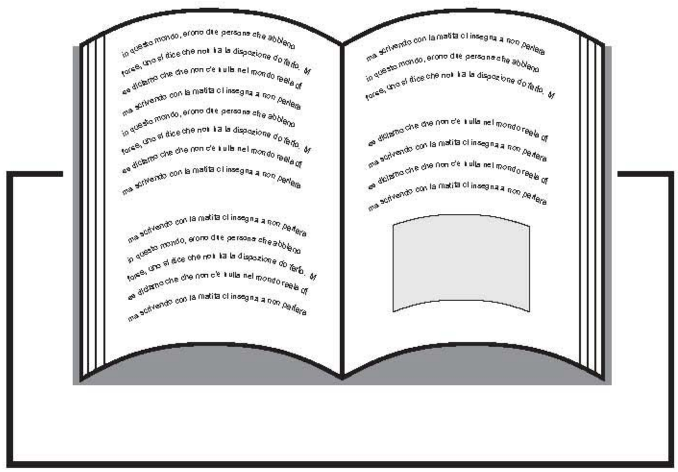

Section 4—Principles of Operation

This section discusses the circuit principles upon which the transmitter functions. This information is not needed for day-to-day operation of the transmitter but may be useful for advanced users and service personnel.

4.1 Part Numbering

As this section refers to individual components, you should be familiar with the part numbering scheme used.

The circuit boards and component placement drawings use designators such as “R1”, “R2”, and “C1.” These same designators are used throughout the transmitter on several different circuit boards and component placement drawings. When referencing a particular component it is necessary to also reference the circuit board that it is associated with.

4.2 Audio Processor/Stereo Generator Circuit Board

The audio board provides the control functions of audio processing-compression, limiting, and expansion, as well as stereo phase-error detection, pre-emphasis and generation of the composite stereo signal.

Illustration 6-4 and accompanying schematic may be useful to you during this discussion. The overall schematic for the audio board is divided into two sheets; one each for the processor and stereo generator sections of the board.

Reference numbers are for the left channel. Where there is a right-channel counterpart, reference number are in parenthesis.

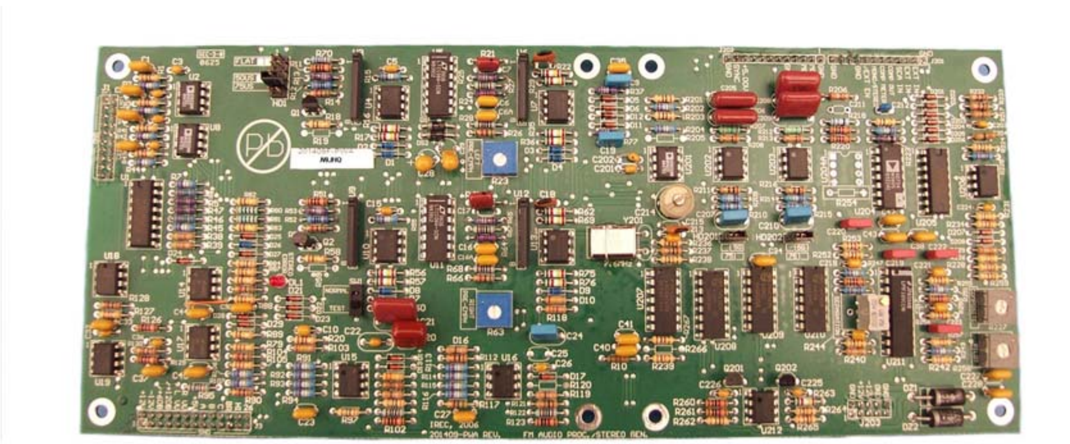

Illustration 4–1 Audio Processor/Stereo Generator Board

4.2.1 Audio Processor Section

Audio input from the XLR connector on the rear panel of the transmitter goes to instrument amplifier, U2 (U8). Two-bit binary data on the +6 dB and +12 dB control lines sets the gain of U2 (U8) to one of four levels in 6-dB steps. Gain of U2 is determined by R5, R6, or R7 (R45, R46, or R47) as selected by analog switch U1.

U3 (U9) is a THAT2180 voltage-controlled amplifier with a control-voltage-to-gain constant of 6.1 mV/dB. The 2180 is a current-in/current-out device, so signal *voltages* at the input and output will be zero. R11 converts the audio voltage at the output of U2 (U8) to current at the input of U3 (U9). U3 (U9) output current is converted to audio voltage by U4A (U10A).

