Yamaha Professional Audio Products

EMX5000 Powered Mixer

Switchmode Power Supply Circuit (SMPS) explanation

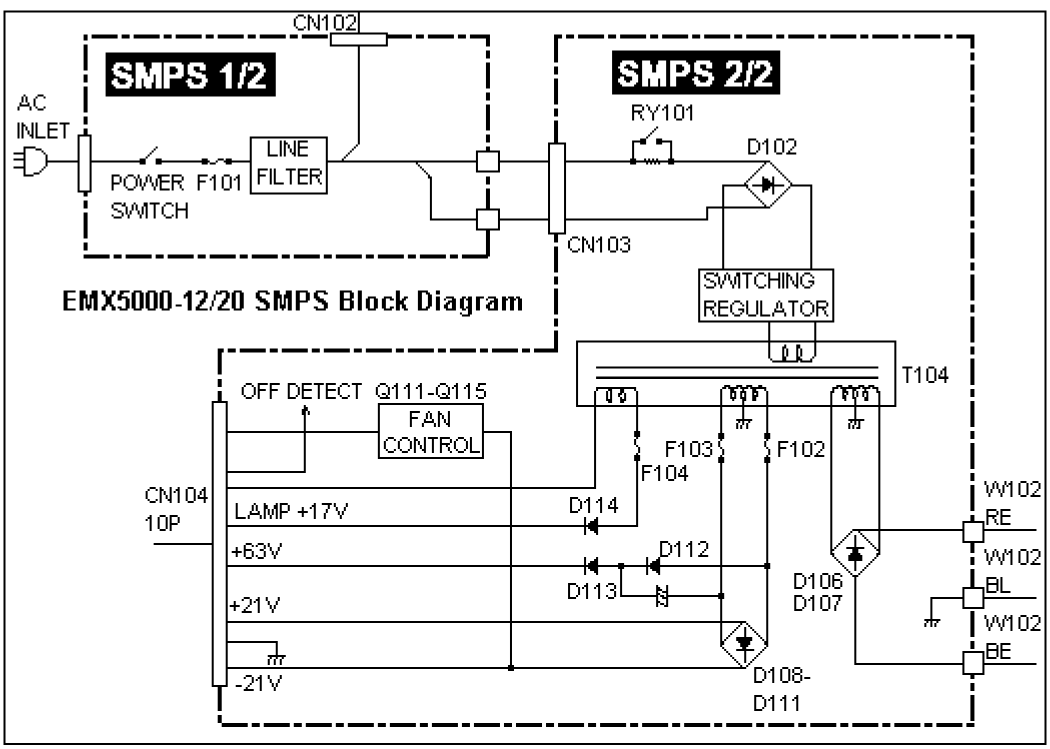
1. Introduction

The EMX5000 is the latest addition to Yamaha's range of EMX Powered Mixers, and is available in 12-channel (EMX5000-12) and 20-channel (EMX5000-20) configurations. The basic concept of a self-contained, multi-channel mixer and amplifier with effects has remained virtually unchanged since the introduction of the EMX150/200/300 models in 1984. In 1997, the EMX640 was introduced and used a new, high-efficiency output stage circuit in its power amplifiers. All EMX models released since then have incorporated this "EEEngine" circuitry to improve efficiency and therefore reduce weight through the use of smaller heatsinks.

The EMX5000-12/20 continues the use of EEEngine circuitry in its power amplifiers, which are now rated at 500W continuous per channel into 4-ohms, or 1000W continuous into a bridged 8-ohm load. In order to provide this power capability without the weight penalty of a large conventional power supply transformer, a lightweight, high-efficiency switchmode power supply (SMPS) is used. Should repair be necessary, the SMPS printed circuit boards (PCBs) can be removed from the chassis and tested independently of the remainder of the mixer's circuitry.

This document provides a detailed explanation of the SMPS circuitry and the suggested diagnosis and repair method.

2. Block Diagram



The SMPS consists of two separate PCBs labelled SMPS1/2 and SMPS2/2 mounted close together on the bottom panel of the EMX5000. The SMPS1/2 PCB contains the AC mains inlet socket, POWER on/off switch, mains fuse and line filter. The SMPS2/2 PCB contains the remainder of the power supply components.

These include an “in-rush current” protection relay RY101, a fixed-frequency switching regulator that drives isolation transformer T104 and its secondary components, and fan-control transistors Q111 to Q115. The only power supply component that is not mounted on these PCBs is the line filter coil. As mentioned previously, the two PCBs (and if necessary, the coil) can be removed from the chassis and tested as a complete, self-contained assembly. This reduces the possibility of damage to mixer circuitry if the SMPS is not repaired correctly.

3. Circuit description

The complete circuit diagram of the SMPS is shown on the last page of this document. The functions of the power switch, fuse and filter components on the SMPS1/2 PCB are self-explanatory. The non-PCB mounted 4.4mH filter coil is connected to CN102.

