A Look at the Low Voltage Section of the 516F-2 Power Supply and Related Issues

By

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August 20, 2018

Over the years there have been a number of emails on the CCA reflector discussing the voltage produced by the low voltage B+ (LVB+) section of the 516F-2 power supply. Some of these emails discussed the need to produce a more suitable voltage level in view of line voltages being higher today and that a large percentage of 516F-2 power supplies in service use solid state diode rectifiers replacing the 5U4GB and 5R4GYA tubes. Along with this, there were emails that discussed ways to reduce the LVB+ voltage. Two of the ways were to insert a resistor just before L2 and, alternatively, putting a 20 Volt Zener diode in the center tap lead to ground of the transformer section suppling the LVB+. For power supplies with solid-state diodes, there has been discussion about utilizing the two unused 5 VAC filament windings as part of the transformer's primary to increase the number of primary turns. Doing so would lower the turns ratios for all sections of the secondary. To learn more about transformer winding techniques, you can read the article written by Don Jackson, W5QN in the Q1, 2015 issue of *The Signal*. Lastly, there were emails that discussed using a regulator to control the LVB+ and, as it turns out, some are in use.

I have one 516F-2 waiting to be refurbished and five operational 516F-2 power supplies, four of which are used with S-Line stations using 32S-3s. Needless to say, I have a vested interest in this topic. As a result, I decided to look into the LVB+ voltage issue by testing ten LVB+ supply configurations to generate data. This data would address known issues such as the effects on the LVB+. The data would also potentially reveal unknown issues, such as unanticipated secondary effects or interactions that may need to be dealt with. Moreover, I wanted any changes I made to my 516F-2s to be fact-based and data driven with the goal of using a power supply configuration that is more appropriate for our aging radios and to identify potentially beneficial changes.

But first, some background.

Figure 1 is a partial schematic of the 516F-2 power supply that highlights the low voltage B+ section including the combined bias circuitry. This was taken from the owner's manual, which includes the voltages shown on the schematic. The owner's manual also states at a 115 VAC line voltage, the low voltage B+ should be no less than (NLT) 250 VDC during transmit and no more than (NMT) 310 VDC in receive.

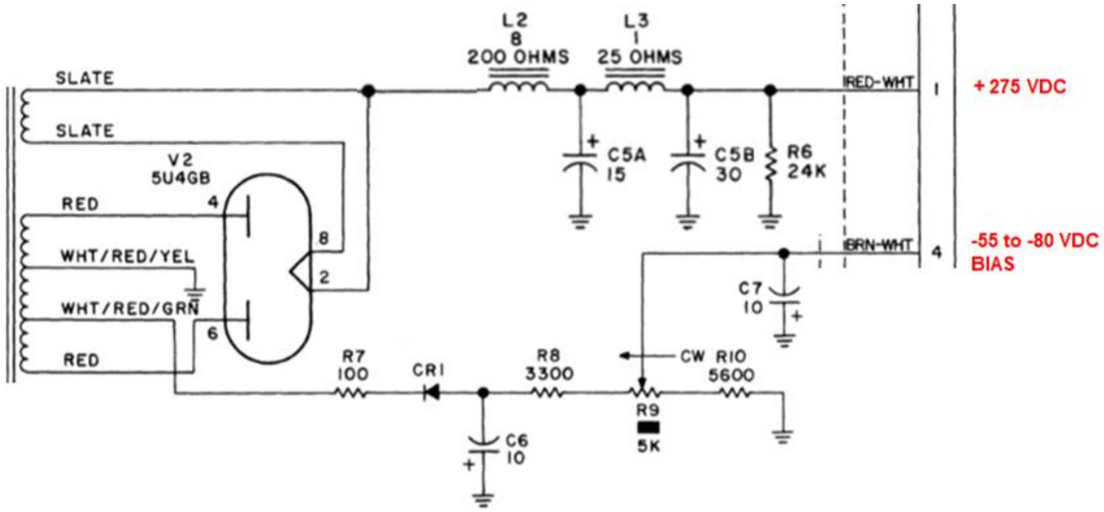


Figure 1 – Partial Schematic of 516F-2 Using Tubes

In August, 1976 Collins issued a Service Information Letter, SIL 1-76, for the 516F-2 with the stated purpose of eliminating arcing problems of the rectifier tubes by replacing them with solid state diodes. With this change, the LVB+ section looks like the partial schematic shown in **Figure 2.** Here too Collins shows power supply voltages at a line voltage of 115 VAC. Further, on page 1 of the SIL, it mentions the change from tubes to solid state diodes will increase the voltages by 12% and that you should reset the bias level as operating voltages have changed. This statement alerts us that when different modifications are made to the configuration shown in **Figure 1**, the bias may need to be reset for two reasons. The operating conditions for a 32S-3 or KWM-2 will change and some modifications, such as putting a Zener diode in the transformer's center tap to ground lead, may alter the bias circuit's operation. The data in this article will illustrate the impact of the 12% increase in voltages, and the effects of higher line voltages and the effect of circuit modifications. Part of the testing included taking bias circuit voltage readings. If the bias voltage and operating point have changed, it seems reasonable that you only need to readjust the bias pot (R9) to set the plate idling plate current to either 40 or 50 mA. This should not be a big deal. I will come back to this topic.

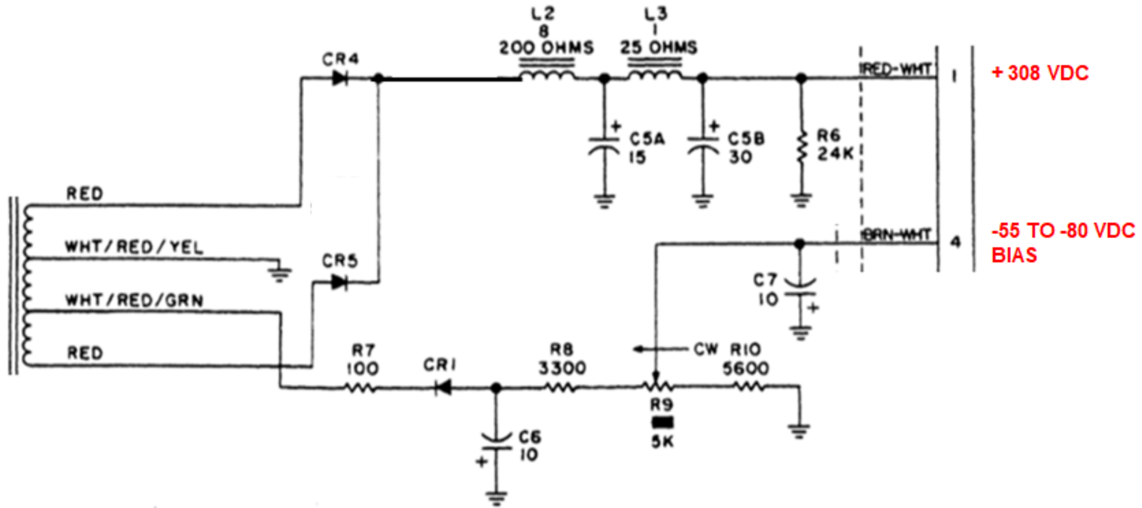


Figure 2 –Partial Schematic of a Solid State 516F-2 per SIL 1-76

The general increase in line voltages and higher voltages produced by using solid state diodes may be harmful to our rigs. To counter this, there are three commonly used circuit changes that provide different levels of mitigation. One of the most common methods with units converted to use solid state diodes is to install a 200 Ohm resistor just before L2 as shown in **Figure 3**. There are several rebuild kits that use this approach and this is what K7RMT, aka The Budster, did as part of the over five hundred 516F-2s he modified. This is one of the configurations I tested as well as the SIL 1-76 version shown in **Figure 2,** which does not have the dropping resistor. I do not know who first came up with using a dropping resistor. The earliest mention of this approach I am aware of was in an article in the September, 1979 issue of *Ham Radio* written by Bill Orr, W6SAI, although the article showed a 130 Ohm resistor. I do not know when 200 Ohms became common practice or who first started doing this. As a point of interest, all configurations of the 516F-2 have an inherent form of dropping resistor provided by the windings of L2 and L3. The schematics show these to be 200 and 25 Ohms respectively. Measurements by Don, W5QN, using his 516F-2 and two of mine showed these resistances to be in the 150 to 183 Ohm and 16 to 38 Ohm ranges.

