MP7720

20W Class D Mono Single Ended Audio Amplifier

Monolithic Power Systems

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General Description

The MP7720 is a mono 20W Class-D Audio Amplifier. It is one of MPS' second generation of fully integrated audio amplifiers which dramatically reduces solution size by integrating the following:

- **180mW power MOSFETs**
- **Start up / shut down pop elimination**
- **Short circuit protection circuits**
- **Mute / Stand By**

The MP7720 utilizes a single ended output structure capable of delivering 20W into 4Ω speakers. As in all other MPS Class-D Audio Amplifiers, this device exhibits the high fidelity of a Class A/B amplifier at efficiencies greater than 90%. The circuit is based on the MPS' proprietary variable frequency topology Analog Adaptive Modulation (AAM™, Patent pending) that delivers excellent PSRR, fast response time and operates on a single power supply.

Features

- 20W output at V_{DD}=24V into a 4Ω load
- THD+N as low as 0.06%
- 90% efficiency at 20W
- Low Quiescent Current (2mA)
- Switching Frequency to 1MHz
- 7.5V to 24V operation from single supply
- Integrated Start up and Shut Down Pop Elimination Circuit
- Thermal protection
- Integrated 180mΩ switches
- Mute / Standby-mode (Sleep)
- **Tiny 8 Pin SOIC or PDIP Package**
- **Evaluation Board Available**

Applications

- Surround Sound DVD Systems
- Televisions
- Flat Panel Monitors
- Multimedia computers
- Home stereos

Ordering Information

Part Number *	Package	Temperature
MP7720DS	SOIC8	-40°C to + 85°C
MP7720DP	PDIP8	-40°C to + 85°C

* For Tape & Reel use suffix - Z (e.g. MP7720DS-Z)

Figure 1: Typical Application Circuit

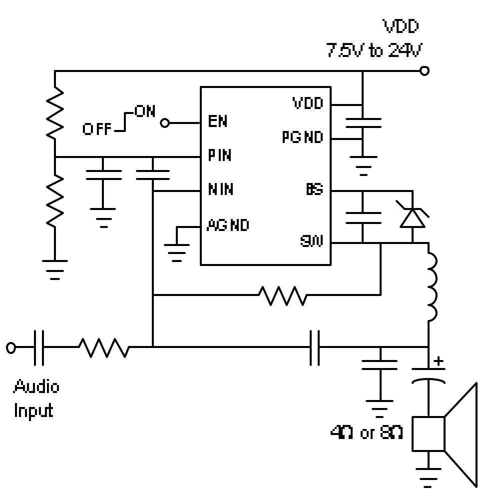
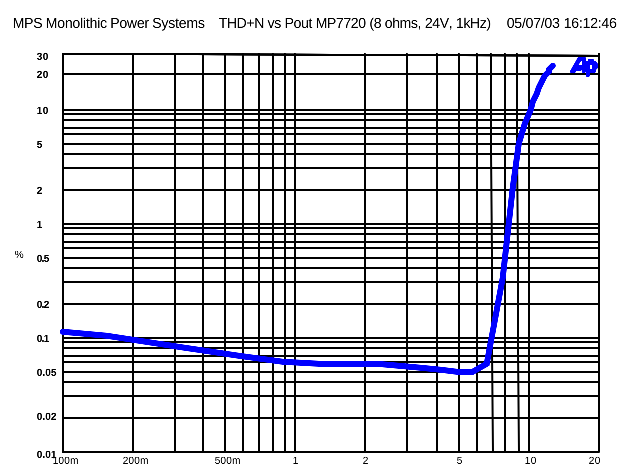


Figure 2: THD+N vs. Power (24V, 8W)



Absolute Maximum Ratings (Note 1)

Supply Voltage V_{DD}	26V
BS Voltage	V_{SW}-0.3V to V_{SW}+6.5V
Enable Voltage V_{EN}	-0.3V to 6V
V_{SW}, V_{PIN}, V_{NIN}	-1V to V_{DD}+1V
AGND to PGND	-0.3V to 0.3V
Junction Temperature	150°C
Lead Temperature	260°C
Storage Temperature	-65°C to 150°C

Recommended Operating Conditions (Note 2)