U4B (U10B) is a unity-gain inverter. When the positive peaks at the output of U4A (U10A) or U4B (U10B) exceeds the gain-reduction threshold, U15 generates a 0.25 Volts-per-dB DC control bias, producing wide-band gain reduction for U3 (U9). The dB-linear allows a front-panel display of gain control on a linear scale with even distribution of dB.

Q1 (Q2) is a recover/expansion gate with a threshold about 18 dB below the normal program level. The amount of short-term expansion and time for gain recovery is controlled by the PROCESSING control, located on the front panel display board. (See section 3.5.)

Audio components above 15,200 Hz are greatly attenuated by eighth-order switched-capacitor elliptical filter, U5 (U11). The filter cut-off frequency is determined by a 1.52-MHz clock (100 x 15,200 Hz) signal from the stereo generator section of the board. The broadband signal level at the output of U5 (U11) is about 5 dB below that required for full modulation. (With normal program material, the 5 dB of headroom will be filled with pre-emphasized audio.)

Pre-emphasis in microseconds is the product of the capacitance of C7 (C17), multiplied by the current-gain of U6 (U12), times the value of R22 (R62). (For description of the device used for U6 (12), see explanation for U3 (U9) above.) For a 75 micro-seconds pre-emphasis, the gain of U6 (U12) will be about 1.11.

Selection of the pre-emphasis curve (75 µS, 50 µS, or Flat) is made by moving the jumper on HD1 to the pins designated on the board. Fine adjustment of the pre-emphasis is made with R23 (R63). (See section 5.1.)

For high-band processing, the peak output of U7A (U13A) and U7B (U13B) is detected and gain-reduction bias is generated, as with the broadband processor. The high-band processing, however, shifts the pre-emphasis curve rather than affecting overall gain. Peak audio voltages are compared to plus and minus 5-volt reference voltages at the outputs of U19A and U19B. This same reference voltage is used in the stereo generator section.

A stereo phasing error occurs when left and right inputs are of equal amplitude but opposite polarity. The most common cause is incorrect wiring of a left or right balanced audio line somewhere in the program chain-sometimes at the source of a recording. When this happens, all the audio is in the left-minus-right stereo subcarrier-none in the left-plus-right baseband. The error can go unnoticed by one listening on a stereo receiver, but the audio may disappear on a mono receiver. In normal programming there may be short-term polarity reversals of left versus right, either incidental or-for effect-intentional. A phase error of several seconds duration is processed by U14A and U14B and interpreted as a real error. During a phasing error the right-channel level is gradually reduced by 6 dB. For a listener to a stereo radio, the right-channel volume will be lower, while on a mono receiver there will be a reduction of volume.

NORMAL/TEST switch. In the TEST position, the stage gains are set to a fixed level. See section 6.2

4.2.2 Stereo Generator Section

Composite stereo signal is generated from left and right-channel audio inputs. This section also has the amplifier (U201) for an optional external composite input and provision for insertion of SCA signal(s).

Processed, pre-emphasized left and right audio is passed through third-order lowpass filters comprised of U202A (203A) and associated circuitry. The filters decrease the level of audio products below 30 Hz. This low-frequency roll off is necessary to prevent disturbance to the phase-lock loop in the RF frequency synthesizer by extremely low-frequency audio components. (See caution at section 2.8.)

U204 is a precision, four-quadrant, analog multiplier. The output of U204 is the product of 38 kHz applied to the Y input and the difference of left and right audio (L-R signal) applied to the X input. The resulting output is a double sideband, suppressed carrier/the L-R subcarrier.

Spectral purity of the stereo subcarrier is dependant on a pure 38-kHz sinewave at the multiplier input.

