MODULE 36

POWER AMPLIFIER BLOCK DIAGRAM ANALYSIS

OBJECTIVE

Without reference explain the function of each major circuit in the 208U-3A Power Amplifier IAW TO 31R2-2TSC60-32, para 4-4 thru 4-54 or 31S1-2TSC66-22, para 4-4 thru 4-53 for the 208U-10A Power Amplifier.

PREREQUISITES

Must complete Modules 1 thru 3 and 15.

INFORMATION

In this Module we'll tour the 208U-3A (OG-90) and the 208U-10A (OG-89) Amplifier-Power Supplies used in the TSC-60(V)2 and (V)3 systems respectively. The only real difference between the two units is their size. Electrically, they are both the same. They are both laid out the same, and the components are pretty much in the same locations. In other words, if you understand one, you understand the other.

The Power Amplifiers in the TSC-60 are another highly feared part of the system, like the computer. The reason may be because of their size or the fact that they contain very high voltages. This fear could be a blessing in disguise. There **is** high voltage in the amplifiers and a great deal of caution should be exercised when working on these units. However, there is a difference between caution and fear. The knowledgeable technician exercises caution when working on a piece of equipment, but the unknowledgeable technician may fear it.

Get TO 31R2-2TSC60-32 and look at Figure 1-2. The PA is divided into two major units: the amplifier and the power supply. This explains the why it was called the Amplifier-Power Supply instead of a Power Amplifier. The top half is the amplifier, (unit 1), and the bottom half is the power supply (unit 2).

The cabinet is divided into five compartments. The large compartment on the top is called the plate compartment. This is where the final amplifier tube and the output tuning circuits are located. Below the plate compartment are the grid compartment, on the left, and the cold compartment, on the right. The grid compartment houses the RF input circuits and the driver tubes. Since the driver output is fed to the grid of the PA tube, someone decided that this should be called the grid compartment. The cold compartment is called that because it doesn't contain any high voltage components. (That doesn't mean no dangerous voltages are present, though). It is sometimes referred to as the control compartment because this is where all the mechanical and electrical control elements are located.

Directly below the grid compartment and the cold compartment is the circuit breaker panel. This panel runs the width of the cabinet and serves as a kind of separator between the amplifier and the power supply. This panel also contains most of the controls that you will be adjusting.

The large compartment on the bottom of the unit is the power supply. What can we tell you about a power supply? Everything in this compartment is part of the "voltageproducing" circuitry, except the blower.

Each of these five compartments has a removable cover that is fastened with thumbscrews. Each compartment cover, with the exception of the cold compartment and the circuit breaker compartment, must be in place for the units to operate. There are two reasons for this:

1. There is an interlock switch on each compartment cover, except the cold compartment and circuit breaker compartment.

2. There is an air pressure sensor/interlock switch. If air pressure is lost the system will shut down.

We'll discuss the Power Amplifier in four sections; RF amplifier, tuning, control, and power supply. Look at Figure 23 of your Diagrams booklet and we'll get right into the RF amplifier.

RF AMPLIFIER

This block diagram shows the RF amplifier and the tuning circuits. The four triangles represent amplifier stages.

The input from the Exciter is applied to the feedback mixer (1A1Q1). This mixer is not like the one you would find in the Receiver or Exciter to translate frequency. Rather, it mixes the incoming RF from the Exciter with a sample of the PA output and provides a negative feedback. With negative feedback, the greater the output of the PA, the less the gain of the mixer stage. In this way, the PA is kept operating in the linear portion of its range, without being overdriven. This prevents intermodulation. Now, what is intermodulation?

Intermodulation is distortion which results from two or more modulating signals mixing to form other signals that are still within the bandpass of the amplifier. For example, let's assume we are operating at 2.00MHz. The second harmonic of 2.00MHz (4.00MHz) is well outside the range of the filters on the output of the PA. No problem. However, if the 2.00MHz signal was modulated with two audio tones at 400Hz and 1000Hz, the sum of those two signals, 1400Hz, is well within the bandpass and, therefore, could cause the output of the PA to be distorted by adding the third, unwanted signal. This intermodulation is normally caused when an amplifier is operating in the nonlinear portion of its amplification range and/or it is overdriven.

