

## All-Digital High Efficiency Power Amplifier

### FEATURES

- HIGH OUTPUT CAPABILITY
- **2 x 35W** into 8Ω or **1 x 70W** into 4Ω @ <1% THD
- **2 x 50W** into 8Ω or **1 x 100W** into 4Ω @ 10% THD
- SINGLE SUPPLY (+9V to +30V)
- COMPACT SURFACE MOUNT PACKAGE
- HIGH EFFICIENCY, >88%
- THERMAL OVERLOAD AND SHORT CIRCUIT PROTECTION

### BENEFITS

- COMPLETE SURFACE MOUNT DESIGN
- POWER SUPPLY SAVINGS

### APPLICATIONS

- DIGITAL POWERED SPEAKERS
- PC SOUND CARDS
- CAR AUDIO
- SURROUND SOUND SYSTEMS
- DIGITAL AUDIO COMPONENTS

### GENERAL DESCRIPTION

The DDX-2060 power device is a monolithic dual channel H-Bridge that can provide up to 50 watts per channel of audio power at very high efficiency. The DDX-2060 power device contains a logic interface, integrated bridge drivers, high efficiency MOSFET output transistors and protection circuitry. The device may be used as a dual bridge or reconfigured as a single bridge with double the output current capability.

The benefits of the DDX amplification system are an all-digital design that eliminates the need for a digital to analog converter (DAC) and the high efficiency operation derived from the use of Apogee's patented damped ternary pulse width modulation (PWM). This approach provides an efficiency advantage over conventional Class-D designs and up to three times the efficiency of typical Class A/B amplifiers with music input signals.

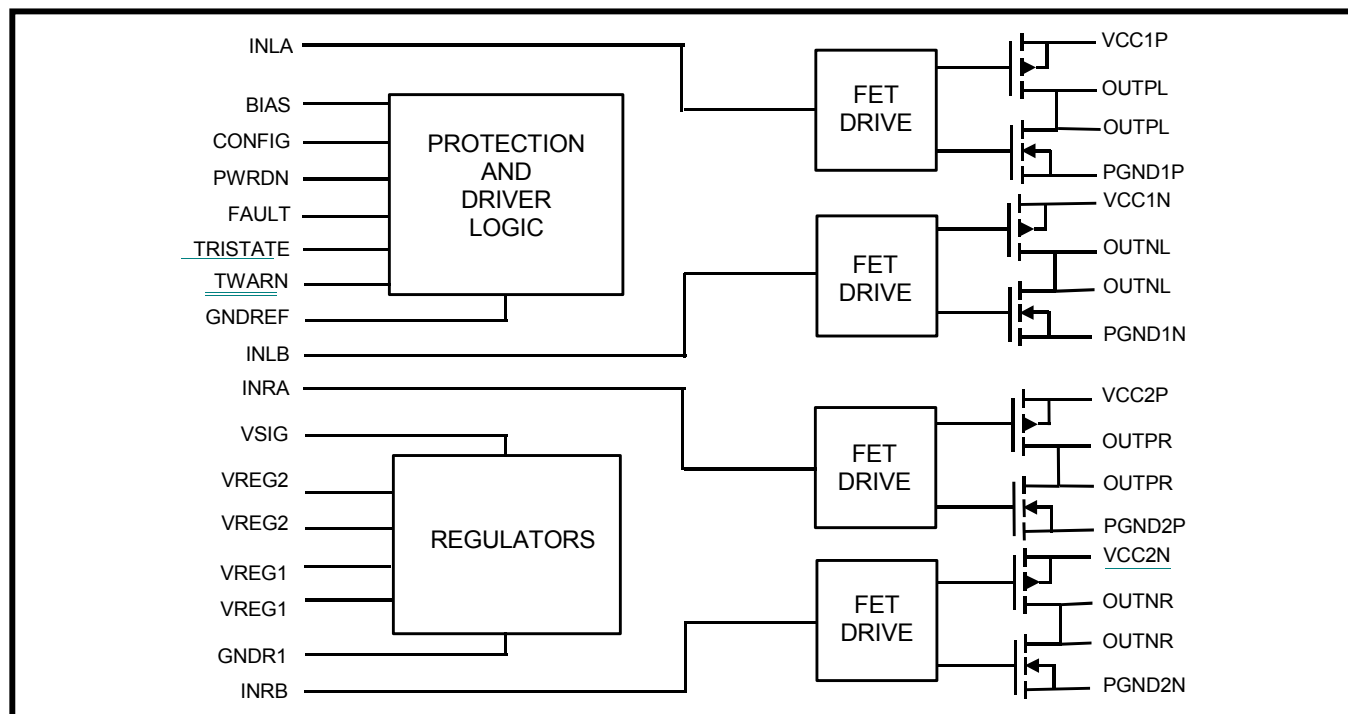


Figure 1. Block Diagram

**Specifications are subject to change without notice.**

**Absolute Maximum Ratings [Note 1]**

SYMBOL	PARAMETER	VALUE	UNIT
VCC	Power supply voltage	40V	V
VL	Input logic reference	5.5V	V
Tj	Operating Temperature Range	0 to 70	°C
Tstg	Storage and Junction Temperature Range	-40 to 150	°C

Note 1: Permanent device damage may occur if ABSOLUTE MAXIMUM RATINGS are exceeded.

Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**Recommended Operating Conditions [Note 2]**

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT
VCC	Power supply voltage [Note 3]	10.0		36.0	V
VL	Input logic reference	2.7	3.3	5.0	V
T <sub>A</sub>	Ambient Temperature	0		70	°C

Note 2: Performance not guaranteed beyond recommended operating conditions.