Supply Voltage V_{DD}	7.5V to 24V
Operating Temperature T_A	-40°C to 85°C

Package Thermal Characteristics

Thermal Resistance Θ_{JA} (8-SOIC)	140°C/W
Thermal Resistance Θ_{JA} (8-PDIP)	100°C/W

Electrical Characteristics (Circuit of Figure 3, V_{DD}=24V, V_{EN}=5V, T_A=25°C)

Parameters	Condition	Min	Typ	Max	Units
Supply Current					
Standby Current	V_{EN} = 0V			10	µA
Quiescent Current (No Load)			2		mA
Output Drivers					
SW On Resistance	Sourcing and Sinking		0.18		Ω
Short Circuit Current	Sourcing and Sinking		4.5		A
Inputs					
PIN, NIN Input Common Mode Voltage Range		0	$\frac{V_{DD}}{2}$	V_{DD}-1.5	V
PIN, NIN Input Current	V_{PIN}=V_{NIN}=12V		1	5	µA
EN Enable Threshold Voltage	V_{EN} Rising		1.4	2.0	V
	V_{EN} Falling	0.4	1.2		V
EN Enable Input Current	V_{EN} = 5V		1		µA
Thermal Shutdown					
Thermal Shutdown Trip Point	T_J Rising		150		°C
Thermal Shutdown Hysteresis			30		°C

Operating Specifications (Circuit of Figure 3, V_{DD}=24V, V_{EN}=5V, 4Ω Load, T_A=25°C)

Power Output	F=1KHz, THD + N = 10%		20		W
Harmonic Distortion + Noise	P_{OUT}=1W f=1KHz		0.07		%
Efficiency	f =1KHz, P_{OUT}=1W		90		%
Maximum Power Bandwidth			20		kHz
Dynamic Range			93		dB
Noise Floor	A-Weighted		175		µV
Power Supply Rejection	f=1KHz		60		dB

Operating Specifications (Circuit of Figure 3, V_{DD}=24V, V_{EN}=5V, 8Ω Load, T_A=25°C)

Power Output		f=1KHz, THD + N = 10%		10		W
Harmonic Distortion + Noise		P_{OUT}=1W, f=1KHz		0.06		%
Efficiency		f=1KHz, P_{OUT}=1W		95		%
Maximum Power Bandwidth				20		kHz
Dynamic Range				93		dB
Noise Floor		A-Weighted		175		µV
Power Supply Rejection		f=1KHz		60		dB

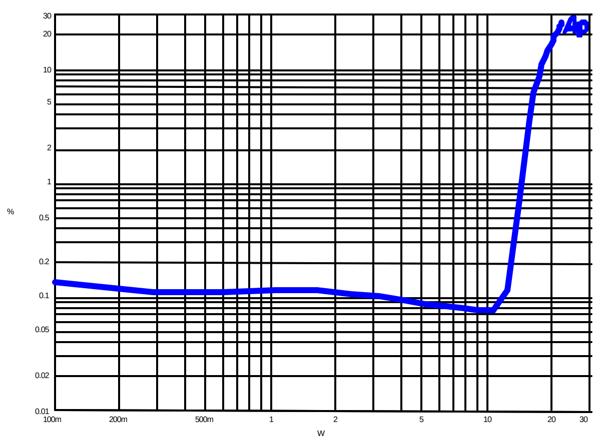
Note 1. Exceeding these ratings may damage the device.
Note 2. The device is not guaranteed to function outside its operating rating.

Typical Operating Characteristics

(Circuit of Figure 3, V_{DD}=24V, T_A=25°C Unless Otherwise specified)

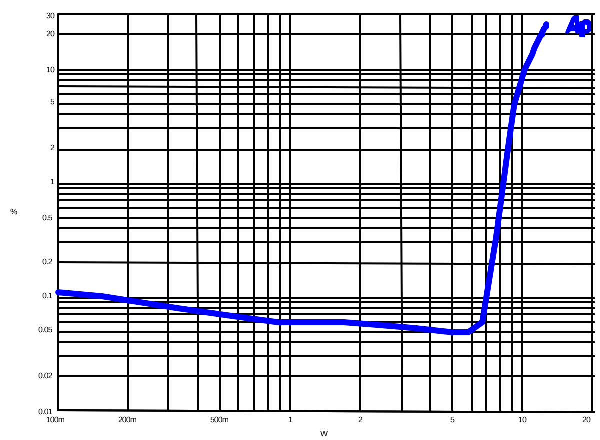
THD+N vs. Output Power (1kHz, 24V, 4Ω)