The input line to the mixer stage is sampled and applied to the performance monitor circuits. The ALC/TGC signal is also applied to the input line. The input is capacitively coupled to the mixer so the ALC/TGC circuits won't affect the mixer stage.

The output of the feedback mixer is fed to the input amplifier (IA). This is a broadband amplifier, so there is no tuning network on the input or the output. It amplifies everything applied to it. The gain of the input amplifier is held constant by the PA internal gain control (IGC). The cathode current of the tube is monitored by the Maintenance Display so you can get an idea of how "hard" the tube is conducting.

The output of the IA is applied to the grid of the driver tube. Here, the signal is sampled twice; once by the driver phase discriminator and once for the performance monitor system. We'll discuss the discriminator when we explain amplifier tuning. The driver cathode current is also monitored.

The driver-PA interstage network is a tuned tank tied to the driver plate. We'll get into how this tank tunes shortly. From the interstage network the signal is capacitively coupled to the grid of the PA tube. A sample of the grid RF voltage input is sent to the Maintenance Display for you to monitor the input to the tube.

The output of the PA tube is sampled by the PA plate detector assembly and sent to the feedback network. We've already discussed the feedback network. The plate detector assembly provides a sample of the RF voltage at the plate for monitoring on the Maintenance Display, and the samples for ALC delay, ADL plate, TGC, loading comparator, and IGC.

The PA plate is capacitively coupled to the primary tune coil assembly. This is the tuned tank for the PA tube. The output of this tuned tank is applied to the loading coil assembly. The loading coil assembly adjusts the gain of the PA stage and applies the output to the low-pass filter.

The low-pass filter passes all signals below 44MHz to the directional coupler. The directional coupler provides samples of the forward and reflected RF output for metering and for internal gain control. From here the RF goes through the tune resistor assembly to the output of the PA. During tuning, this assembly limits the VSWR to 2:1, and the power to the antenna coupler to 250 Watts. After tuning is completed it provides direct connection to the antenna.

TUNING

The PA tunes in seven steps. You need to be familiar with these in order to maintain the system.

STEP 1, Ready to tune. Tune start is initiated with a new frequency control word from the computer. A coarse tuning frequency analog voltage is developed. All four tuning servos are disabled and the equipment remains in step 1 until high voltage is present and all interlock switches are closed.

STEP 2, Coarse tune. This is initiated by a key-enable signal. All four tuning servos are enabled and the amplifier is course-tuned. Step 2 is held until all servos have nulled and RF output from the Exciter is present (indicated by the RF input performance monitor).

STEP 3, Fine tune 1. This is initiated automatically when step 2 is completed. The loading servo is disabled. TGC/ALC relay control selects TGC. TGC inhibit relay prevents TGC voltage from affecting the Exciter output level. The tune power control selects the tuning power output level. Step 3 is held until the servos are nulled and RF is present on the plate of the PA tube as indicated by the performance monitor.

STEP 4, Fine tune 2. This step is initiated automatically when step 3 is completed. The loading servo is enabled and all four servos are fine-tuned. The TGC inhibit releases TGC to the Exciter. The PA output level is limited to tuning power. Step 4 is held until the PA tune signal indicates the associated antenna coupler has tuned and all four tuning servos have nulled.

STEP 5, Fine tune 3. If the servos remain nulled and no faults exist, the sequence advances automatically to step 6.

STEP 6, Full power trim. The tune power control signal enables full power operation of the amplifier. The PA is still protected against overload by TGC. Step 6 is held until the servos are nulled and the Exciter tune/operate signal indicates the Exciter is tuned.

STEP 7, Operate. All servos are disabled and the ALC/TGC relay control selects ALC. The PA operate request and tune complete signals indicate the PA is tuned and ready to operate. Max tuning time is 10 seconds as specified by the -12 TO. The PA will fault if tuning time takes 20 seconds or more.