Relay RY101 on the SMPS2/2 PCB is initially unenergised and its contacts are open when power is first applied, so the incoming 240V AC from the SMPS1/2 PCB reaches the bridge rectifier D102 via two series-connected 6.8-ohm 5W resistors R101 and R134. These limit the peak current into the (initially) discharged electrolytic capacitors C106 to C109. After the SMPS starts up, RY101’s coil is energised and its contacts short out R101 and R134 to provide full power capability.

Using the negative terminals of C108 and C109 as a reference, the voltage at the positive terminals of C106 and C107 is about 340V DC (A-spec model). The 10Kohm resistors R102 to R105 maintain a “half supply” of 170V DC. A regulated +15V DC supply for the switching regulator IC102 is derived from low-voltage transformer T101 and 7815-type regulator IC101.

Switching regulator

Resistor R107 and capacitor C113 are the timing components for the 70KHz oscillator inside IC102. Out-of-phase rectangular pulses of 15V p-p amplitude appear at pins 7 and 5, and drive complementary transistor pairs Q101/Q102 and Q104/Q105. Each pair drives its respective power-switching transistor Q103/Q106.

One end of the primary winding of the high-frequency, switching transformer T104 is connected via capacitor C118 to the 170V “half supply” mentioned earlier. The other end of T104’s primary winding is alternately switched to either 0V or 340V DC by Q103/Q106. The voltages induced in T104’s secondary windings are rectified and filtered in conventional fashion to provide all of the required supply rails for the mixer. Note that there is no actual regulation of secondary voltages by optical or transformer feedback to IC102.

Insulated Gate Bipolar Transistors (IGBT’s)

At first glance, Q103/Q106 appear in the circuit diagram to be conventional bipolar transistors. They are in fact new devices (as far as their use in Yamaha equipment is concerned) known as Insulated Gate Bipolar Transistors. They differ from conventional bipolar transistors in that they have a “gate” rather than a “base” terminal and are voltage-operated rather than current-operated. In other words, an input voltage rather than a current is required to produce a collector-emitter current flow. The effective on-resistance of an IGBT is much lower than that of a power MOSFET, which is the device normally used in this application.

Although voltage-operated, a current is required to charge and discharge the gate capacitance of an IGBT (just like a MOSFET) to allow efficient switching at high frequencies. This is the reason why Q103/Q106 are driven by buffer stages rather than directly from IC102. Gate resistors R117/R118 slow down the turn-on time of their respective IGBT, while diodes D120/D121 ensure rapid turn-off. This increases the short period of time (the necessary “dead time”) within each switching cycle when neither IGBT is on.

Overcurrent protection

Fuses F102 to F104 protect against short-circuits or faults that draw excessive currents from any of the low-voltage secondary supplies. A power amplifier failure or shorted loudspeaker output that draws excessive current from the +B or -B high-voltage supply rails will activate the SMPS’s overcurrent protection circuit consisting of transistors Q107, Q109 and Q110 to effectively switch off the entire power supply.

Under normal conditions, Q107 is off and IC102 operates to produce switching pulses. When an overload occurs, the current reflected into T104’s primary winding from the high secondary winding current develops a voltage across resistors R119/R120 that switches on Q110. This in turn switches on Q109 and Q107. This disables IC102’s oscillator and all switching of T104 ceases. In addition to turning on Q107, Q109 also feeds back to the base of Q110, which “latches” on to maintain this shutdown state. The only way to restore switching operation (assuming a temporary overload condition initiated the shutdown) is to turn off the mixer’s POWER switch, then turn it back on.

A sustained, high secondary current draw whose value is not sufficient to trip the overcurrent protection circuit will tend to increase the dissipation of Q103/Q106, making them run hotter than normal. To protect against excessively high device temperatures, a Positive Temperature Coefficient (PTC) thermistor PR101 is mounted on the same heatsink as Q106 and monitors its temperature. When cold, PR101’s resistance is low and transistor Q108 is off. If Q106 gets too hot, the subsequent increase in PR101’s resistance will allow Q108 to turn on and initiate the same shutdown sequence described earlier.

Transistor Q116 inhibits IC102’s oscillator (and consequently, SMPS operation) for a short time after initial power-up. Initially, C136 is discharged and turns on Q116, which turns on Q107, inhibiting oscillation. As C136 charges up, Q106 and Q107 progressively turn off to allow normal SMPS operation.

Power-off detection

This circuit is used to switch off the EMX5000’s loudspeaker protection relay (situated on the main power amplifier PCB) as soon as either the POWER switch is turned off or if there is any interruption to the 240V AC supply.

The low-voltage AC from transformer T101 is half-wave rectified and lightly filtered, and illuminates the LED portion of the photo-coupler PH101. Consequently, PH101’s transistor saturates and puts –21V onto the OFF DETECT terminal pin 7 of connector CN104. In this condition, the loudspeaker relay is allowed to operate subject to its own local conditions (DC protect, power-on delay, etc). As soon as the EMX5000 is switched off, PH101’s LED is extinguished, which turns off the –21V to the OFF DETECT terminal. This results in the immediate de-activation of the loudspeaker protection relay.