MPS Monolithic Power Systems THD+N vs Pout MP7720 (4 ohms, 24V, 1kHz) 05/07/03 16:14:16



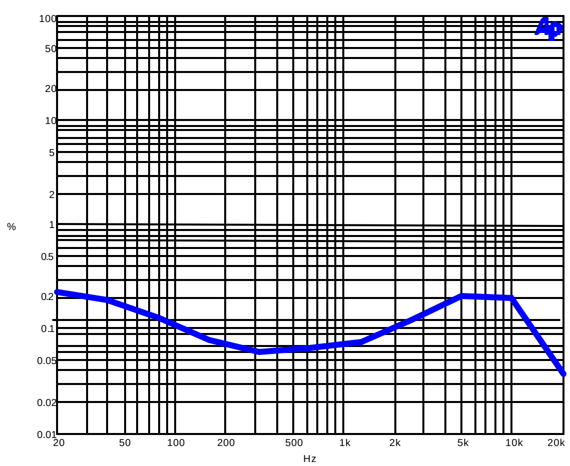
THD+N vs. Output Power (1kHz, 24V, 8Ω)

MPS Monolithic Power Systems THD+N vs Pout MP7720 (8 ohms, 24V, 1kHz) 05/07/03 16:12:46



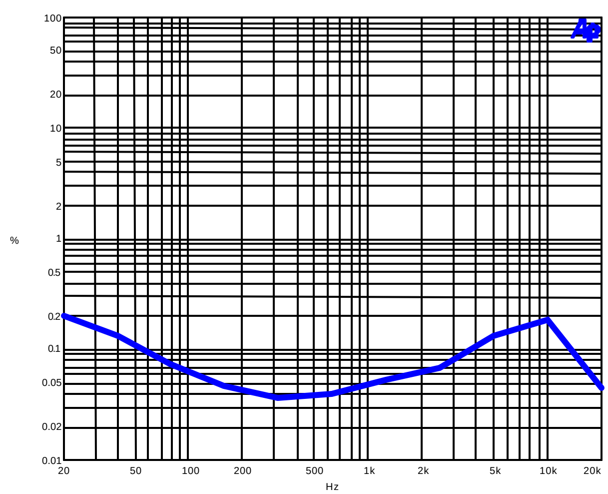
THD+N vs. Frequency (24V, 4W, 19.6W)

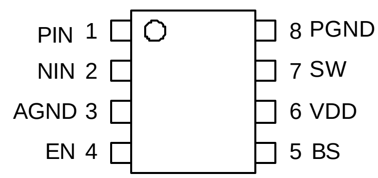
MPS Monolithic Power Systems THD+N vs Freq MP7720 (24V, 4ohms, 9.6W) 05/07/03 16:46:16



THD+N vs. Frequency (24V, 8W, 14.5W)

MPS Monolithic Power Systems THD+N vs Freq MP7720 (24V, 8ohms, 4.5W) 05/07/03 16:42:45