Now look at the bottom half of Figure 23 in your Diagrams booklet. When a frequency is selected, the computer sends a control word to the PA telling it what this new frequency is. The 309F-1 digital-to-analog converter slice (shown on the left side of the drawing) establishes a DC voltage depending on the frequency selected. This DC voltage is sent to the voltage shaper circuit shown on the bottom of Figure 23. From here we'll follow the tuning of the driver tuning stage as an example.

The DC voltage from the shaper circuit is applied to the contacts of the course/fine tune relay. In coarse tune the DC is applied to the servo preamp circuit. Now find the follow potentiometer. just above the relay on the drawing. It gets its voltage from the digital-to-analog slice. The wiper is mechanically connected to the servo motor. The DC voltage on the wiper indicates the position of the servo motor within its range of travel.

In the servo preamp circuit, the voltage from the follow potentiometer is compared with the voltage from the shaper circuit. The difference in the two voltages can be either positive or negative depending on the relationship of the two inputs. This "error voltage" is amplified by the servo amplifier and applied to the servo motor to move it in a direction that will cause the voltage on the wiper of the follow potentiometer to equal the frequency analog voltage from the voltage shaper. When the two inputs are equal, the servo is positioned in the proper place for the frequency selected. This same coarse positioning occurs in all four servo mechanisms at the same time during tune step 2. When all four servos are properly positioned, the sequence counter advances to tune step 3.

Step 3 starts the fine tuning sequence. Let's look at each of the four servos separately here. Look at Figure 23 again and find the driver phase discriminator, 1A1A1. This discriminator circuit compares the phase relationship of the input and output of the driver. The two should be exactly 180 degrees out of phase with each other. The sample of the input to the driver is capacitively coupled into the phase discriminator. The sample of the output is taken in the interstage network by T1. The relationship of these two signals is represented in a DC voltage that is fed from the discriminator to the mode relay.

Since we are now in fine tune, the output of the discriminator is fed through the contacts of the relay to the servo preamp. In the servo preamp the signal is compared with ground from the other contacts of the relay. The result is applied to the servo amp, which feeds the driver tuning servo motor. The servo motor drives L1 and C1 until the output of the discriminator is zero. When the output of the discriminator is zero, the input and output of the driver are exactly 180 degrees out of phase with each other, and the circuit is tuned. Now let's look at the primary tune circuit, 1A18.

This circuit tunes the primary tune coil for a 180 degree phase shift across the PA tube. The discriminator gets one sample from the interstage network, and the other is capacitively coupled from the plate of the PA tube. The output of the discriminator is sent to the mode relay for the primary tuning drive and is handled the same as in the driver tuning circuit. One of the few differences between the two is the tachometer on the drive motor.

As the servo motor runs, a tachometer produces a voltage proportional to the speed of the motor and opposite in polarity to the error amplifier input voltage. This voltage is used as a dynamic brake for the servo motor. If the servo motor is still running at a high speed when the circuit is nulled, the voltage from the tachometer will be applied through the servo amp to stop the motor. Without this circuit, the inertia of the motor would allow it to go way past the null point and have to back up. In the long run, this damping effect reduces the tuning time.

Capacitor C14, across the secondary of the tune coil assembly, is tuned by the secondary phase detector. The input to the tune coil is sampled as well as the output. The phase discriminator looks for a 90-degree phase shift across the tune coil and adjusts capacitor C14 for that shift.

After these three circuits have initially fine-tuned, there will be RF voltage on the plate of the PA tube. When the servos are nulled and RF is present at the output of the PA tube, the sequence counter advances to step 4. Here the loading coil is tuned and the fine tuning of the other three servos is double-checked. The loading comparator looks for the proper gain of the PA tube. The input and output of the tube are sampled and compared. The result is applied to the servo amps to control the load coil, L1. During this step TGC is released to the Exciter but the output is still limited to tune power. The PA is held in this step until the antenna coupler is tuned if you are using the Transmit Orthogonal or the Whip. After all four servos and the coupler (if there is one) are tuned, the sequence counter advances to step 5.