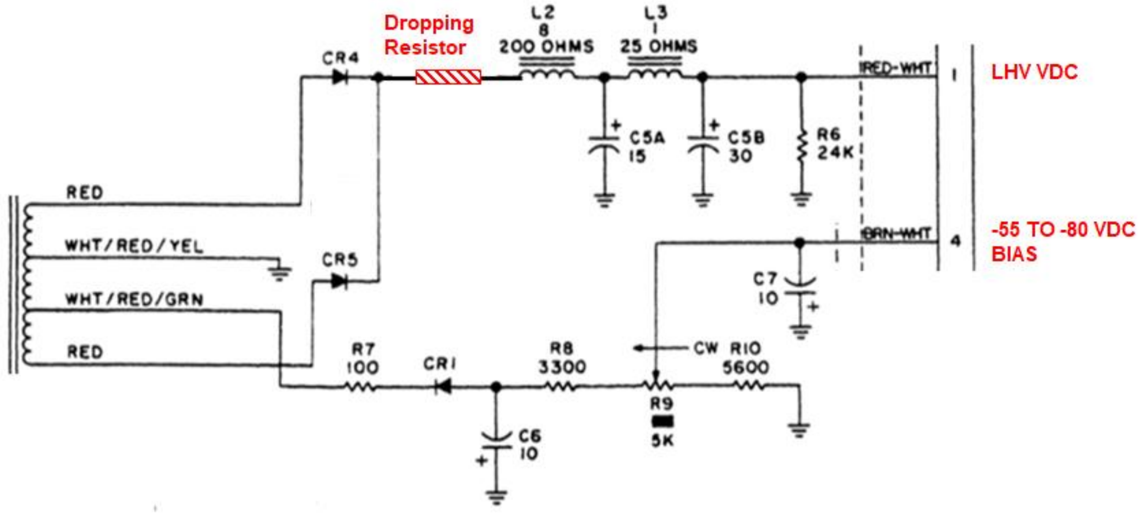
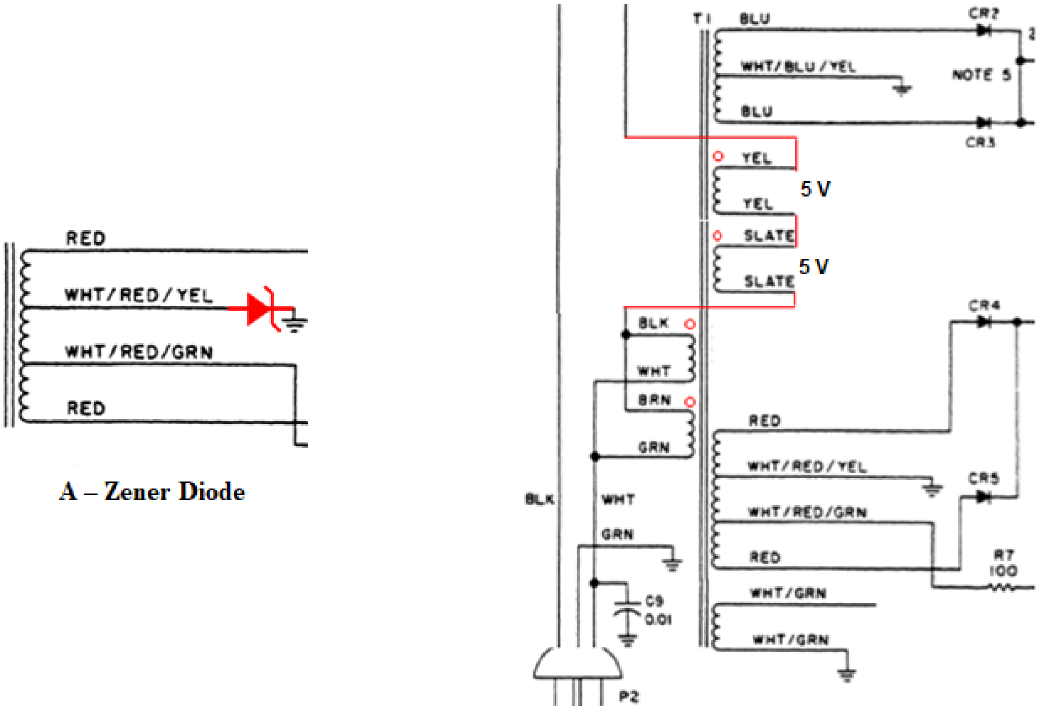


Figure 3 – Partial Schematic for a Solid State 516F-2 with Dropping Resistor

I mentioned earlier that one method discussed uses a Zener diode in the center tap of the transformer section suppling the LVB+ as shown by the partial schematic in **Figure 4A**. The thought was a 20 Volt Zener diode would lower the voltage produced by the LVB+ supply by about 20 VDC. This is another configuration I tested.

The last configuration I tested is illustrated in **Figure 4B**. This can be used with a 516F-2 that has solid state diodes in place of the two rectifier tubes. Not using the tubes frees-up the two 5 VAC filament windings so they can be wired as part of the primary. Doing so adds turns to the primary, which lowers the step-up ratios for the secondary's sections. This is one of the wiring arrangements covered in Don's article.



A – Zener Diode

B – Using Filament Windings

Figures 4A and 4B – Zener Diode and Filament Winding Modifications

Now on to testing and results.

Testing was done using two 516F-2 power supplies. One could be configured to use diodes or tubes. To use diodes, the rectifier tubes were pulled and octal plugs with diodes soldered to the correct pins were installed in place of them. This unit had a 200 Ohm dropping resistor as shown in **Figure 3**. I also added two 10 Volt Zener diodes in series in the center tap lead-to-ground of the transformer section suppling the LVB+. Using jumper leads, I could bypass the dropping resistor, the Zeners, or both. I could also remove the tubes and install the octal plugs with diodes. With this power supply there were eight different combinations I could test – four with tubes and four with the diodes. In the following tables, test configurations 1-4 used tubes and 5-8 used diodes. I included configurations 4 and 8 just to see what the results would be and to create data out of the area of interest. I do not see these “out of interest” configurations as viable and I do not consider them later except in a few cases.

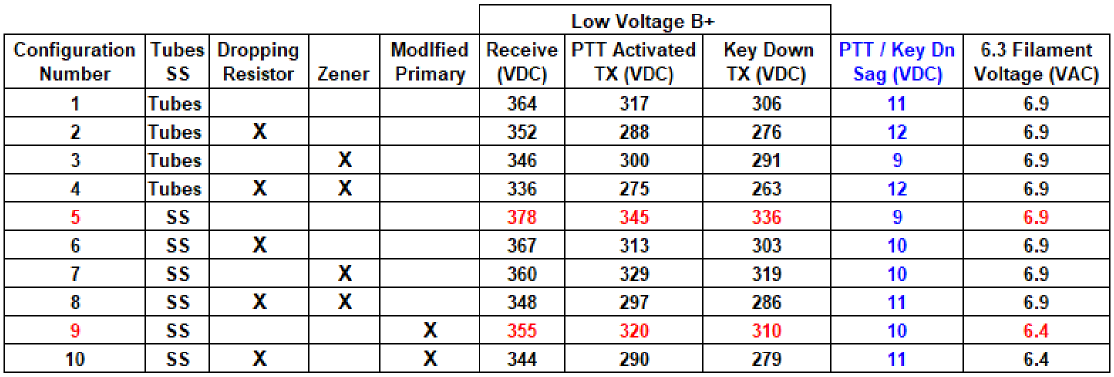
The second 516F-2 uses a power supply board made by Farm Radio Products. It uses the basic circuit shown in **Figure 2,** but with the two sets of unused 5 VAC filament leads in the transformer’s primary as shown in **Figure 4B**. There are two configurations listed using this board. The first uses the Farm Radio Products board as intended and the second configuration adds a 200 Ohm dropping resistor. In the tables below, these two configurations are listed as configurations 9 and 10.

Table 1 and **Table 2** show the measured voltages seen using one of my 32S-3s and a borrowed KWM-2 from Dexter, K5WDW using the ten LVB+ configurations at a line voltage of 123

VAC. The tables show whether or not a dropping resistor was used, whether or not a Zener diode was used, and whether or not the primary winding was changed. You will also see configurations where both a dropping resistor and Zener diodes were used. The table has three measured LVB+ voltages listed. The first is for when the 32S-3 and KWM-2 were in Receive, the second was when the PTT was activated, referred to as PTT Activated, and the third is for Key Down. During this testing and testing discussed later, the 32S-3 was putting 100 Watts into a dummy load while the KWM-2 was putting out between 80-90 Watts. There are additional columns in blue. For the 32S-3, the single blue column shows the differences between the PTT Activated and Key Down measured values, which is how much the LVB+ sags during transmit. Also listed are the measured values for the filament voltages seen by the tubes in the 32S-3. For the KWM-2 there are two blue columns. The first shows the differences between the PTT Activated and Key Down measured values, which is how much the LVB+ sags during transmit. The second column is how much the KWM-2's LVB+ sags between Receive and Key Down. I will address this topic later.

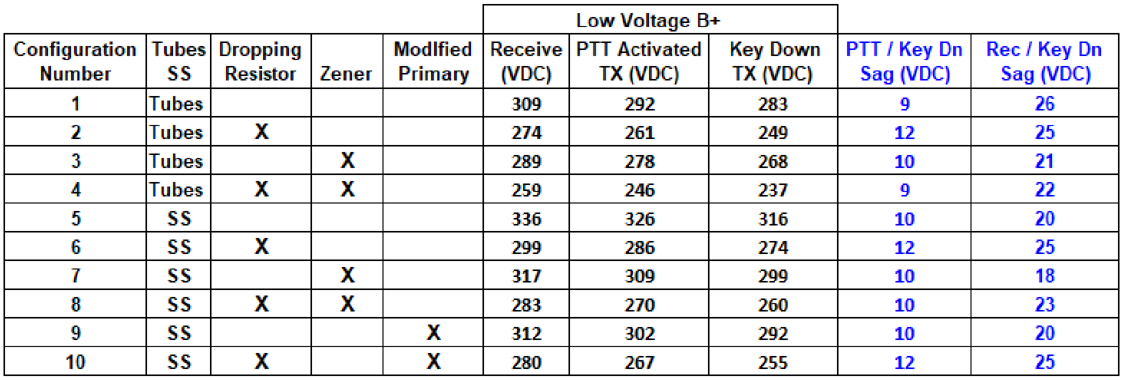
The two tables show different voltage levels for different configurations as we would expect. What is of immediate interest, though, is the amount the LVB+ sags when in the transmit mode. The sag between PTT Activated and Key Down is in the 9-12 VDC range regardless of configuration. So there appears to be no value to using a regulator to limit the LVB+ sag when in the transmit mode. However, there may be a role for an LVB+ regulator if you believe the LVB+ is too high overall or wish to set it to a specific, regulated level.