U207A and Y201 comprise a 7.6-MHz crystal oscillator from which the 19 and 38-kHz subcarriers are digitally synthesized. U207F is a buffer. The 7.6 MHz is divided by 5 in U208A to provide 1.52 Mhz, used by switched-capacitor filters U5 and U11 in the audio section. 3.8 MHz, 1.9 MHz, and 304 kHz are also derived from dividers in U208. Exclusive-OR gates, U210C and U210D, provide a stepped approximation of a 38-kHz sine wave. With the resistor ratios used, the synthesized sine wave has very little harmonic energy below the 7th harmonic. U210A and B generate the 19-kHz pilot subcarrier. U211 is a dual switched-capacitor filter, configured as second-order, low-pass filters, each one with a Q of 5. The 38 and 19-kHz outputs of pins 1 and 20, respectively, are fairly pure sine waves. Harmonic distortion products are better than 66 dB down-with a THD of less than 0.05%. SEPARATION control R244 sets the 38-kHz level at the Y input of U204.

Resistor matrix R219, R220, R221, and R223 sum the L+R audio with the L-R subcarrier to produce a current at the junction of R221 and R223 that will be converted to composite stereo (less pilot) at the output of summing amplifier U206A. SCA signal is also injected at the input of U206A. 19-kHz pilot is combined with composite stereo in summing amplifier U206B.

Analog switch U205, at the input of U206A, provides switching of left and right audio for stereo and mono modes. In the mono mode, right channel audio is disabled, and the left channel audio is increased from 45% modulation to 100%.

MON L and MON R outputs go to the AF Monitor jacks on the rear panel. R209+R210 (R214+R215) and C207 (C210) is a de-emphasis network. Processed, de-emphasized samples of the left and right audio are used for a studio monitor and for audio testing. Jumpers at HD201 (HD202) allow selection of 50-µsec or 75-µsec de-emphasis.

VR212A and B supply +7 volts and -7 volts, respectively. A 5-volt reference from the audio processor section supplies the subcarrier generators.

For an explanation of on-board adjustments see section 5.2.

4.3 RF Exciter Circuit

This circuit is also known as the Frequency Synthesizer. The Frequency Synthesizer part of the motherboard is no longer a separate module as was the case on older transmitters.The entire component side of the motherboard is a ground plane. Frequency selector switches located on the front panel of the transmitter establish the operating frequency. The VCO (voltage-controlled oscillator) circuitry is inside an aluminum case.

Illustration 6-6 and accompanying schematics can be used as reference in this discussion.

VCO1 operates at the synthesizer output frequency of 87 MHz to 108 MHz.
The frequency is controlled by a voltage applied to pin 8 of the VCO.
A sample of the RF comes from A2 and is fed to the PLL chip U13.
U13 is a phase-locked-loop frequency synthesizer IC. The 10.24 MHz from the crystal oscillator is divided to 10 kHz. Internal programmable dividers divide the 87 - 108 MHz RF to 10 kHz. Differences between the two signals produce error signals at pins 7 and 8 of U14.

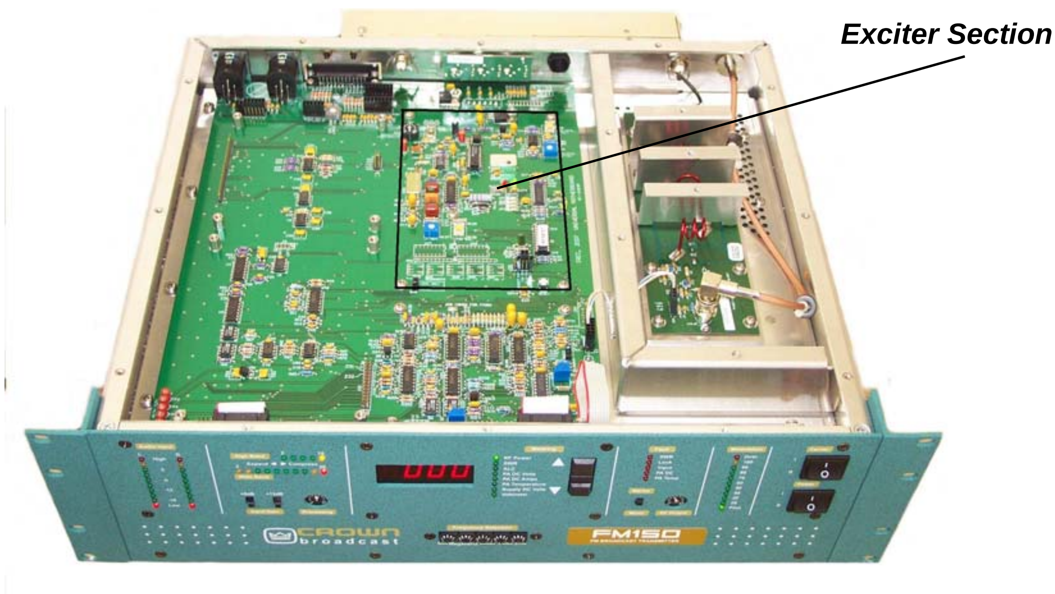

Illustration 4–2 Motherboard (Exciter Section)

Frequency selector switches are read by shift registers U17 and U18. Data from the shift registers is read by U16 which then programs the PLL (Phase Lock Loop) IC U13.