Fan control

The EMX5000 incorporates a chassis-mounted, variable-speed cooling fan that is controlled by transistors Q111 to Q115 mounted on the SMPS2/2 PCB. The fan and its control circuitry use GND and –21V as their supply rails (a positive-ground system).

Zener diode D115 maintains Q111's emitter at 15-volts above the –21V rail. When the EMX5000 is cold, the series connected PTC thermistors PR102 (mounted on the SMPS2/2 PCB) and PR102 (mounted on the main amplifier PWR PCB) have a low resistance and turn on Q113. This shorts the base of Darlington-connected Q114/Q115 to the –21V rail, disabling the fan. As the thermistors' resistances rise with increasing temperature, Q113 is turned off, the fan starts to turn at low speed and the voltage available to Q114 via D116, Q112 and D117 progressively increases relative to the –21V rail. The fan's speed is therefore controlled until maximum speed is reached at about 70-deg C.

4. SMPS failure repair guide

Applicable SMPS PCB part numbers and mains voltages

Part number	Circuit Board Name	AC mains voltage
V8269300	SMPS J circuit board	AC100V/50Hz
V8269400	SMPS U circuit board	AC120V/60Hz
V8269500	SMPS H circuit board	AC230V/50Hz
V8485200	SMPS A circuit board	AC240V/50Hz

Electrolytic Capacitor Discharge Precautions

To prevent electrical shock when handling the SMPS circuit boards after they have had power applied, discharge the electrolytic capacitors by connecting resistances across the measurement terminals specified in the table above. Additionally (and importantly), discharge capacitors C106 to C109 by temporarily connecting a 10Kohm 5W resistor between C106 (+) and C108 (-). Note that discharging is not necessary if the unit is allowed to stand for 10 minutes after the POWER switch is turned off.

Confirming normal operation of the SMPS

After repairs have been completed, prepare the SMPS as follows –

- Ensure AC mains voltage is correct for each destination PCB (see table above).
- Connect SMPS1/2 PCB terminals W101YE and W101BR to SMPS2/2 PCB connector CN103.
- Plug coil into CN102.
- Connect load resistances across DC supply voltage outputs (see table below).
- Plug in AC mains lead to CN101 (AC inlet).

Voltage of each supply

When SW101 (POWER SWITCH) is on, the output voltage of each supply is normal if within the range shown in the table below. If output voltages are measured without connecting load resistances, or if the correct AC mains voltage is not applied, the output voltages shown may not be attained.

Measured Supply	Measured Location	Output Voltage (DC)			Load Resistance
		J	U	H, A	
+ B supply	W102RE – W102BL	+104.2 +/- 2V	+102.3 +/- 2V	+94.2 +/- 2V	10Kohm 3W
- B supply	W102BE – W102BL	-104.2 +/- 2V	-102.3 +/- 2V	-94.2 +/- 2V	10Kohm 3W
+ Analog supply	CN104 Pin 1 – Pin 2	+27.4V +/- 2V	+28.8V +/- 2V	+26.3V +/- 2V	10Kohm 1/4W
- Analog supply	CN104 Pin 3 – Pin 2	-27.4V +/- 2V	-28.8V +/- 2V	-26.3V +/- 2V	10Kohm 1/4W
Lamp, DSP supply	CN104 Pin 5 – Pin 6	+20.4V +/- 2V	+21.4V +/- 2V	+19.7V +/- 2V	10Kohm 1/4W

Suggested diagnosis procedure if there are no secondary output voltages at all

1) Check resistance values of R101, R134 (6.8-ohm 5W). Replace if open.
2) Check resistance values across Q103, Q106 collector-emitter terminals. Replace if shorted or if resistance has fallen to several ohms.
3) Visually inspect Q101, Q102, Q104 and Q105 for damage (cracks, leakage, etc). Replace if necessary.
4) Check resistance values across Q101, Q102, Q104 and Q105 collector-emitter terminals. Replace if shorted or if resistance has fallen to several ohms.
5) Check resistance values of R117, R118. Replace if open or higher than correct value.
6) Check resistance values of D120, D121. Replace if shorted.
7) If desired, the opportunity can be taken to confirm the existence of switching pulses from IC102 without the risk of damage to high-power, high-voltage components. **With the SMPS disconnected from the 240VAC mains**, connect an external 15-30VDC voltage supply across capacitor C110 (observe correct polarity). After confirming the output of IC101 (3-terminal regulator) is +15VDC, an oscilloscope can then be used to monitor the waveform produced between IC102 pin 5 (LO) and pin 4 (COM). A 70KHz rectangular waveform should be observed.
8) If oscillation cannot be observed, check for any shorts in Q107, Q108, Q109, Q110 or Q116. If all these measure OK, replace IC102. Note that if Q106, PR101 and their common heatsink have been removed from the circuit board, a link must be soldered across the vacant PCB holes at PR101's location before checking for oscillation.

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