Table 1 – Low Voltage B+ Supply and 6.3 VAC Filament Voltage Testing with a 32S-3



					Low Voltage B+				
Configuration Number	Tubes SS	Dropping Resistor	Zener	Modified Primary	Receive (VDC)	PTT Activated TX (VDC)	Key Down TX (VDC)	PTT / Key Dn Sag (VDC)	6.3 Filament Voltage (VAC)
1	Tubes				364	317	306	11	6.9
2	Tubes	X			352	288	276	12	6.9
3	Tubes		X		346	300	291	9	6.9
4	Tubes	X	X		336	275	263	12	6.9
5	SS				378	345	336	9	6.9
6	SS	X			367	313	303	10	6.9
7	SS		X		360	329	319	10	6.9
8	SS	X	X		348	297	286	11	6.9
9	SS			X	355	320	310	10	6.4
10	SS	X		X	344	290	279	11	6.4

Table 2 – Low Voltage B+ Supply Testing with a KWM-2



					Low Voltage B+				
Configuration Number	Tubes SS	Dropping Resistor	Zener	Modified Primary	Receive (VDC)	PTT Activated TX (VDC)	Key Down TX (VDC)	PTT / Key Dn Sag (VDC)	Rec / Key Dn Sag (VDC)
1	Tubes				309	292	283	9	26
2	Tubes	X			274	261	249	12	25
3	Tubes		X		289	278	268	10	21
4	Tubes	X	X		259	246	237	9	22
5	SS				336	326	316	10	20
6	SS	X			299	286	274	12	25
7	SS		X		317	309	299	10	18
8	SS	X	X		283	270	260	10	23
9	SS			X	312	302	292	10	20
10	SS	X		X	280	267	255	12	25

Questions about the effectiveness of putting the unused 5 VAC filament windings in the primary can be answered by comparing configurations 5 and 9 in **Table 1**. Both use the SIL1-76 configuration shown in **Figure 2.** Configuration 5 does not make use of the two 5 VAC windings while configuration 9 uses them in the primary of the transformer. The receive LVB+ voltage drops from 378 to 355, the PTT Activated voltage drops from 345 to 320, and the Key Down voltage drops from 336 to 310. In addition, the table shows a drop in the filament voltage from 6.9 to 6.4 VAC. Clearly, configuration 9 is a viable method as it lowers the LVB+ and the filament voltage. As the table shows, both configurations 9 and 10 had the 5 VAC filament windings in the transformer's primary. Based on the change of the turns ratio for the 6.3 VAC windings, we would expect to see the filament voltage to drop by about 0.5 Volt, which is what testing shows for both configurations 9 and 10.

As a result of higher levels of LVB+ in general, I wanted to see if there was an effect on the 0A2 voltage regulator tube (V13) and resistor R17 in a 32S-3. Spec sheets for the 0A2 state the cathode current should be between 5 to 30 mA with 30 mA as the maximum. Using three power supply configurations, I measured the cathode current for the 0A2 when the PTT was activated and for Key Down using the three configurations that produce the highest levels of LVB+ during PTT Activated and Key Down. The first test used configuration number 5, which has the highest

LVB+ levels overall. The cathode current measured 38.1 mA with the PTT activated and 35.5 mA for Key Down. Both are too high.

The second test used power supply configuration 6, which is configuration 5 with a 200 Ohm dropping resistor. This time testing showed the cathode current was 30.1 mA for PTT Activated and 27.2 mA for Key Down. Both are near the spec limit of 30 mA. Needless to say, this begs the question about configuration 9, which has the 5 VAC filament windings in the primary. Using configuration 9, I measured 31.5 mA for PTT Activated and 28.5 mA for Key Down.

When the LVB+ was in the 275 VDC range, a 4,000 Ohm R17 may have been adequate. Now that LVB+ can be in the 276 to 345 VDC range, it is not. The 0A2 is operating above its upper spec limit and R17 can be producing more heat than its rated dissipation of 7 Watts. Changing the value of R17 to a higher resistance can solve both problems. As a note, 32S-3 schematics up to about 1975 show R17 to be 5000 Ohms while the parts list shows it to as 4000 Ohms. A 1975 schematic shows R17 to be 4000 Ohms while its parts list says 4000 Ohms. It appears there was an error in the schematic, which was corrected in 1975 or earlier.

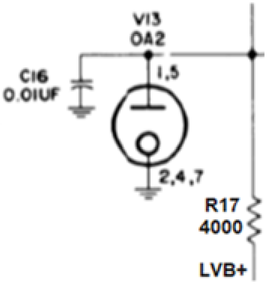
Using the data taken with the factory R17, a more appropriate value of 7000 Ohms was calculated. As a result, I replaced the 4000 Ohm R17 with a 7000 Ohm, 10 Watt, resistor and reran the three tests using configurations 5, 6, and 9. Also configuration 2 was tested because it is the configuration that produces the lowest values of LVB+ during PTT Activated and Key Down.

This time I have put the prior results and results after changing R17 in **Table 3** along with a partial schematic showing V13 and R17. This table shows changing R17 to 7000 Ohms drops the cathode current to more acceptable levels and is able to accommodate configurations 2, 5, 6, and 9. The question now is what about configuration 1, which is a factory configured, tubed power supply. **Table 1** shows configuration 1's LVB+ voltages are almost the same as configuration 9's. As a result, you can use the values for configuration 9 in **Table 2** to assess configuration 1.

Table 3 shows the cathode currents that result for the higher LVB+ voltages. Changing R17 to 7000 Ohms ensures cathode currents at these LVB+ levels are below the maximum spec rating of 30 mA. For the 0A2 to regulate at lower levels of LVB+, we need to be sure its cathode current does not drop below 5 mA. Testing showed the 0A2's current for configuration 2 was 9.1 and 8.1 mA for PTT Activated and Key Down respectively – both well above the 5 mA lower limit. With R17 changed to 7,000 Ohms we can be assured the 0A2 will provide regulated DC to its load over the range of LVB+s for all 516F-2 configurations tested. In reality, I did test configuration 4, but did not include the results in **Table 3.** For those of you who are just dying to know, the currents were 6.7 and 5.7 mA. There is also a motive to use 7000 Ohms for R17 rather than something like 6000 Ohms. Using a lower value R17 would move 0A2 cathode currents up a bit. But using 7000 Ohms results in a regulator that produces less heat than one using a lower resistance for R17.

Table 3 – 0A2 (V13) Cathode Current in a 32S-3 for Two Values of R17

		Measured 0A2 Currents (mA)	
Configuration	TX Mode / LVB+	R17 = 4000 Ohms	R17 = 7000 Ohms
5	PTT Act. / 345 VDC	38.1	17.3
	Key Down / 336 VDC	35.5	15.8
6	PTT Act. / 313 VDC	30.1	12.9
	Key Down / 303 VDC	27.2	11.2
9	PTT Act. / 320 VDC	31.5	14.1
	Key Down / 310 VDC	28.5	12.4
2	PTT Act. / 288 VDC		9.1
	Key Down / 276 VDC		8.1



Changing R17 to 7000 Ohms will lower V13's cathode currents to acceptable levels. At the same time, heat produced by the regulator, consisting of V13 and R17, will also be lowered. **Table 4** shows the heat levels for the PTT Activated state with the factory value of R17 and when it is changed to 7000 Ohms. You can see the net heat when R17 is 7000 Ohms is about half of when it was 4000 Ohms, but this savings is not realized all the time. During receive the 0A2 regulator in a 32S-3 is not fed LVB+ because relay K1 is open, which disconnects the LVB+. Due to this, there is no heat produce by the regulator during receive. You will, though, see the heat savings when the 32S-3 is in transmit mode – either PTT Activated or Key Down. Although a 10 Watt 7,000 Ohm resistor was used for testing, an 8 Watt version is more suitable as a replacement R17 due to its smaller size and dissipation margin for the heat loads shown in **Table 4.**