Tune step 5 is simply a final check before applying full power. The null of all four servos is verified. If everything is still looking good, the sequence counter advances to step 6.

In step 6 full power is applied, although it is controlled by TGC, to allow the servos one last chance to fine tune. If all four servos still are nulled, and the Exciter exhibits a tune complete signal, the PA will initiate its own tune complete signal and advance the sequence counter to step 7. The PA remains in step 7 until you tell it to retune. Now that we have the PA tuned, let's take a look at the control circuits.

CONTROL

When we speak of control of the PA, we are primarily talking about the black boxes (slices) in the control compartment. These slices provide five main functions for the PA:

1. Computer interface
2. Tuning control
3. Keyline circuits
4. Internal Gain Control (IGC)
5. Monitoring

There are five slices that perform these functions.

599Z-1 (SB-3401) Electrical Test Panel. Contains jacks to provide access to the control lines for maintenance purposes and switches that control the address strapping.

915X-1 (C-8376) Control Monitor (DCU/DCFE). Provides interface between the computer control system and the PA.

309F-1 (CV-2674) Digital-to-Analog Converter. Converts the serial digital frequency information to an analog voltage for coarse tuning. Sequences and monitors PA operation to protect the equipment.

915V-1 (C-8365) and 915V-2 (C-8366) Amplifier Control. Contains circuits for monitoring the condition of the PA, servo amplifiers for operation of the tuning servos, internal gain control (IGC) circuits, and control circuits for the primary voltage regulator. The 915V-1 is used in the 208U-10A, and the 915V-2 is used in the 208U-3A.

333H-2 (AM-6229) Electronic Control Amplifier. Contains the servo amplifier circuits that actually drive the tuning servos.

652J-13 (PP-6542) Power Supply. A sixth slice that provides the necessary voltages to operate the control slices.

Follow along in Figure 25 of the Diagrams booklet while we discuss the functions of the control circuits. We'll start with the computer interface since without the computer we can't do much of anything.

The CCCS bus is applied to the 599Z-1 test panel. Nothing happens here unless there is something patched into the jacks on the front of the unit. From here the signals are passed on to the 915X-1 DCU/DCFE.

In the 915X-1 the biphase modulated CCCS bus signal is converted back to logic level data. The address of the incoming control word is compared with the address selected in the 599Z-1 to make sure the information is for the PA. If the address matches, the appropriate command from the control word is sent to the 309F-1. Get TO 31S1-2TSC60-122, and let's take a closer look at the 309F-1.

Turn to Figure 4-4. This is a simplified schematic of the fault and interlock circuits. With this drawing you can see how the 309F-1 monitors the condition of the PA for protection. First, the access plug interlock circuit is a daisy chain of all the compartment covers and connectors in the entire unit. Each and every connector in the entire unit has two pins connected together. All these connectors are connected in series. If any connector is not plugged in, the line is open. The compartment cover interlocks are in this same series chain. If all the covers are properly installed and all the connectors are connected, a ground is felt on pin 23 of the tune sequence control board.

This ground causes a low on pin 26 of the circuit card and a high on pin 11 of U3C. All of the circuit breakers in the PA have a switch built in so that, if any circuit breaker is not turned on, there will be a high on pin 29. The low on pin 29, indicating that all circuit breakers are on, causes a high to be felt on pin 12 of U3C. Pin 13 of U3C is connected to the filament enable line.

Setting the XMIT PWR switch on the transmit control head to STBY (standby) applies a ground to pin 14 of the circuit card. This puts a high on pin 13 of U3C, which satisfies all three inputs to U3C and places a high on the blower control line to energize the blower contactor in the power supply cabinet.

The blower contactor is really just a relay with big contacts. There's a lot of power going through those contacts; so they need to be a bit large. Look at figure 24 in your Diagrams booklet and find the blower control line on the lower left side of the page.

The high on the blower control line turns on a transistor driver which, in turn, energizes the relay. The relay passes AC line voltage to the blower transfer contactor and the bias supply.