U14B is a differential amplifier and filter for the error signal. Audio that is out of phase with that appearing on the error voltage is introduced by U14A., allowing for greater loop bandwidth with less degradation of the low frequency audio response.

Lock and unlock status signals are available at the outputs of U15E and U15F respectively.

Modulation is introduced to the VCO though R72 and R122.

4.5 Metering Circuit

The ALC and metering circuitry is on the motherboard (see Illustration 6–6). This circuit processes information for the RF and DC metering, and produces ALC (RF level-control) bias. It also provides reference and input voltages for the digital panel meter, voltages for remote metering, fan control, and drive for the front-panel fault indicators.

Illustration 6–6 and accompanying schematics complement this discussion.

PA voltage and current come from a metering shunt on the power regulator board. The PAI input is a current proportional to PA current; R153 converts the current to voltage used for metering and control. A voltage divider from the PAV line is used for DC voltage metering.

Illustration 4–3 Metering Circuit

U23A, U23B, and U24A, with their respective diodes, are diode linearity correction circuits. Their DC inputs come from diode detectors in the RF reflectometer in the RF low-pass filter compartment.

U24B, U24C, are components of a DC squaring circuit. Since the DC output voltage of U24C is proportional to RF voltage squared, it is also proportional to RF power.

U22C, U22A, U20A, and U22D are level sensors for RF power, reflected RF power, PA temperature, and external PA current, respectively. When either of these parameters exceeds the limits, the output of U22B will be forced low, reducing the ALC (RF level control) voltage, which, in turn, reduces the PA supply voltage.

The DC voltage set point for U22A (reflected RF voltage) is one-fifth that of U22C (forward RF voltage). This ratio corresponds to an SWR of 1.5:1 [(1+.2)/(1– .2)=1.5]. The U25 inverters drive the front panel fault indicators.

4.6 Motherboard

The motherboard is the large board in the upper chassis interconnecting the audio processor/stereo generator board or the optional receiver module or the Omnia digital audio processor to the RF exciter and metering circuits. The motherboard provides the interconnections for this boards, eliminating the need for a wiring harness, and provides input/output filtering. The RF exciter and Metering circuits are an integral part of the motherboard and are no longer separate boards as in past transmitter designs.

Also contained on the motherboard is the +5.00 volt reference and the composite drive Op amp and its associated circuitry.

The motherboard has configuration jumpers associated with different options that can be added at the time of order or at a later time as an upgrade. The motherboard configuration chart for these jumpers can be found on the following page.

Configuration Jumpers

Illustration 4–4 Configuration Jumpers

Motherboard Jumper Configuration Chart 4.6.1

Jumper	FMA "E"	FMA"T" 50KΩ input	FMA"T" 600Ω input	FMA "R"	FMA "Omnia" Analog input	FMA "Omnia" AES input
Z1	Short	Short	Short	Short	Short	Open
Z2	Short	Short	Short	Short	Short	Open
Z3	Open	Open	Short	Open	Open	Open
Z4	Open	Open	Open	Open	Open	Short
Z5	Open	Open	Short	Open	Open	Open
Z6	Open	Open	Open	Open	Open	Short
Z7	Open	Open	Short	Open	Open	Open
Z8	Open	Open	Short	Open	Open	Open
Z9	Short	Open	Open	Open	Open	Open
Z10	Short	Open	Open	Open	Open	Open
Z11	Short	Open	Open	Open	Open	Open
Z12	Short	Open	Open	Open	Open	Open
Z13	Short	Open	Open	Open	Open	Open
Z14	Short	Open	Open	Open	Open	Open
Z15	Open	Open	Open	Open	Open	Open
Z16	Open	Open	Open	Open	Open	Open
Z17	Open	Open	Open	Open	Open	Open
Z18	Open	Open	Open	Open	Open	Open
Z19	Open	Open	Open	Open	Open	Open
Z20	Open	Open	Open	Open	Open	Open
Z21	Open	Open	Open	Open	Open	Open
Z22	Open	Open	Open	Open	Open	Open
Z23	Short	Short	Short	Short	Short	Short
Z24	Short	Short	Short	Short	Short	Short
Z25	Short	Short	Short	Short	Short	Short
Z26	Short	Short	Short	Short	Short	Short
Z27	Short	Short	Short	Short	Short	Short
Z28	Short	Short	Short	Short	Short	Short
Z29	Short	Short	Short	Short	Short	Short
Z30	Short	Short	Short	Short	Short	Short
Z31	Open	Open	Open	Open	Open	Open
Z32	Short	Open	Open	Open	Open	Open
Z33	Short	Open	Short	Open	Open	Open
JMP1	Open	Open	Open	Open	Open	Open
JMP2	Open	Open	Open	Open	Open	Open