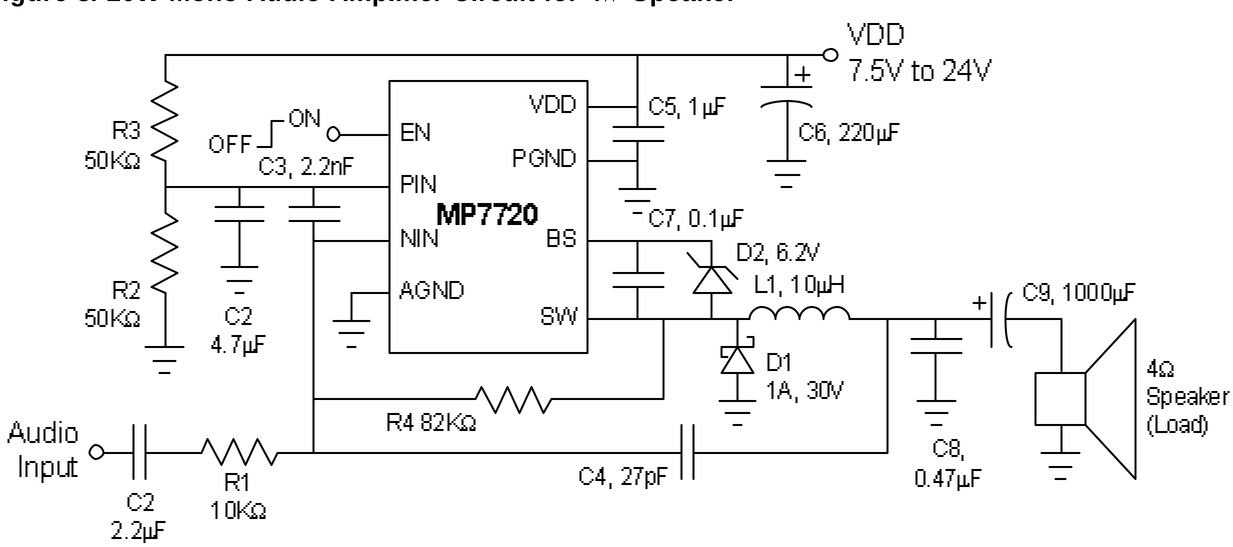




Pin Designators

Pin Number	Pin Name	Pin Function
1	PIN	Amplifier Positive Input. PIN is the positive side of the differential input to the amplifier. Use a resistive voltage divider to set the voltage at PIN to $V_{DD}/2$. See Figure 3.
2	NIN	Amplifier Negative Input. NIN is the negative side of the differential input to the amplifier. Drive the input signal and close the feedback loop at NIN. See Figure 3.
3	AGND	Analog Ground. Connect AGND to PGND at a single point.
4	EN	Enable Input. Drive EN high to turn-on the amplifier, drive it low to turn it off.
5	BS	High-Side MOSFET Bootstrap Input. A capacitor from BS to SW supplies the gate drive current to the high-side MOSFET. Connect a 0.1µF to 1µF capacitor from SW to BS. Place a 6.2V zener diode from BS to SW to prevent overstressing of the internal circuitry.
6	VDD	Power Supply Input. VDD is the drain of the high-side MOSFET switch, and supplies the power to the output stage and the MP7720 internal control circuitry. Bypass VDD to PGND with a 1µF or greater capacitor.
7	SW	Switched Power Output. SW is the output of the MP7720. Connect the LC filter between SW and the output coupling capacitor. See Figure 3.
8	PGND	Power Ground. Connect PGND to AGND at a single point.

Figure 3: 20W Mono Audio Amplifier Circuit for 4W Speaker



Functional Description

The MP7720 is a single-ended Class-D audio amplifier. It uses the Monolithic Power Systems proprietary Analog Adaptive Modulation to convert the audio input signal into pulses. The pulses drive a high-current output stage when filtered through an external inductor-capacitor filter, reproduces the input signal across the load. Because of the switching Class-D output stage, power dissipation in the amplifier is drastically reduced compared to Class A, Class B or Class A/B amplifiers while maintaining high fidelity and low distortion.

The amplifier uses a differential input to the modulator. PIN is the positive input and NIN is the negative input. The common mode voltage of the input is set to half the DC power supply input voltage ($V_{DD}/2$) through the resistive voltage divider formed by R2 and R3. The input capacitor C1 couples the AC signal at the input.

The amplifier voltage gain is set by the combination of R1 and R4 and is calculated by the equation:

$$A_V = -R4 / R1.$$

The output driver stage uses two 180mΩ n-channel MOSFETs to deliver the pulses to the LC output filter which in turn drives the load. To fully enhance the high-side MOSFET, the gate is driven to a voltage higher than the source by the bootstrap capacitor between SW and BS. While the output is driven low, the bootstrap capacitor is charged from V_{DD} through an internal circuit on the MP7720. The gate of the high-side MOSFET is driven high from the voltage at BS, forcing the MOSFET gate to a voltage higher than V_{DD}, allowing the MOSFET to turn on fully, reducing power loss in the amplifier.