The blower transfer contactor is controlled by the blower transfer sensor. This sensor checks to see whether the line voltage is 400Hz or 50-60Hz. The blower motor has windings for either frequency and the transfer contactor simply routes the line voltage to the proper windings. Now go back to Figure 4-4 in the TO.

The PA cabinet contains an air pressure sensor. If the blower is operating properly and the cabinet covers are in place, the blower will create pressure within the cabinet. When the pressure is sufficient, the air pressure switch will place a low on the air temp interlock line at pin 53 of the circuit card. This places a high on U4C. The other input to U4C comes from the access plug interlock, circuit breaker interlock, and filament enable lines all summed together. The resulting low from U4C enables the filament timer and the filament control lines. The filament control line simply turns on the filaments. The filament timer does a little more.

The filament timer blocks the power control line and the high voltage control from being enabled and the PA from being keyed until the filaments have had sufficient time to heat up and stabilize. After the timer has completed its cycle, the power control line can go low, energizing a relay in the 309F-1 and allowing power to the remainder of the logic circuits. Also, the high voltage contactor can be enabled, turning on the rest of the main power supply.

From this point, the tune cycle can be initiated. During the operation of the PA, including tuning, this circuit monitors the inputs you see on the left side of the card. A fault in any of those lines will be applied to the high voltage summary gate, which will remove high voltage. The antenna interlock monitor, in the lower left corner of the drawing, will prevent the PA from being keyed if there is not a proper load connected to it.

Since we've already discussed how the amplifier tunes, all we'll see here is how the control of the tuning circuits relates to the control compartment. Look back at Figure 25 in the Diagrams booklet. The frequency that was selected on the control head is interpreted in the 915X-1 and passed on to the 309F-1.

In the 309F-1 the digital frequency information is converted to an analog voltage that represents the frequency selected. At the same time, a voltage from an internal power supply is applied to the high side of the follow pots. The voltage from the wipers of the follow pots and the frequency analog voltage is sent to the 915V-2.

In the 915V-2 the frequency analog voltage is compared with the voltage from the wipers of the follow pots and the difference is produced as a servo error voltage. This servo error voltage is sent to the 333H-2.

The 333H-2 amplifies the servo error voltage to a level strong enough to drive the servo motors. There is a separate servo amplifier circuit for each of the four servo motors.

You've already seen how the keyline is controlled in the 309F-1. Now let's see what happens in the rest of the PA when it is keyed. The Transmit/Receive relay and the directional coupler are located in the top of the PA cabinet, above the RF amplifier. When the 309F-1 tells the

PA to key, the key signal is sent to the Transmit/Receive (T/R) relay. This relay has two sets of contacts to accommodate the following:

1. Switching RF signals to and from the antenna.
2. The delayed keyline.

Look at Figure 36-1. When the relay is deenergized (PA not keyed), the antenna is connected to the Simplex connector on the RF patch panel. This allows the Receiver to be connected to the same antenna as the Transmitter in simplex operation. The second set of contacts applies the ground from the original keyline to the power supply on the delayed keyline. It's called the delayed keyline because it cannot key the power supply until the antenna is connected to the PA. Now look at Figure 24 in the Diagrams booklet.

```
Simplex____________o
                    \o________________Antenna
PA_________________o|
                    |
                   o|
                    \o_________delayed keyline
      Ground_______o|
                    |
                    |
                   []
```

Figure 36-1. T/R Relay

The delayed keyline appears on the bottom of the page and is fed to the key relay driver, which drives the key relay. The contacts of this relay are connected to the output of the PA bias circuit and the driver bias circuit.

When the PA is not keyed, the bias voltages for these circuits are -1100 and -68 volts respectively, which keeps both tubes at cutoff. When the key relay is energized (the PA is keyed) a voltage divider is added to the output of each of the two bias supplies to reduce the bias voltages to -960 and -3 volts, allowing the tubes to conduct.

> NOTE: The voltages given are for the 208U-3A only. The voltages for the 208U-10A are different, but the method of achieving them is the same for both units.