4.7 Display Circuit Board

The front-panel LEDs, the numeric display, the slide switches, and the processing and RF level controls are mounted on the display circuit board. To access the component side of the board, remove the front panel by removing 12 screws. The board contains circuits for the digital panel meter, modulation peak detector, and LED display drivers, as well as indicators and switches mentioned above.

Illustration 6–9 and accompanying schematic complement this discussion.

Left and right audio from input stages of the audio processor board (just after the Input Gain attenuator) go to the L VU and R VU input on the display board. Peak rectifiers U1A and U1B drive the left and right Audio Input displays. The LED driver gives a 3–dB per step display. The lowest step of the display driver is not used; rather a red LOW indicator lights when audio is below the level of the second step. Transistors Q1 and Q2 divert current from the LOW LEDs when any other LED of the display is lit.

Resolution of the linear displays, High Band, Wide Band, and Modulation, has been improved using dither enhancement. With dither, the brightness of the LED is controlled by proximity of the input voltage relative to its voltage threshold. The effect is a smooth transition from step to step as input voltage is changed. U6A, U6B, and associated components comprise the dither generator. Dither output is a triangular wave.

Composite stereo (or mono) is full-wave detected by diodes D5 and D6, U7, U13, Q3, and Q4 are components of a peak sample-and-hold circuit.

Oscillator, U9F, supplies a low-frequency square wave to the Fault indicators, causing them to flash on and off.

Digital multimeter inputs are selected with push buttons located to the right of the multimeter menu. Signals from the push buttons are conditioned by U9A and U9B. U10 is an up/down counter. Binary input to U11 from U10 selects a green menu indicator light, and lights the appropriate decimal point on the numeric readout. The binary lines also go to analog data selectors on the ALC/ metering board.

Processing control, R50, is part of the audio processor. (See section 4.2.)

The DPM IN and DPM REF lines are analog and reference voltage inputs to digital multimeter IC U12. They originate from analog data selectors on the ALC/ metering board.

4.8 Voltage Regulator Circuit Board

The voltage regulator board is the longer of two boards mounted under the chassis toward the front of the unit. It has switch-mode voltage regulators to provide +12, –12, and 20 volts. It also contains the program detection and automatic carrier control circuits.

Illustration 6–10 and accompanying schematic complement this discussion.

U3E and U3F convert a 38–kHz sine wave from the stereo generator into a synchronization pulse. In the transmitter, synchronization is not used, thus D9 is omitted.

U4 and U5 form a 20–volt switching regulator running at about 35 kHz. U4 is used as a pulse-width modulator; U5 is a high-side driver for MOSFET switch Q1. Supply voltage for the two IC's (approximately 15.5 volts) comes from linear regulator DZ2/Q5. Bootstrap voltage, provided by D10 and C14, allows the gate voltage of Q1 to swing about 15 volts above the source when Q1 is turned on. Current through the FET is sensed by R38 and R38A. If the voltage between pin 5 and 6 of U05 exceeds 0.23 volts on a current fault, drive to Q1 is turned off. Turn-off happens cycle by cycle. The speed of the turn-off is set by C13.

U6 is a switching regulator for both +12 volts and –12 volts. It runs at about 52 kHz. Energy for –12 volts is taken from inductor L2 during the off portion of the switching cycle. The –12 volts tracks the +12 volts within a few tenths of a volt. There will be no –12 volts until current is drawn from the +12 volts.

