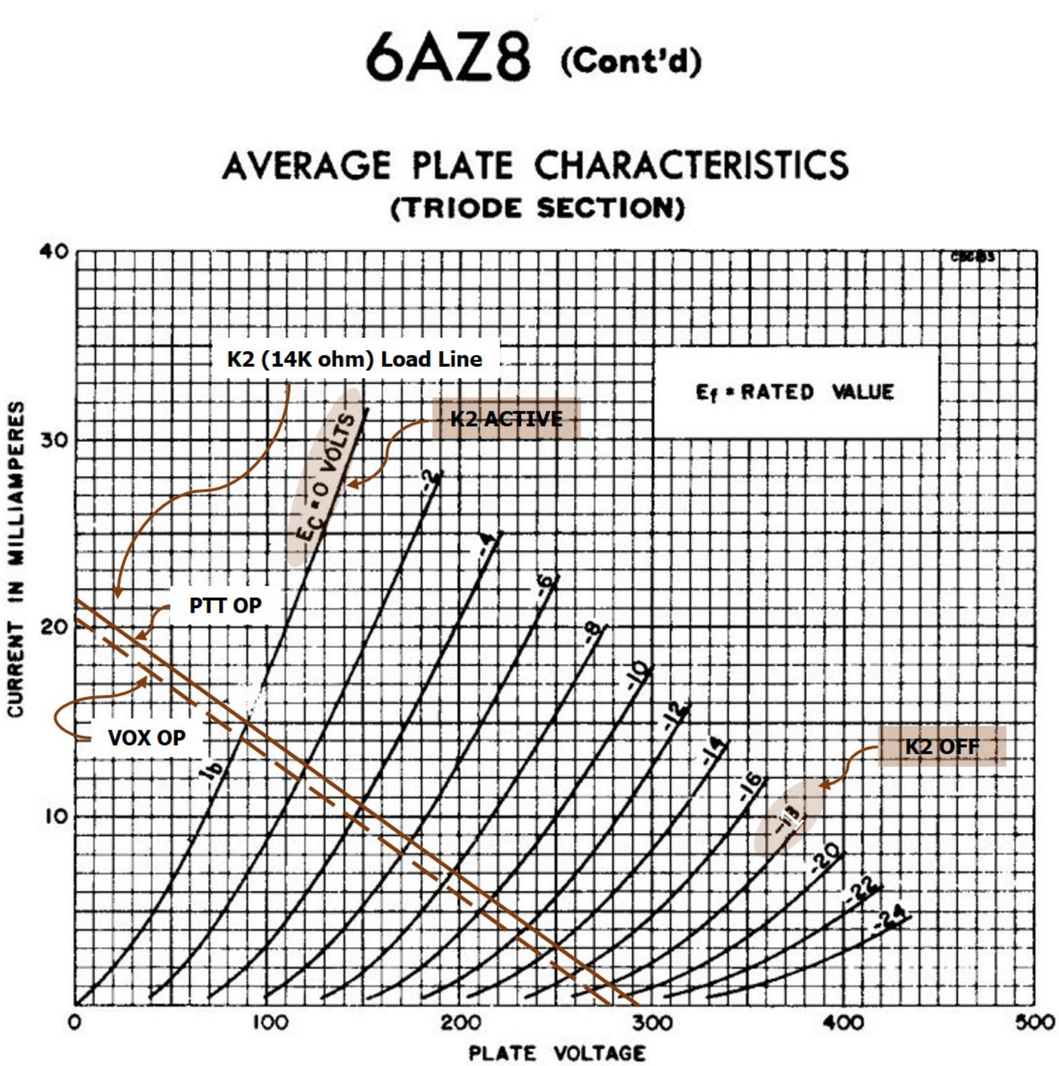
My thanks to Marc Niebergall, K7WXK for his help in generating data to do this documentation and for his good technical work. Also thanks to Dan Jackson, W5QN and the *Signal Magazine* Technical Editor, for his help in proofing the work technically.

There is also a <u>strong caution to anyone working on a KWM-2</u>. That radio is complex… OK, you knew that. But, what you may not know is that the first 25 radios built by production all did not work – at all. They all had to be reworked to get the grounds and shield grounding lead lengths as short and direct as the engineering guys had meant them to be. That radio has a lot of stray signal feed through going on and only by minimizing that, does the radio work reliably. Even the best repair guys that work on hundreds of M-2s will throw up their hands sometimes on a radio that has been "worked on" too much, and has too many lead placement issues to run down. So…the lesson is, be very careful about lead placement, cable bundling and wire routing. Do your documentation carefully and your work even more carefully. You may find component locations or routings that do not make sense to you. Leave them alone.

<u>Supplemental Information</u>

<u>6AZ8 Triode Characteristics (Source Sylvania Data Sheet)</u> – Shown with V4B Load line (Dashed is VOX)

Ec = Grid Voltage w/ respect to the Cathode



Late M-2 Relay Data 1978 9th Edition Manual	**CPN**		**Sup P/N**
K3 Item 201(1978)	970 1914 000	[p 36 of 86 pdf website] No coil resistance given	KR2565-1
K2 Item 667(1978) Shown P24/86	970 1940 000 970 2439 010	(V71482) (V70309)	
K4 Item 662(1978) Shown P57 & 58 of 86	979 1941 000 970 2439 020	(V04221) (V70309)	110-3680 T163X97

Note, there appears to be a schematic error that is a vestigial hang out from the pre-plug-in relay days. In the 9th Edition manual, the schematic shows the coil resistance of K2 as the older 14K ohms when we now believe it is 1.4K, this requiring the addition of the 12 K resistor in the plate lead of V4B.