The internal gain control (IGC) circuit is covered fairly well in the TO. Get TO 31R2-2TSC60-32. Read para 4-91 thru 4-111 and then continue with the module. Refer to TO Figure 4-6 as you read.

That wasn't too bad, was it? Basically the IGC is another protection circuit to control the output power of the PA. The input amplifier bias is the key to the whole IGC system. With no IGC the control amplifier is saturated, which means its output is a ground. This makes a voltage divider of the two bias resistors. As a reduction in gain is needed, the control transistor conducts less, making its output effectively above ground. This causes the voltage on the wiper of the bias adjustment to become more negative, which cuts down on the conduction of the input amplifier tube.

The input to the IGC control amplifier is made up of five inputs from throughout the PA. If any of them increases beyond its threshold, the control amplifier acts as we just mentioned. Now lets discuss the power supply unit.

POWER SUPPLY

Follow along using Figure 24 in your Diagrams booklet as we take a tour through the power supply, unit 2 of the PA. Three-phase AC line voltage is applied to the main circuit breaker. From this circuit breaker the line voltage is applied to the filament circuits, the high voltage circuits, and the bias voltage circuits. We'll look at these groups of circuits separately, starting with the filament circuits.

You are probably wondering why so much emphasis on simply providing voltage to the filaments? With the amplification in the PA accomplished primarily in one very powerful tube and its drivers, the voltage on the filaments could greatly affect the output power. Now find the regulator sensor on the left side of Figure 24.

A sample of the output of the boost transformer is applied to the regulator sensor. The regulator sensor is really just a full-wave rectifier circuit which provides a DC voltage proportional to the 225VAC. This DC voltage is applied to one side of the line voltage regulator adjustment potentiometer. The other side is connected to a zener diode. The system is adjusted so that when the voltage applied to the filament transformers is exactly 225VAC, the voltage on the wiper is zero. Any deviation above or below zero on the wiper of the pot indicates a fluctuation in AC line voltage. The wiper is connected to the 915V-2 in the control compartment.

In the 915V-2, the voltage is amplified and applied back to the power supply to drive a servo motor tied to the autotransformer. The output of the autotransformer is coupled to the boost transformer. If the 225VAC that was sampled was high, the voltage from the autotransformer to the boost transformer is out of phase, which lowers the output of the boost transformer. Likewise, if the sample was low, the output of the autotransformer is in phase, which boosts the output of the boost transformer.

The block diagram on Figure 24 readily displays which power supplies are controlled by specific circuit breakers and contactors. The high voltage contactor supplies the PA plate supply, PA screen supply, and the low-level supply. All three of these power supplies are basically simple, standard power supplies. There are no fancy regulator circuits or any "odd" methods of obtaining their voltages.

We've already talked about the bias supplies, since they provide the keying for the PA. Remember, the bias on the PA tube and the driver tube is changed so that they are cutoff when the PA is unkeyed and conducting when it is keyed.

The 28-volt supply is very important. Without the 28VDC from here, none of the contactors would work. Without the contactors, you couldn't enable any of the supplies; therefore, the whole PA would be dead.

That covers the power supply unit in the PA. If you have any questions, read para 4-133 thru 4-169 in TO 31R2-2TSC60-32 for the 208U-3A or 31S1-2TSC60-22 for the 208U-10.

ADDITIONAL INSTRUCTIONS

Answer the review questions and check your answers with the confirmation key. Review the material in the module for any questions you missed. Next, ask your trainer for the KEP questions. After your trainer checks your answers and reviews the questions missed with you, go on to the next module.

REVIEW QUESTIONS

1. Name the five compartments in the Amplifier-Power Supply.

2. What is the purpose of the feedback mixer stage?

3. What is the purpose of the tune resistor stage?

4. List the seven tuning steps and give a brief description of each.

5. List the four servo tuning mechanisms and state what they look for during fine tune.

6. List the slices in the cold compartment and the function of each.

7. List five conditions required to enable the high voltage.

8. How is the power amplifier tube keyed?