Table 4 – 32S-3 Regulator Heat When R17 is 4000 and 7000 Ohms

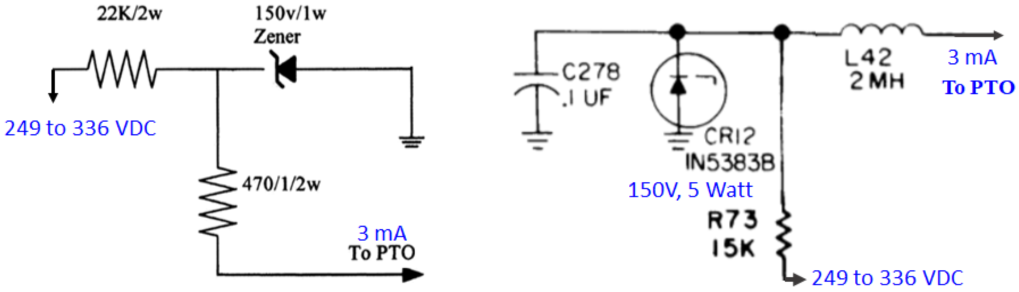
		R17 = 4000 Ohms			R17 =7000 Ohms			
Configuration	TX Mode / LVB+	0A2 Heat (W)	R17 Heat (W)	Net (W)	0A2 Heat (W)	R17 Heat (W)	Net (W)	Heat Reduction (Watts)
5	PTT Act. / 345 VDC	5.7	9.9	15.6	2.6	5.7	8.3	7.4
	Key Down / 336 VDC	5.3	9.0	14.4	2.4	5.2	7.5	6.8
6	PTT Act. / 313 VDC	4.5	7.0	11.5	1.9	4.0	5.9	5.6
	Key Down / 303 VDC	4.1	6.2	10.2	1.7	3.5	5.2	5.0
9	PTT Act. / 320 VDC	4.7	7.6	12.3	2.1	4.3	6.4	5.9
	Key Down / 310 VDC	4.3	6.7	11.0	1.9	3.8	5.7	5.3

There is one last important question about changing R17 to 7000 Ohms. When R17 is 7,000 Ohms, how well does the 0A2 regulate the voltage fed to the 32S-3's PTO? **Table 5** shows the resulting voltages and resulting PTO frequency changes for four power supply configurations when going between the PTT Activated and the Key Down states. I was amazed how well the 0A2 regulator worked. In fact, I could not measure with any certainty a PTO frequency shift. As a result, I have listed the PTO's frequency change as 0-1 Hz. It is also very interesting to see the regulator holds its output within about 1 Volt over a supplied LVB+ range of 276 to 345 VDC. This means as your line voltage changes, you will see essentially no change in the voltage fed to the PTO. It also means you can use any 516F-2 configuration and be assured you will have well regulated voltage for the PTO.

Table 5 – 32S-3 0A2 Regulation With a 7,000 Ohm R17

Configuration	Mode / LVB+	0A2 Voltage (VDC)	PTT Act. / Key Dn PTO Freq Shift (Hz)
5	PTT Act / 345	147.0	0-1
	Key Down / 336 VDC	146.8	
6	PTT Act / 313 VDC	146.6	0-1
	Key Down / 303 VDC	146.5	
9	PTT Act / 320 VDC	146.9	0-1
	Key Down / 310 VDC	146.7	
2	PTT Act / 288 VDC	146.2	0-1
	Key Down / 276 VDC	146.1	

The discussion of the 0A2 regulator raises the same questions for the Zener regulator in the KWM-2. I know of two Zener regulator circuits in use. These are illustrated in **Figures 5A and 5B**. **Figure 5A** was in an article written by John Fuhrman, K0LFA in the Q4, 2001 issue of *The Signal*. This circuit is often referred to as the Vietnam Mod and, sometimes, it is called the Vietnam Fix. I do not know the history of Vietnam Mod – when it was first used or who first implemented it. **Figure 5B** is from the January, 1978 KWM-2 owner's manual, which is reported to be the first manual (1) that shows use of a Zener regulator for the PTO. This is corroborated by note 11B on the schematic in this edition. Originally, the KWM-2 did not supply regulated DC to its PTO, which resulted in a reported 50 to 100 Hz frequency shift as the LVB+ sagged between receive and transmit.



5A (Vietnam Mod)

5B (Owner's Manual)

Figures 5A and 5B – KWM-2 PTO Zener Diode Voltage Regulators

For the two Zener regulator configurations shown in **Figures 5A** and **5B**, and variants I included, we will look at three aspects of their operation. Since there are a number of 516F-2 configurations a KWM-2 could be used with, we need to see how well different regulator designs provide regulated voltage to the rig's PTO for LVB+ in range of 249 to 336 VDC. Second, we need to be sure the minimum Zener current flowing is large enough to ensure the circuit is able to operate as a regulator and that the maximum current seen is not over the Zener's upper current limit. Lastly, we need to be sure both the series resistor and Zener diode are operating within their rated heat dissipations.

Before we look at test data, we can use the diagrams in **Figure 8** to show what is going on. The circuit diagram shows the Zener modeled as a 150 VDC source in series with RDR, which is called the dynamic resistance or dynamic impedance of the Zener. RDR behaves as a variable resistor with decreasing resistance as the current through the Zener increases. This effect can be seen by the example Zener curve of bias voltage versus Zener current. As the reverse bias is increased (more negative) there is little current flowing as illustrated by the red part of the curve until the breakdown voltage is reached. At this point, the Zener current rapidly increases with applied voltage. This is shown as the blue line portion of the Zener curve. RDR is a parameter that partially defines the regulation performance of the Zener diode, and can be thought of as the "slope" of the Vz vs. Iz curve, ΔVz/ΔIz. Clearly, RDR is different depending on Iz. In practice, a guideline for Zener regulators (2) is to not allow the minimum Zener current to be less than 5-10% of its maximum current rating. Following this guideline will ensure the Zener current is above the knee in the Zener curve shown in **Figure 8.** Below this current you can drop out of regulation or generate noise.

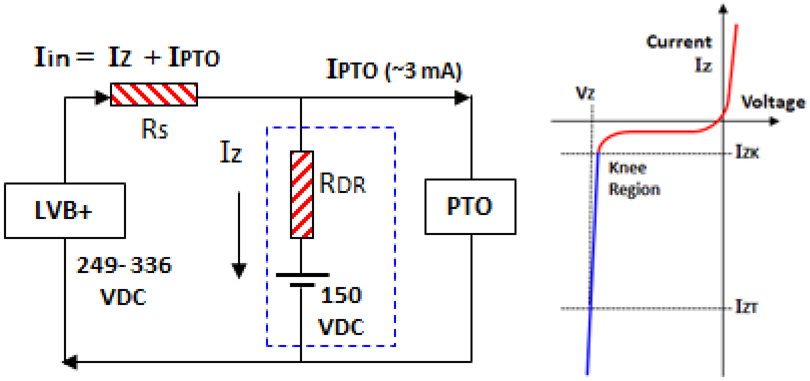
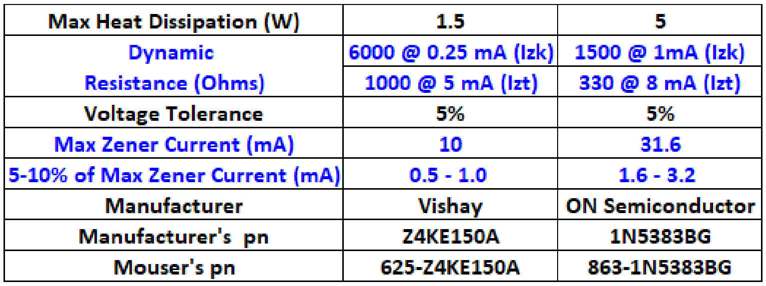


Figure 8 – 150 Volt Zener Regulator Circuit Model and Example Zener Curve

Table 6 lists some of the characteristics for the two Zeners used to investigate the impact of a range of LVB+ on the regulated voltage fed to a KWM-2's PTO. First thing to notice is I show a 1.5 Watt Zener rather than a 1 Watt Zener. This is because I could not find a 1 Watt version, but I could easily get one that was 1.5 Watt. The table includes the dynamic resistances at two Zener current levels for each of the two diodes. You can see how RDR decreases with increasing Iz. Also listed are the maximum allowable Zener currents, the maximum heat dissipation capacity for each, and the minimum values for Iz that follow the 5-10% of maximum Iz design guideline. You will also find the manufacturer's and Mouser's part numbers.

Table 6 – Characteristics of 150 Volt Zener Diodes Used for Testing



Max Heat Dissipation (W)	1.5	5
Dynamic Resistance (Ohms)	6000 @ 0.25 mA (Izk)	1500 @ 1mA (Izk)
	1000 @ 5 mA (Izt)	330 @ 8 mA (Izt)
Voltage Tolerance	5%	5%
Max Zener Current (mA)	10	31.6
5-10% of Max Zener Current (mA)	0.5 - 1.0	1.6 - 3.2
Manufacturer	Vishay	ON Semiconductor
Manufacturer's pn	Z4KE150A	1N5383BG
Mouser's pn	625-Z4KE150A	863-1N5383BG

Testing the KWM-2's Zener regulator was a bit more complicated than the 0A2 in a 32S-3. This is because the two commonly used baseline configurations are sometimes implemented a bit differently and that I added to these for a total of six variations, all of which use 150 Volt Zener diodes. The baseline Vietnam Mod shown in **Figure 5A** has a Zener with a 1 Watt heat dissipation rating and the baseline factory regulator shown in **Figure 5B** uses a 5 Watt Zener. As mentioned, I used a 1.5 Watt Zener in place of a 1 Watt version. In all cases, the series resistors have heat dissipation ratings of 2 Watts.