Q2, Q3, and Q4 form an active filter and switch, supplying DC voltage to the RF driver, when the Carrier switch is on.

The program detection circuit is made up of U1 and U2. U1A and U1D and associated circuitry discriminate between normal program material and white noise (such as might be present from a studio-transmitter link during program failure) or silence. U1A and surrounding components form a band-pass filter with a Q of 3 tuned to about 5 kHz. U1D is a first-order low-pass filter. Red and green LEDs on the board indicate the presence or absence of program determined by the balance of the detected signals from the two filters. U2 and U1C form a count-down timer. The time between a program fault and shutdown is selected by jumpering pins on header JP1. For times, see section 5.7. The times are proportional to the value of R21 (that is, times can be doubled by doubling the value of R21) and are listed in minutes.

4.9 Power Regulator Circuit Board

The power regulator board is the shorter of two boards mounted under the chassis toward the front of the unit. The board has the isolating diode for the battery input, the switch-mode voltage regulator for the RF power amplifier, and circuitry for PA supply current metering.

Illustration 6–10 and accompanying schematic complement this discussion.

Diode D4, in series with the battery input, together with the AC-supply diode bridge, provides diode OR-ing of the AC and DC supplies.

U1 and U2 form a switching regulator running at about 35 kHz. U1 is used as a pulse-width modulator; U2 is a high-side driver for MOSFET switch Q1. Power for the two IC’s comes from the 20–volt supply voltage for the RF driver (available when the Carrier switch is on). The voltage is controlled at 16 volts by zener diode DZ1. Bootstrap voltage provided by D2 and C9 allows the gate voltage of Q1 to swing about 16 volts above the source when Q1 is turned on. Current through the FET is sensed by R12A and R12B. If the voltage from pin 5 to 6 of U2 exceeds 0.23 volts on a current fault, drive to Q1 is turned off. This happens on a cycle-by-cycle basis. The speed of the turnoff is set by C5.

U3 and Q2 are used in a circuit to convert the current that flows through metering shunt, R19, into a current source at the collector of Q3. Forty milli-volts is developed across R19 for each amp of supply current (.04 ohms x 1 amp). Q3 is biased by U3 to produce the same voltage across R16. The collector current of Q3 is the same (minus base current) as that flowing through R22 resulting in 40 microamperes per amp of shunt current. R5 on the metering board converts Q3 collector current to 0.1 volt per amp of shunt current (.04 ma X 2.49 k). (See section 5.4.)

4.10 RF Driver/Amplifier (FM30)

The RF Driver/Amplifier assembly is mounted on a 100 mm x 100 mm plate in the under side of the chassis.

Illustration 6-14 and accompanying schematic complement this discussion.

The driver amplifies the approximate 20 milliwatts from the frequency synthesizer to 30 watts. An MHW6342T hybrid, high-gain, wideband amplifier, operating at about 20 volts, provides about one watt of drive to a single BLF246 MOSFET amplifier. The BLF245 stage operates from a supply voltage of 28 volts in the FM30.
The circuit board has components for input and output coupling and for power supply filtering.

4.11 RF Driver (FM150/FM300)

The RF Driver assembly is mounted on a 100 mm x 100 mm plate in the under side of the chassis.

Illustration 6-14 and accompanying schematic complement this discussion.

The driver amplifies the approximate 20 milliwatts from the frequency synthesizer to about 8 watts to drive the RF power amplifier. An MHW6342T hybrid, high-gain, wideband amplifier, operating at about 20 volts, provides about one watt of drive to a single BLF245 MOSFET amplifier. The BLF245 stage operates from a supply voltage of approximately 20 volts.

The circuit board provides for input/output coupling and for power supply filtering.

4.12 RF Amplifier (FM150/FM300)

The RF power amplifier assembly is mounted on back of the chassis with four screws, located behind an outer cover plate. Access the connections to the module by removing the bottom cover of the unit. The RF connections to the amplifier are BNC for the input and output. Power comes into the module through a 5–pin header connection next to the RF input jack.

Illustration 6-12 and accompanying schematic complement this discussion.

The amplifier is built around a ST MicroElectronics SD2942, a dual power MOSFET rated for 50 volts DC and a maximum power of about 350 watts. When biased for class B, the transistor has a power gain of about 20 dB. (It is biased below class B in the transmitter.)