Pop Elimination

The capacitor C9 passes only AC currents to the load. To insure that the amplifier passes low frequency signals, the time constant of $C9*R_{LOAD}$ needs to be long. When EN is asserted, the capacitors charges over a long period and in a normal amplifier cause a turn-on and/or turn-off “pop”. The MP7720 includes integrated circuitry that eliminates the turn-on and turn-off pop associated with the AC coupling capacitor.

Short Circuit/Overload Protection

The MP7720 has internal overload and short circuit protection. The currents in both the high-side and low-side MOSFETs are measured. If the current exceeds the 4.5A short circuit current limit, both MOSFETs are turned off. Then the MP7720 restarts with the same power up sequence that is used for normal starting to prevent a pop from occurring after a short circuit condition is removed.

Mute/Enable Function

The MP7720 EN input is an active high enable control. To enable the MP7720, drive EN with a 2.0V or greater voltage. To disable the amplifier, drive it below 0.4V. While the MP7720 is disabled, the VDD operating current is less than 10µA and the output driver MOSFETs are turned off. The MP7720 requires approximately 500ms from the time that EN is asserted (driven high) to when the amplifier begins normal operation.

Applications Information

The MP7720 uses a minimum number of external components to complete a Class-D audio amplifier. The circuit of Figure 3 is optimized for a 24V power supply and a 1V RMS input signal. This circuit is suitable for most applications. If this circuit is not suitable use the following sections to determine how to customize the amplifier for a particular application.

Setting the Voltage Gain

The voltage gain sets the output voltage swing for a given input voltage swing. The output voltage swing is limited by the power supply, since it can not swing above or below the power supply voltage. To achieve the maximum power out of the MP7720 amplifier, set the gain such that the maximum input signal results in the maximum output voltage swing.

The maximum output voltage swing is $\pm V_{DD}/2$. For a given input signal voltage, where $V_{IN}(pk)$ is the peak input voltage, the maximum voltage gain is:

$$A_V(max.) = V_{DD} / (2 * V_{IN}(pk))$$

This voltage gain setting results in the peak output voltage approaching it's maximum for the maximum input signal. In some cases the amplifier is allowed to overdrive slightly, allowing the THD to increase at high power levels, and so a higher gain the $A_V(max.)$ is required.

Setting the Switching Frequency

The switching frequency is set by the capacitor C3 and the feedback resistor R4. Lower switching frequencies result in more inductor ripple, causing more quiescent output voltage ripple, increasing the output noise and distortion. Higher switching frequencies result in more power loss. The optimum quiescent switching frequency is approximately 600kHz.

To set the switching frequency to some other value, see the nomograph of Figure 3.

Figure 3: Switching Frequency vs. Integrating Capacitor and Feedback Resistor (to be inserted in future data sheet revision)

Choosing the LC Filter

The Inductor-Capacitor (LC) filter converts the pulse train at SW to the output voltage that drives the speaker. Typical values for the LC filter are shown in Figure 3, 10µH inductor and 0.47µF capacitor.

The characteristic frequency of the LC filter needs to be high enough to allow high frequency audio to the output, yet needs to be low enough to filter out high frequency products of the pulses from SW. The characteristic frequency of the LC filter is:

$$f_0 = 1 / (2\pi\sqrt{LC})$$

The voltage ripple at the output is approximated by the equation:

$$V_{RIPPLE} \cong V_{DD} * (f_0 / f_{SW})$$

The quality factor (Q) of the LC filter is important. If this is too low, output noise will increase, if this is too high, then peaking may occur at high signal frequencies reducing the passband flatness. The circuit Q is set by the load resistance (speaker resistance, typically 4O or 8O). The Q is calculated as:

$$Q = \omega_0 * L / R = 2\pi * f_0 * L / R$$

ω_0 is the characteristic frequency in radians per second and f_0 is in Hz. Use an LC filter with Q between 0.7 and 1

The actual output ripple and noise is greatly affected by the type of inductor and capacitor used in the LC filter. Use a film capacitor and an inductor with sufficient power handling capability to supply the output current to the load. The inductor should exhibit soft saturation characteristics. If the inductor exhibits hard saturation, it should operate well below the saturation current. Gapped ferrite, MPP, Powdered Iron, or similar type torroidal cores are recommended. If open or shielded bobbin ferrite cores are used for multi-channel designs, make sure that the start windings of each inductor line up (all starts going toward SW pin, or all starts going toward the output) to prevent crosstalk or other channel-to-channel interference.