The six versions of the regulators were combinations using two different Wattage 150 Volt Zeners each with the same three series resistor values. The resistor values used were: 15,000 Ohms shown in the manual, 22,000 Ohms shown for the Vietnam Mod, and 27,000 Ohms, which I added. These were tested using four power supply configurations, which cover the span of the ten configurations used for testing shown earlier. Results are shown in **Tables 7A** through 7**C** for the tests using a 1.5 Watt Zener and shown in **Tables 8A** through **8C** using a 5 Watt Zener.

In the tables the voltages shown in blue are levels produced by the designated regulator design using four power supply configurations when the KWM-2 was in the Receive, PTT Activated, and Key Down states. The selection of power supply configurations included number 5 and number 2, which have the highest and lowest levels of LVB+ respectively.

Table 7A

1.5 Watt 150 Volt Zener - 15,000 Ohm Resistor

Power Supply Config.	Mode / LVB+	Zener Voltage (VDC)	Calculated Zener Currents (mA)	Rec. to Key Down PTO Freq Shift (Hz)
5	Rec / 336 VDC	164.6	8.4	3 - 4
	PTT Act / 326	164.2	7.8	
	Key Down / 316 VDC	163.9	7.1	
6	Rec / 299 VDC	162.4	6.1	3 - 4
	PTT Act / 286 VDC	161.3	5.3	
	Key Down / 274 VDC	160.6	4.6	
9	Rec / 312 VDC	163.7	6.9	3 - 4
	PTT Act / 302 VDC	162.4	6.3	
	Key Down / 292 VDC	162.3	5.6	
2	Rec / 274 VDC	160.7	4.6	3 - 4
	PTT Act / 261 VDC	159.3	3.8	
	Key Down / 249 VDC	158.5	3.0	
	Worst Rec/Key Dn Droop	2.2		

Table 7B

1.5 Watt 150 Volt Zener - 22,000 Ohm Resistor

Power Supply Config.	Mode / LVB+	Zener Voltage (VDC)	Calculated Zener Currents (mA)	Rec. to Key Down PTO Freq Shift (Hz)
5	Rec / 336 VDC	160.6	5.0	3 - 4
	PTT Act / 326	160.3	4.5	
	Key Down / 316 VDC	160.0	4.1	
6	Rec / 299 VDC	158.2	3.4	3 - 4
	PTT Act / 286 VDC	157.5	2.8	
	Key Down / 274 VDC	156.9	2.3	
9	Rec / 312 VDC	159.5	3.9	3 - 4
	PTT Act / 302 VDC	159.0	3.5	
	Key Down / 292 VDC	158.6	3.1	
2	Rec / 274 VDC	158.3	2.3	3 - 4
	PTT Act / 261 VDC	157.3	1.7	
	Key Down / 249 VDC	156.6	1.2	
	Worst Rec/Key Dn Droop	1.7		

Table 7C

1.5 Watt 150 Volt Zener - 27,000 Ohm Resistor

Power Supply Config.	Mode / LVB+	Zener Voltage (VDC)	Calculated Zener Currents (mA)	Rec. to Key Down PTO Freq Shift (Hz)
5	Rec / 336 VDC	158.9	3.6	3 - 4
	PTT Act / 326	158.5	3.2	
	Key Down / 316 VDC	158.2	2.8	
6	Rec / 299 VDC	156.3	2.3	3 - 4
	PTT Act / 286 VDC	155.7	1.8	
	Key Down / 274 VDC	155.3	1.4	
9	Rec / 312 VDC	157.7	2.7	3 - 4
	PTT Act / 302 VDC	157.3	2.4	
	Key Down / 292 VDC	156.9	2.0	
2	Rec / 274 VDC	157.0	1.3	3 - 4
	PTT Act / 261 VDC	156.0	0.9	
	Key Down / 249 VDC	155.3	0.5	
	Worst Rec/Key Dn Droop	1.7		

Table 8A

5 Watt 150 Volt Zener - 15,000 Ohm Resistor

Power Supply Config.	Mode / LVB+	Zener Voltage (VDC)	Calculated Zener Currents (mA)	Rec. to Key Down PTO Freq Shift (Hz)
5	Rec / 336 VDC	160.5	8.7	3 - 4
	PTT Act / 326	160.2	8.1	
	Key Down / 316 VDC	159.8	7.4	
6	Rec / 299 VDC	159.2	6.3	3 - 4
	PTT Act / 286 VDC	158.2	5.5	
	Key Down / 274 VDC	157.3	4.8	
9	Rec / 312 VDC	159.6	7.2	3 - 4
	PTT Act / 302 VDC	159.0	6.5	
	Key Down / 292 VDC	158.6	5.9	
2	Rec / 274 VDC	155.1	4.9	3 - 4
	PTT Act / 261 VDC	154.3	4.1	
	Key Down / 249 VDC	153.6	3.4	
	Worst Rec/Key Dn Droop	1.9		

Table 8B

5 Watt 150 Volt Zener - 22,000 Ohm Resistor

Power Supply Config.	Mode / LVB+	Zener Voltage (VDC)	Calculated Zener Currents (mA)	Rec. to Key Down PTO Freq Shift (Hz)
5	Rec / 336 VDC	157.0	5.1	3 - 4
	PTT Act / 326	156.6	4.7	
	Key Down / 316 VDC	156.3	4.3	
6	Rec / 299 VDC	155.7	3.5	3 - 4
	PTT Act / 286 VDC	154.8	3.0	
	Key Down / 274 VDC	154.1	2.5	
9	Rec / 312 VDC	155.5	4.1	3 - 4
	PTT Act / 302 VDC	155.2	3.7	
	Key Down / 292 VDC	154.8	3.2	
2	Rec / 274 VDC	152.9	2.5	3 - 4
	PTT Act / 261 VDC	152.2	1.9	
	Key Down / 249 VDC	151.7	1.4	
	Worst Rec/Key Dn Droop	1.6		

Table 8C

5 Watt 150 Volt Zener - 27,000 Ohm Resistor

Power Supply Config.	Mode / LVB+	Zener Voltage (VDC)	Calculated Zener Currents (mA)	Rec. to Key Down PTO Freq Shift (Hz)
5	Rec / 336 VDC	153.6	3.8	3 - 4
	PTT Act / 326	153.4	3.4	
	Key Down / 316 VDC	153.3	3.0	
6	Rec / 299 VDC	153.7	2.4	3 - 4
	PTT Act / 286 VDC	153.0	1.9	
	Key Down / 274 VDC	152.4	1.5	
9	Rec / 312 VDC	154.2	2.8	3 - 4
	PTT Act / 302 VDC	153.9	2.5	
	Key Down / 292 VDC	153.5	2.1	
2	Rec / 274 VDC	151.4	1.5	3 - 4
	PTT Act / 261 VDC	150.8	1.1	
	Key Down / 249 VDC	150.3	0.7	
	Worst Rec/Key Dn Droop	1.3		

To help compare the performance of the six regulators, each table shows a number in red labeled “Worst Rec/Key Dn Droop.” This shows the worst-case regulated voltage droop when switching from Receive to Key Down using the four power supply configurations. This gives a look at the worst-case regulation provided by the designated regulator design over the range of LVB+ supplied by different power supply configurations including the ones that produce the highest and lowest levels of LVB+.

There is a second indicator of a regulator's performance shown in the tables for each power supply configuration. This is how much the KWM-2's PTO's frequency changed between the Receive and Key Down states. I was unable to accurately measure the shift because the PTO did not settle to one exact frequency but moved around a bit. However, I was able to determine it was consistently between 3-4 Hz, which is undetectable on the air.

For the regulators using 1.5 Watt Zeners, **Tables 7B** and **7C** show to have the same, or nearly the same, lowest red number. For 5 Watt Zeners, **Table 8C** shows the lowest red number followed by **Table 8B**. This may seem to say these regulators are good choices. Before we pick between these, we first need to look a bit deeper at the operation of these designs. Using the measured voltages and using a 3 mA current for PTO, the Zener currents were calculated and are shown for each line entry in the tables. This was done to see if over the range of LVB+ levels the Zeners did not exceed their maximum allowable currents and that the minimum Zener currents were above the minimum values for Iz shown in **Table 6,** which follow the 5-10% of maximum Iz design guideline. A good question is why did I use a current of 3 mA for the PTO. I measured the currents going to the PTOs in three 32S-3s. The measured currents were 2.53, 2.55, and 2.60 mA at 148.0, 147.5, and 149.5 VDC respectively. If these measured values are ratioed to 164 VDC to cover Table 7A, the worst case for the three is 2.85 mA. Similarly, if you use 155 VDC, the outcome is 2.70 mA. As a result, using 3 mA is good number to use because it includes some margin to mitigate uncertainties and is rooted in measured data.