Input transformer, T11, is made up of two printed circuit boards. The four-turn primary board is separated from the one-turn secondary by a thin dielectric film. R12–R17 are for damping. Trim pot R11 sets the bias.

Output transformer, T21, has a one-turn primary on top of the circuit board and a two-turn secondary underneath. Inductors L21 and L22 provide power line filtering.

4.13 Chassis

The AC power supply components, as well as the bridge rectifier and main filter capacitor, are mounted on the chassis. Switching in the power-entry module configures the power transformer for 100, 120, 220, or 240 VAC; see section 2.2 for switching and fuse information. A terminal strip with MOV voltage-surge suppressors and in-rush current limiters is mounted on the chassis between the power entry module and the toroidal power transformer.

> **⚠WARNING**
>
> **Shock hazard!**
>
> **Do not attempt to short the capacitor terminals. A bleeder resistor will discharge the capacitor in approximately one minute after shutdown.**

The main energy-storage/filter capacitor, C01, is located between the voltage and power regulator boards. The DC voltage across the capacitor will be 45–55 volts (FM30 and FM150) or 65–70 volts (FM300) when the carrier is on.

4.14 RF Output Filter & Reflectometer

The RF low-pass filter/reflectometer are located in the right-hand compartment on the top of the chassis. See Illustration 6–13 and accompanying schematic for more information.

A ninth-order, elliptic, low-pass filter attenuates harmonics generated in the power amplifier. The capacitors for the filter are circuit board pads.

The reflectometer uses printed circuit board traces for micro-strip transmission lines. Transmission line segments (with an impedance of about 82 ohms) on either side of a 50–ohm conductor provide sample voltages representative of the square root of forward and reverse power.

DC voltages, representative of forward and reflected power, go through a bulkhead filter board to the motherboard, then to the metering board, where they are processed for power control and metering and for SWR metering and protection.

4.15 Receiver Circuit Board Option

This option allows the transmitter to be used as a translator. The receiver board receives terrestrially fed RF signal and converts it to composite audio which is then fed into the exciter board. Microprocessor controlled phase lock loop technology ensures the received frequency will not drift, and multiple IF stages ensure high adjacent channel rejection. Refer to illustrations 4–6, 6–16 and its schematic for the following discussion.

The square shaped metal can located on the left side of the receiver board is the tuner module. The incoming RF signal enters through the BNC connector (top left corner) and is tuned through the tuner module. Input attenuation is possible with the jumper labeled “LO” “DX”, on the top left corner of the receiver board. Very strong signals can be attenuated 20 dB automatically by placing the jumper on the left two pins (“LO” position). An additional 20 dB attenuation is also available with the jumpers in the top left corner of the board. The frequencies are tuned by setting switches SW1 and SW2 (upper right corner). These two switches are read upon power up (or by momentarily shorting J7) by the microprocessor (U4). The microprocessor then tunes the tuner module to the selected frequency. The frequency range is 87.9 Mhz at setting “00” to 107.9 Mhz at setting “64”. Other custom ranges are available.

Located in the lower left-hand corner of the Receiver Module is a 3.5mm headphone jack. Demodulated Left and Right audio is present at this jack. A regular pair of 32 ohm stereo headphones, such as the types used with portable audio devices, can be used to monitor the audio on the receiver module.

Illustration 4–5 Receiver Module

When a stereo signal is present, LED 3 illuminates which indicates that left and right audio is available. Then the stereo signals go to gain stages and out to the RCA jacks on the back of the cabinet. These can be used for off-air monitoring of the audio signal. Incoming frequency can be monitored from the frequency monitor BNC jack on the back. The stereo buffer, stereo decoder, and gain stages and have no effect on the signal that goes through the transmitter.

The power supply is fairly straight forward. The incoming 12 volt supply goes to a 7809, 9 volt regulator (VR1) which supplies all 9–volt needs on the board. The 9 volts also supplies a 7805, 5 volt regulator (VR2) which supplies all 5–volt needs on the board. Plus and minus 12 volts from the motherboard is filtered and supplies various needs on the board. Finally there is a precision reference voltage. Two 2.5 volt reference shunts act very much like a very accurate zener diode to provide a precision 5 volt supply to the metering board.