Output Coupling Capacitor

The output AC coupling capacitor, C9, passes only AC current from the LC filter to the load (speaker). The capacitor must be large enough to pass the lowest frequencies. If too large a capacitor is used, a longer period is required to charge the capacitor at turn on. The corner frequency of the output coupling capacitor and the load is:

$$f_{OUT} = 1 / (2\pi\ R_{LOAD}\ C9)$$

Set the output corner frequency (f_{OUT}) at or below the minimum passband frequency.

The output coupling capacitor caries the load current, so choose a capacitor whose ripple current rating is greater than the maximum load current. Aluminum electrolytic or tantalum capacitors are recommended.

Input Coupling Capacitor

The input coupling capacitor, C1, is used to pass only the AC signal at the input. The source input signal is typically centered around the circuit ground, but the MP7720 input is at half the power supply voltage ($V_{DD}/2$). The input coupling capacitor transmits the AC signal from the source to the MP7720 while blocking the DC voltage. Choose an input coupling capacitor such that the corner frequency (f_{IN}) is less than the passband frequency. The corner frequency is:

$$f_{IN} = 1 / (2p * R1 * C1).$$

Use a ceramic capacitor for C1. Make sure that the dielectric changes little with capacitor bias voltage and temperature. Use NPO, X7R, X5R or equivalent type capacitors.

Power Source

For maximum output power, the amplifier circuit requires a regulated external power source to supply the power to the amplifier. The higher the power supply voltage, the more power can be delivered to a given load resistance, however if the voltage exceeds the maximum operating voltage of 24V, the MP7720 may sustain damage. When the amplifier is disabled (EN is driven low), the power supply voltage is allowed to increase to the 26V absolute maximum rating.

The power source must be able to source the peak load current. The power supply rejection of the MP7720 is excellent (60dB typ.), however noise at the power supply can get to the output, so care must be taken to minimize power supply noise within the passband frequencies. Bypass the power supply with a large capacitor (typically aluminum electrolytic or tantalum) along with a smaller 0.1µF or greater ceramic capacitor at the MP7720 VDD input.

Circuit Layout

The circuit layout is critical for optimum performance and low output distortion and noise. Place the following components as close to the MP7720 as possible:

1. **Power supply bypass, C5**. C5 caries the transient current for the switching input stage. To prevent overstressing of the MP7720 and excessive noise at the output, place the power supply bypass capacitor as close to pins 6 (VDD) and 8 (PGND) as possible.
2. **Output Catch Diode, D1**. D1 caries the current over the dead-time while both MOSFET switches are off. Place D1 between pins 7 (SW) and 8 (PGND)

to prevent the voltage at SW from swinging excessively below ground.

3. **Input Modulator Capacitor, C3**. C3 is used to set the amplifier switching frequency. Place C3 as close to the differential input pins (1 and 2) as possible to reduce distortion and noise.
4. **Reference Bypass Capacitor C2**. C2 filters the ½ V_{DD} reference voltage at the PIN input (pin 1). Place C2 as close to PIN as possible to improve power supply rejection and reduce distortion and noise at the output.

Use two separate ground planes, analog ground (AGND) and power ground (PGND), and connect the 2 grounds together at a single point to prevent noise injection into the amplifier input to reduce distortion. Power components (C5, D1, C6 and C8) connect to the power ground. The quiet analog components (C2, C3, R2, and the input source ground) connect to the analog ground.

Place the input and feedback resistors R1 and R4 as close to the NIN input as possible. Make sure that any traces carrying the switching node (SW) voltage are far from the input signal. If multiple amplifiers are used on a single board, make sure that each channel is physically separated to prevent crosstalk. If it is required to run the SW trace near the input, shield the input with a ground plane between the traces. Make sure that all inductors used on a single circuit board have the same orientation.

If multiple channels are used on a single board, make sure that the power supply is routed from the source to each channel individually, not serially. This prevents channel-to-channel coupling through the power supply input.