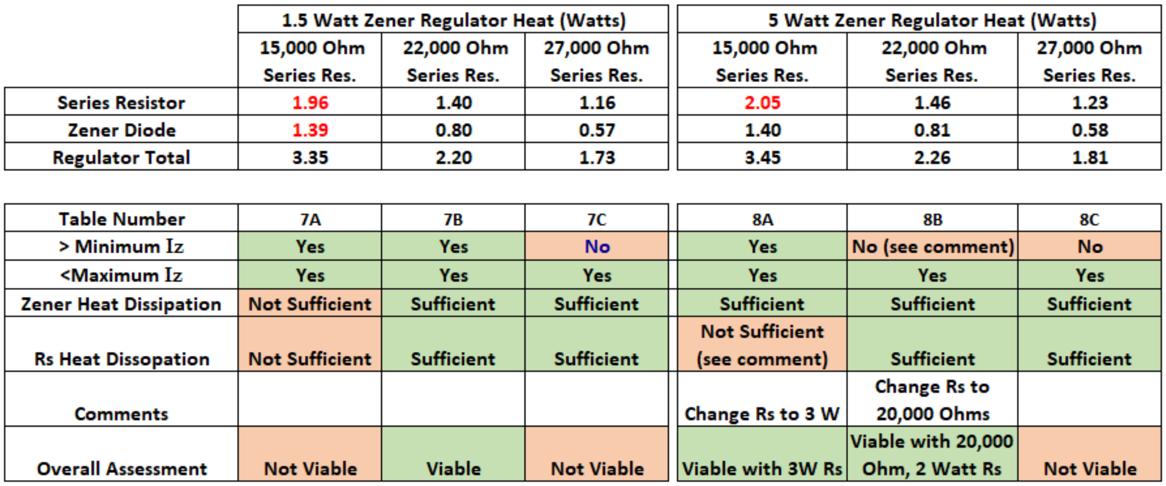
The Zener current levels that are below their minimums are highlighted with a beige background as seen in **Tables 7C** and **8C**. I would rule out these designs unless you are always going to be operating with a higher LVB+ than provided by 516F-2 configuration 2. **Table 8B** has a beige entry that is right on the edge of being acceptable. The minimum Zener current could be increased from 1.4 mA to about 1.8 mA if the 22,000 Ohms series resistor was 20,000 Ohms instead.

It appears as though the designs covered in **Tables 7A, 7B, 8A**, and **8B** (with a 20,000 Ohm series resistor) are potentially viable designs. Now it comes down to the heat generated by the series resistors and Zeners. To assess the heat produced, the voltages for 516F-2 configuration 5 were used because it produces the highest levels of LVB+ and there are a number of these power supplies with this configuration in service. **Table 9** shows heat loads for the individual components and the total for each regulator design. When we look at a component's generated heat and compare it to its rated dissipation, it is not sufficient for generated heat to be at or slightly below its dissipation rating. This is because the ratings are generally stated with a 25ºC (77ºF) ambient with limits on the lead lengths that are used to conduct heat to their end connections in addition to the heat removed from the component's body by convection. To accommodate higher temperature surroundings and longer lead lengths, the stated dissipation has to be reduced or derated. If you look up a component's rating and how they are stipulated, you will see we almost never meet those conditions. In view of this, we need to ensure the heat generated by the components we use is lower than stated heat dissipation levels.

For example, **Table 9** shows 1.39 Watts of heat being generated by a 1.5 Watt Zener when used with a 15,000 Ohm series resistor. It is because of this that I stated the design was not viable. No one suggested this design was potentially viable to begin with – it was included to look at the trade space to find limits. You can see going to a 22,000 Ohm series resistor with a 1.5 Watt Zener (7B) you wind up with 0.80 Watts of Zener heat, which is well below the its dissipation rating. Also, Rs is below its 2 Watt rating. As a point of interest, the design with a 22,000 Ohm resistor and 1.5 Watt Zener is essentially the Vietnam Mod, but with a 1.5 Watt Zener. If a 1 Watt Zener had been available, the data would have most likely have shown a similar heat load. As a result, I would have labeled that design to be not viable. If you have installed the Vietnam mod with a 1 Watt Zener, you should consider replacing it with a 1.5 Watt Zener.

In the lower part of **Table 9** is a summary assessment of the six Zener regulators designs and how they compare to each other along with some comments. Those entries highlighted with light green are acceptable or meet some level of metric for proper operation. Those with the beige highlighting do not.

Table 9 – Zener Regulator Heat Levels with a Configuration 5 Power Supply and Overall Assessment



	1.5 Watt Zener Regulator Heat (Watts)			5 Watt Zener Regulator Heat (Watts)		
	15,000 Ohm Series Res.	22,000 Ohm Series Res.	27,000 Ohm Series Res.	15,000 Ohm Series Res.	22,000 Ohm Series Res.	27,000 Ohm Series Res.
Series Resistor	1.96	1.40	1.16	2.05	1.46	1.23
Zener Diode	1.39	0.80	0.57	1.40	0.81	0.58
Regulator Total	3.35	2.20	1.73	3.45	2.26	1.81

Table Number	7A	7B	7C	8A	8B	8C
> Minimum Iz	Yes	Yes	No	Yes	No (see comment)	No
<Maximum Iz	Yes	Yes	Yes	Yes	Yes	Yes
Zener Heat Dissipation	Not Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient
Rs Heat Dissopation	Not Sufficient	Sufficient	Sufficient	Not Sufficient (see comment)	Sufficient	Sufficient
Comments				Change Rs to 3 W	Change Rs to 20,000 Ohms	
Overall Assessment	Not Viable	Viable	Not Viable	Viable with 3W Rs	Viable with 20,000 Ohm, 2 Watt Rs	Not Viable

From **Table 9** I believe it is safe to conclude the following:

- The Vietnam Mod with a 1.5 Watt Zener (7B) is a viable design. Both component generated heat levels are below their rated dissipations. This, in effect, provides increased margin relative to what their derated component heat dissipations may be. Granted, we do not know the exact component temperatures, but the margin is significantly better than using room temperature conditions with ideal lead terminations to assess whether or not there is adequate heat dissipation capability.
- The 5 Watt Zener design with a 15,000 Ohm resistor (8A) can be made viable if the series resistor has a 3 Watt or larger heat dissipation rating.
- The design using a 5 Watt Zener and 22,000 Ohm series resistor (8B) is marginally viable because the Zener current with a configuration 2 power supply may be on the verge of dropping out of regulation for the Key Down state as shown in **Table 8B.** This can be solved by changing to a 20,000 Ohm, 2 Watt resistor. Doing so will result in a viable design.

Now you can make a choice between three alternatives. Each will work for any of the 516F-2 configurations except number 4, which is not of interest. I have not made this choice because I do not own a KWM-2. But if I did own a KWM-2, I would use the Vietnam Mod with a 1.5 Watt Zener (7B). I would do so because it produces the least heat. If the KWM-2 had a 5 Watt Zener and 15,000 Ohm series resistor (8A, factory design), I would change the resistor to 20,000 Ohms, 2 Watt.

Although the Zener regulator investigation was more extensive than the effort to assess the 0A2 in a 32S-3, it was well worth doing to understand the impact of different 516F-2 configurations on the regulated B+ fed to a KWM-2's PTO. It was also worth it to see the LVB+ from different 516F-2 configurations could be accommodated. If you would like to read more about regulators using Zener diodes, I suggest you read the on-line article titled *Silicon Zener Diodes* (2) published by Vishay Semiconductors.

While taking LVB+ data using a 32S-3, I recorded the minimum and maximum bias voltages over the adjustment range of R9 for each of the ten power supply configurations. I wanted to see the if changes in the LVB+ supply section affected the bias – especially if a Zener diode was used as shown in **Figure 4A**. I was also interested in the bias supply because the settings of R9 to produce idling plate currents of 40 or 50 mA with my 32S-3s have always been very near the higher voltage end stop of R9. **Table 10** shows the test results.

In the table you can see the measured voltage levels at the end positions of R9 and whether or not I could adjust the bias to produce a 40 or 50 mA idling plate current. This chart captures the effects of three voltages that change with power supply configuration. The first two are the LVB+ and the high voltage B+ (HVB+). Both of these set the rig's operating point, which dictates the required bias to set either 40 or 50 mA. The question is, can the 516F-2 produce the required bias voltage within R9's adjustment range. Has the minimum voltage produce by the bias section dropped such that R9's adjustment range has slipped too low? The owner's manual shows this range as -80 to -55 VDC. It appears configurations 1 through 8 may have bias problems and, in some cases, they do.

Table 10 – Measured Bias Voltages for a 32S-3 With Different 516F-2 Configurations

					Bias Adjust Range		Able to Set Bias	
Configuration Number	Tubes SS	Dropping Resistor	Zener	Modified Primary	Bias min (VDC)	Bias max (VDC)	40 mA	50 mA
1	Tubes				-115.9	-63.2	Y	Y
2	Tubes	X			-116.5	-64.2	Y	N
3	Tubes		X		-130.1	-71.8	N	N
4	Tubes	X	X		-131.0	-72.2	N	N
5	SS				-117.7	-64.4	Y	Y
6	SS	X			-117.0	-64.0	Y	Y
7	SS		X		-131.0	-71.9	Y	N
8	SS	X	X		-131.4	-72.3	N	N
9	SS			X	-92.7	-48.3	Y	Y
10	SS	X		X	-90.4	-47.0	Y	Y

Table 10 shows I could not adjust the bias in all cases. Looking at the chart you can see how the bias adjustment range changed depending on the power supply configuration. Most notable, configurations using a Zener diode shifted the most. This is to be expected because the Zener diode affects both the LVB+ and bias supplies. There's an easy way to solve this problem. But first, you can see the bias adjust range is shifted upward by about 20 Volts with configurations 9 and 10, both of which use a Farm Radio Products board.

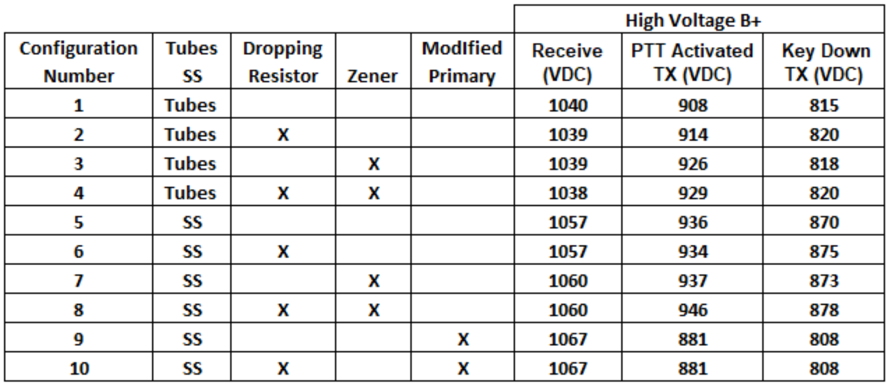
The designers of the Farm Radio Products board recognized the bias adjust problem. Their solution was to raise the adjustable span of R9 by changing R8 from 3,300 Ohms to 5,600 Ohms, which is has the same value as R10. Doing this results in about -70 to -68 Volts at the mid span of R9 rather than something in the -101 to -89-Volt range. For three of my four 516F-2s that do not have a Farm Radio Products board, I have changed R8 to 5,600 Ohms, 1 Watt. With these three power supplies, I now can set an idling plate current of either 40 or 50 mA with R9 near its midpoint. The remaining one of the four has a separate issue, which I will explain.

Early versions of the 516F-2 used a 2,500 Ohm pot for R9, which was later replaced with a 5,000 Ohm version. If you look in a 32S-1 owner's manual, you will find a 516F-2 schematic that shows this. I have one of these older 516F-2s in service, which is one of my four 516F-2s that does not have the Farm Radio Products board. When I took delivery of it, I could not set the idling plate current with the 32S-3 I paired it with. After a few minutes of trouble shooting, I found the problem and fixed it by replacing R8 and R10 with resistors that allowed me to set bias voltage I needed near the midpoint of R9's adjustment range. Further, my 516F-2 power supply that needs to be rebuilt also has a 2,500 Ohm R9. From this, it appears there may be a number of power supplies in service with a 2,500 Ohm R9.

I mentioned earlier that Service Information Letter 1-76 stated the change from tubes to solid state diodes will increase the voltages by 12% and that you should reset the bias level as operating voltages have changed. At the time SIL 1-76 was written, they were addressing the increase of HVB+ and LVB+ with a line voltage of 115 VAC. At that time, R9's voltage range was probably adequate. Now with line 125 VAC line voltages, it may not be adequate. Changing R8 fixes the bias problem with 516F-2s that have a 5,000 Ohm R9.

While taking data, I also recorded the high voltage B+ (HVB+) levels seen by a 32S-3, which are listed in **Table 11.** I took this data to answer questions about the impact different power supply configurations have on the HVB+. Since modifications were made to the LVB+ supply section and not the HVB+ section, we would not expect the ten different configurations to give us ten different sets of HVB+ voltages. This is what we see. **Table 11** shows the HVB+ levels fall into three groups. Configurations 1 through 4 use tubes. Configurations 5 through 8 use solid state diodes in place of the tubes. For these, the HVB+ increased as we would expect. Configurations 9 and 10 using solid state diodes have lower levels of HVB+, which results from putting the unused 5 VAC filament windings in the primary. Data for LVB+ and HVB+ show operating conditions can vary and why you will most probably have to readjust the bias.

Table 11 – High Voltage B+ Levels for Different 516F-2 Configurations With a 32S-3



					High Voltage B+		
Configuration Number	Tubes SS	Dropping Resistor	Zener	Modified Primary	Receive (VDC)	PTT Activated TX (VDC)	Key Down TX (VDC)
1	Tubes				1040	908	815
2	Tubes	X			1039	914	820
3	Tubes		X		1039	926	818
4	Tubes	X	X		1038	929	820
5	SS				1057	936	870
6	SS	X			1057	934	875
7	SS		X		1060	937	873
8	SS	X	X		1060	946	878
9	SS			X	1067	881	808
10	SS	X		X	1067	881	808

One of the questions we need to address is how the life of tubes in our rigs are affected by higher filament voltages. In our case, we are seeing tubes designed for 6.3 VAC operation now running at 6.9 VAC, which is about 10 percent higher. In Robert Tomer's book, *Getting the Most Out of Vacuum Tubes*, he states, "Tubes, when operated at ten percent above their rated heater voltage, will suffer up to a fifty percent decrease in heater life." (3) Tomer also says this conclusion was based on failure studies using more than 10,000 burned out tubes. Tomer's statement gives us insight into filament failures. It tells us the potential impact of not reducing the filament supply voltage to the 6.3 VAC range.

There are also reliability issues with our rigs running warmer due to increased internally generated heat because line voltages have gone from 115 to 125 VAC. One source of increased heat is due to both the 6.3 VAC and 5 VAC filament tubes seeing higher filament voltages. For a 32S-3, the filament heat increases from 41 Watts to 49 Watts. For a KWM-2 it jumps from 63 Watts to 76 Watts. If you use a 516F-2 with tubes, the rectifier filament heat goes from 25 Watts to 29.5 Watts. There is also be more heat produced due to higher levels of LVB+ and HVB+.

How do we distinguish between failures attributed to normal aging and accelerated aging due to our rigs running warmer? I don't believe anyone has kept accurate records for our rigs over a number of years. Regardless, we can get an idea about how much failure rates differ for only a 5ºC (9ºF) rise in component temperature using **Equation 1.** This gives us the acceleration factor, A, which is the ratio when failure rates at two temperatures are compared. This equation is derived starting with the equation for the Law of Arrhenius. (4)

$$A = exp\left[\frac{E}{k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right] \qquad T_1 > T_2$$

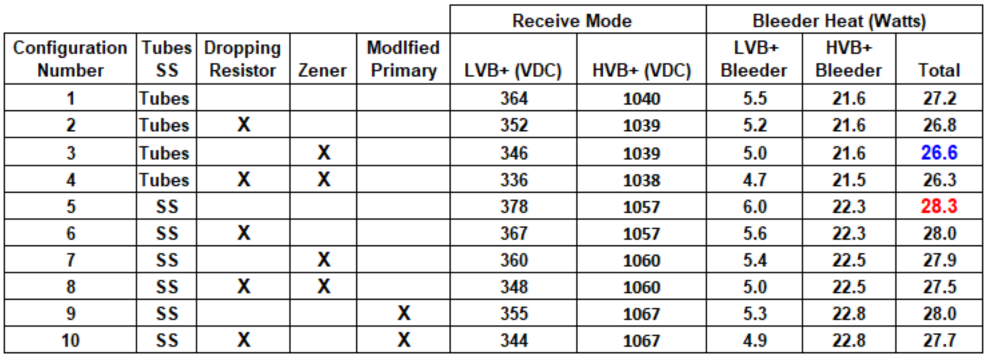
A = Acceleration Factor
T_1 = Temperature (ºK)
T_2 = Temperature (ºK)
E = Activation Energy (eV)
k = 8.63 E-05 eV/ºK (Boltzmann's constant)

Equation 1 – Reliability Acceleration Factor Based on the Law of Arrhenius

For example, if we use a conservative activation energy of 0.6 eV with an upper temperature of 60ºC (140ºF) for T_1 and 55ºC (131ºF) for T_2, the failure rate at T_1 will be about 1.4 times higher than it was at T_2. In our case, it is difficult to say what the temperatures are for components in our rigs. This is complicated by all the parts being at different temperatures. Though this does show components will have a lower reliability with increased temperature – of course we all knew that. In our case, our rigs produced some level of heat with a line voltage of 115 VAC. Now that it is in the 125 VAC range, the heat has gone up somewhere in the 18 percent range, which will increase component temperatures. What we can do, though, is to reduce the heat the best we can. One viable way is to drop the 6.9 VAC filament voltage back to the 6.3 VAC range. This not only improves the reliability of the tubes but helps reduce the net heat within a rig. Other ways to reduce heat is to make changes to the voltage regulators and drop LVB+ and HVB+ to lower levels.