Electro-Magnetic Interference (EMI) Considerations

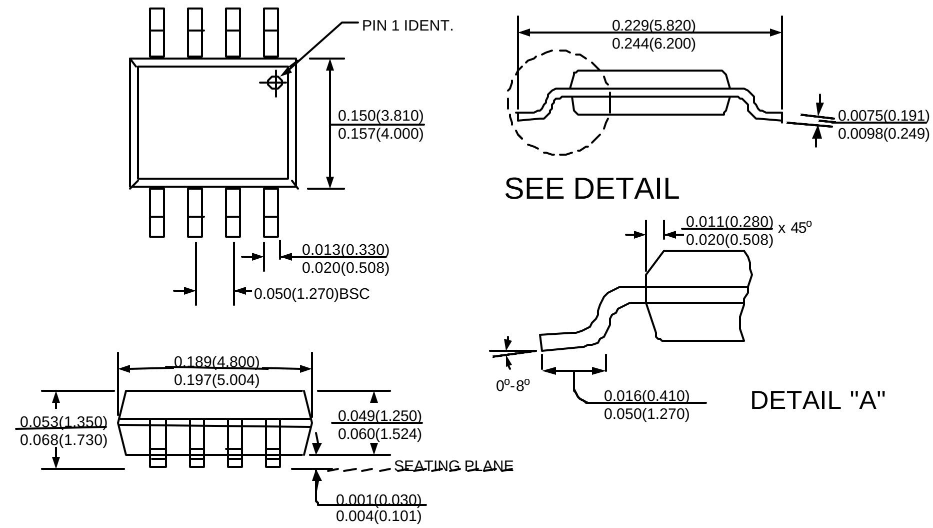
Due to the switching nature of the Class-D amplifier, care must be taken to minimize the effects of electromagnetic interference from the amplifier. However, with proper component selection and careful attention to circuit layout, the effects of the EMI due to the amplifier switching can be minimized.

The power inductors are a potential source of radiated emissions. For the best EMI performance, use torroidal inductors, since the magnetic field is well contained inside the core. However torroidal inductors can be expensive to wind. For a more economical solution, use shielded gapped ferrite or shielded ferrite bobbin core inductors. These inductors typically do not contain the field as well torroidal inductors, but usually can achieve a better balance of good EMI performance with low cost.

The size of high-current loops that carry rapidly changing currents needs to be minimized. To do this, make sure that the V_{DD} bypass capacitor (C5) is as close to the MP7720 as possible.

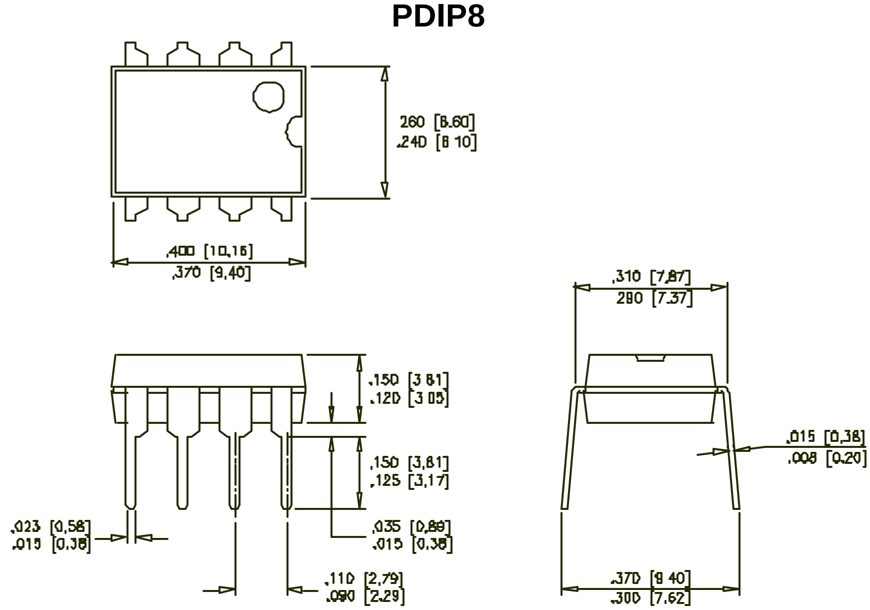
Nodes that carry rapidly changing voltage, such as SW, need to be made as small as possible. If sensitive traces run near a trace connected to SW, place a ground shield between the traces.

SOIC8



NOTE:
1) Control dimension is in inches. Dimension in bracket is millimeters.

PDIP8



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