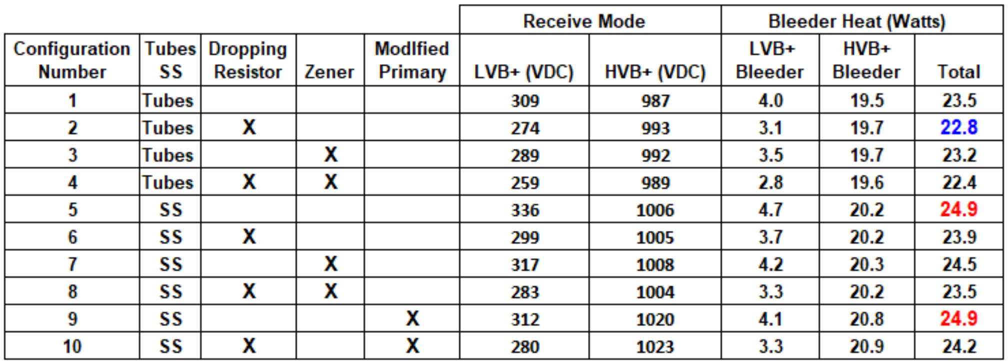
In a 516F-2 there are two additional, and quite evident, sources of heat. These are the bleeder resistors R6 (24,000 Ohms) across the LVB+ and the series connected R4 and R5 (25,000 Ohms each) across the HVB+. **Table 12** shows the heat produced by R6 and the R4/R5 combination for a 32S-3 in its receive mode. As you can see in the table, the total bleeder heat loads produced by the different 516F-2 configurations vary within a band of 1.7 Watts. In the PTT Activated or Key Down modes, the net heat will be less as the LVB+ and HVB+ sections are more heavily loaded. In my case, I use CW only working DX and spend more than 95% of my time listening. As a result, it is appropriate for me to use the receive mode to assess the bleeder heat. **Table 13** shows the heat produced by a KWM-2 when in its receive mode. Here the total bleeder heat loads produced by different power supply configurations vary within a band of 2.2 Watts. As a result, I do not believe bleeder heat is an issue when figuring out which 516F-2 configuration to use with either a 32S-3 or KWM-2.

Table 12 – 516F-2 Bleeder Resistor Heat Loads Using a 32S-3



					Receive Mode		Bleeder Heat (Watts)		
Configuration Number	Tubes SS	Dropping Resistor	Zener	Modified Primary	LVB+ (VDC)	HVB+ (VDC)	LVB+ Bleeder	HVB+ Bleeder	Total
1	Tubes				364	1040	5.5	21.6	27.2
2	Tubes	X			352	1039	5.2	21.6	26.8
3	Tubes		X		346	1039	5.0	21.6	26.6
4	Tubes	X	X		336	1038	4.7	21.5	26.3
5	SS				378	1057	6.0	22.3	28.3
6	SS	X			367	1057	5.6	22.3	28.0
7	SS		X		360	1060	5.4	22.5	27.9
8	SS	X	X		348	1060	5.0	22.5	27.5
9	SS			X	355	1067	5.3	22.8	28.0
10	SS	X		X	344	1067	4.9	22.8	27.7

Table 13 – 516F-2 Bleeder Resistor Heat Loads Using a KWM-2



					Receive Mode		Bleeder Heat (Watts)		
Configuration Number	Tubes SS	Dropping Resistor	Zener	Modified Primary	LVB+ (VDC)	HVB+ (VDC)	LVB+ Bleeder	HVB+ Bleeder	Total
1	Tubes				309	987	4.0	19.5	23.5
2	Tubes	X			274	993	3.1	19.7	22.8
3	Tubes		X		289	992	3.5	19.7	23.2
4	Tubes	X	X		259	989	2.8	19.6	22.4
5	SS				336	1006	4.7	20.2	24.9
6	SS	X			299	1005	3.7	20.2	23.9
7	SS		X		317	1008	4.2	20.3	24.5
8	SS	X	X		283	1004	3.3	20.2	23.5
9	SS			X	312	1020	4.1	20.8	24.9
10	SS	X		X	280	1023	3.3	20.9	24.2

Summary Comments

- To improve the reliability of our rigs, we should reduce the heat they produce. As we have seen, there are opportunities to do so with a 516F-2, a 32S-3, and KWM-2. In addition, some improvements to reduce heat can also result in better performance such as the PTO voltage regulators in a 32S-3 and, to a lesser extent, in a KWM-2. Overall, the most benefit comes from putting the 516F-2's 5 VAC filament windings in the transformer's primary. This will drop the filament heat in a 32S-3 by 8 Watts. For a KWM-2, it will be 13 Watts. Also, this change will ensure better tube life by operating the filaments closer to 6.3 VAC rather than 6.9 VAC. Of course, this requires a 516F-2 to use solid state diodes in place of the rectifier tubes. Not using the tube rectifiers will eliminate 29.5 Watts of filament heat and 10 to 25 Watts of rectifier tube, plate dissipation heat.

- There are a couple of simple changes we can make. For a 32S-3 you should consider changing R17 so it will allow V13 (0A2) to operate within in its current rating. R17 should be a 7,000 Ohm, 8 Watt resistor. This change will reduce the 0A2's regulator heat by about 5 to 7 Watts when the rig is in the PTT Activated or Key Down states. This change also results in a regulator that provides excellent regulation as shown in **Table 5.**

- If you are running a KWM-2 with a Vietnam Mod regulator using a 1 Watt Zener, you should consider changing it to one with a 1.5 Watt rating while retaining the 22,000 Ohm, 2 Watt series resistor. Alternately, you can use a 5 Watt Zener with a 20,000 Ohm, 2Watt series resistor or a 15,000 Ohm, 3 Watt resistor.

- Now comes the issue of which power supply configuration to use. If you use a configuration with tubes, you will not be able to free up the 5 VAC filament windings for use in the primary of the 516F-2's transformer. As a result, you will not lower the heat produced by the tubes in a 32S-3, a KWM-2 or the 516F-2 itself. Further, there will be no improvement in tube life. Regardless, you could use a dropping resistor or Zener diode to reduce LVB+ as shown by comparing configuration 1 to configurations 2 and 3. An alternate approach is to use a variac ahead of your 516F-2, which would allow a tubed version to put out a filament voltage of 6.3 VAC. Doing this would also drop the LVB+ and HVB+ and you would not necessarily have to modify your 516F-2.

- If you decide to put the 5 VAC filament windings in the transformer's primary, you wind up with the option of using either configuration 9 or 10. If you want to further lower the LVB+ from the levels seen for configuration 9, you can add a dropping resistor resulting in the LVB+ levels seen for configuration 10. In addition, there is a side benefit with both of these configurations. Compared to other solid state configurations, they will have a lower HVB+ as shown in **Table 11.**

- If you have a later 516F-2 with a 5,000 Ohm R9, you should consider changing R8 to 5,600 Ohms, 1 Watt. This will ensure you can set the bias regardless of your 516F-2 configuration. If you have installed a Farm Radio Products board, R8 is already 5,600 Ohms.

- With a 32S-3, the LVB+ will be the highest during Receive that drops to a lower voltage when in the PTT Activated state, which then drops an additional 9 to 12 VDC when in the Key Down state. If you want to set the LVB+ to a specific, regulated level, such as 275 VDC, for use with a 32S-3 or KWM-2, I suggest you visit Doug Crompton's (WA3DSP) website to see how he implemented an LVB+ regulator in his 516F-2. His website can be found at http://www.crompton.com/hamradio/collins/index.html.

My S Lines are the only rigs I use and I operate them almost daily on CW working DX on 40, 30 and 20 meters. I want them to run reliably with full performance and, when my life circumstances change, I want my S Lines to be wart free so the next owner can enjoy them. Based on the data shown here and my view of the issues, here is what I have done to enhance the reliability of my 32S-3s and 516F-2s:

- I have changed R7 to 7,000 Ohms, 8 Watt in my four 32S-3s.
- In three of my four 516F-2s that do not have the Farm Radio Products board, I have changed R8 to 5,600 Ohms, 1 Watt. The remaining one of the four has a 2,500 Ohm R9. This one was fixed by using different values for R8 and R10.
- The same four power supplies prior to this investigation had solid state diodes and were configuration 6. I have converted all to configuration 9. I have put the two unused 5 VAC filament windings in the primary and I have removed the 200 Ohm dropping resistor. Although I could have used the existing dropping resistor to further lower LVB+, making it configuration 10, I choose not to because I am comfortable with configuration 9's levels of LVB+. Also, the 516F-2 will see about 7 Watts less heat without the dropping resistor. I believe taking heat out of the 516F-2 by not having rectifier tubes and not have a dropping resistor is the best I can do to enhance its reliability. This approach will drop the heat in a 516F-2 by 46 to 62 Watts as compared to a tube version of the 516F-2. At the same time, there is an increase in reliability by lowering the filament generated heat and an improvement in filament life by running the tube filaments with 6.3 VAC rather than 6.9 VAC. Also, configuration 9, as well as configuration 10, has the lowest HVB+ during the PTT Activated and Key Down states.
- My 516F-2 with the Farm Radio Products board will remain as-is because it is a configuration 9 power supply.

It took a fair amount of time using two 516F-2s to generate and assess the data for ten power supply configurations to address generally known concerns and discover unknown related issues, such as the voltage regulators in a 32S-3 and a KWM-2. As I said at the onset, I wanted changes I decided to implement to be fact-based. I have accomplished this for my own use and I believe this article will allow you to pick-and-choose between different options knowing their impact on generated heat, tube filament life, overall reliability, and PTO voltage regulation.

Even though it took a fair amount of time to generate the data used here, it took a lot longer to write this article. Along the way Don, W5QN provided valuable comments from reading drafts of my article. I wish to thank him and acknowledge his efforts.

Lastly, I would like recognize Dexter White, K5WDW of Houston, Texas whose graciousness and trust enabled me to borrow one of his pristine KWM-2s for taking data and assessing the Zener PTO regulators. Thank you. And thank you to Dexter's brother Roger, W5RDW for arranging the loan.

I hope you find this article to be of value.

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