Note 3: Overvoltage protection may preclude operation above 30V.

**Thermal Data**

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT
$\theta_{JC}$	Thermal resistance junction-case (heat spreader)			2.5	°C/W
T <sub>JSD</sub>	Thermal shut-down junction temperature		150		°C
T <sub>warn</sub>	Thermal warning temperature		130		°C
T <sub>hSD</sub>	Thermal shut-down hysteresis		25		°C

**Electrical Characteristics**

Refer to circuit in Figure 4. VCC = 28V, VL = 3.3V, fsw = 384kHz, T<sub>A</sub> = 25°C, RL = 8Ω unless otherwise specified.

SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
P <sub>o</sub>	Output power per channel [Notes 4,5]	THD+N <1%		35		W <sub>rms</sub>
P <sub>o</sub>	Output power per channel [Notes 4,5]	VCC = 30V, @ 10% THD+N		50		W <sub>rms</sub>
UVL	Undervoltage Lockout Threshold			7	9	V
OVP	Overvoltage Protection Threshold		30	35	40	V
I <sub>PD</sub>	Vcc supply current in Powerdown			1	3	mA
I <sub>ccTri</sub>	Supply current from Vcc in Tristate	TRISTATE = 0		22		mA
I <sub>cc</sub>	Vcc supply current	2-Channel switching at 384kHz.		72		mA
I <sub>sc</sub>	Output Short-circuit Protection limit	Speaker outputs.	3.5	5.0	6.5	A
THD+N	Total Harmonic Distortion+Noise [Note 4]	Po=1 W <sub>rms</sub> Po=30 W <sub>rms</sub>		0.08 0.33	0.18 0.50	% %
THD+N	Total Harmonic Distortion+Noise [Note 5]	Po=1 W <sub>rms</sub> Po=30 W <sub>rms</sub>		0.05 0.15		% %
SNR	Signal to Noise Ratio [Note 4]	A-Weighted		93		dB
SNR	Signal to Noise Ratio [Note 5]	A-Weighted		100		dB
η	Efficiency	Po=2 x 30 W		88		%
R <sub>dsON</sub>	Power MOSFET output resistance	Id=1A		200	270	mΩ
R <sub>dsON</sub> matching		Id=1A	95			%
t <sub>on</sub>	Turn-on delay time	Resistive load			100	ns
t <sub>off</sub>	Turn-off delay time	Resistive load			100	ns
t <sub>r</sub>	Rise time	Resistive load			25	ns
t <sub>f</sub>	Fall Time	Resistive load			25	ns
V <sub>IL</sub>	Low logic input voltage on PWRDN, TRISTATE pins	V <sub>L</sub> = 2.7V V <sub>L</sub> = 3.3V V <sub>L</sub> = 5.0V	0.7 0.8 0.85			V

**Specifications are subject to change without notice.**

**Electrical Characteristics (continued)**

SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
$V_{IH}$	High logic input voltage on PWRDN, TRISTATE pins	$V_L = 2.7V$ $V_L = 3.3V$ $V_L = 5.0V$			1.5 1.7 1.85	V
$V_{IL}$ , PWM Inputs	Low logic input voltage on INLA, INLB, INRA, INRB pins	$V_L = 2.7V$ $V_L = 3.3V$ $V_L = 5.0V$	1.05 1.35 2.2			V
$V_{IH}$ , PWM Inputs	High logic input voltage on INLA, INLB, INRA, INRB pins	$V_L = 2.7V$ $V_L = 3.3V$ $V_L = 5.0V$			1.65 1.95 2.8	V
$I_{fault}$	Output Sink Current, FAULT, TWARN pins	Fault Active		1		mA
$P_{wmin}$	Minimum output pulse width	No load	70		150	ns

Note 4: Characteristics are for the DDX-2060 power device driven by either the DDX-2000 or DDX-4100(A) processor.

Note 5: Characteristics are for the DDX-2060 power device driven by DDX-8000 processor.

**Logic Truth Table**

TRISTATE	INxA	INxB	OUTPx	OUTNx	OUTPUT MODE
0	X	X	OFF	OFF	Hi-Z
1	0	0	GND	GND	DAMPED
1	0	1	GND	VCC	NEGATIVE
1	1	0	VCC	GND	POSITIVE
1	1	1	VCC	VCC	Not Used

**DDX-2060 Pin Function Description**
**PWM Inputs**

Pin Name	Pin No.	Description
INLA	29	Left A logic input signal
INLB	30	Left B logic input signal
INRA	31	Right A logic input signal
INRB	32	Right B logic input signal

**Control/Miscellaneous**

Pin Name	Pin No.	Description
PWRDN	25	Power Down (0=Shutdown, 1= Normal).
TRI-STATE	26	Tri-State (0=All MOSFETS Hi-Z, 1=Normal).
FAULT [Note 6]	27	Fault output indicator; Overcurrent, Overvoltage or Overtemperature (0=Fault, 1=Normal).
TWARN [Note 6]	28	Thermal warning output (0=Warning $T_J \geq 130^\circ C$ , 1=Normal).
CONFIG [Note 7]	24	Configuration (0=Normal, 1=Parallel operation for mono).
NC	18	Do not connect.

Note 6: FAULT and TWARN outputs are open-drain

Note 7: Connect CONFIG Pin 24 to VREG1 Pins 21,22 to implement single bridge operation for high current.

**Power Outputs [Note 8]**

Pin Name	Pin No.	Description
OUTPL	16, 17	Left output, positive reference
OUTNL	10, 11	Left output, negative reference
OUTPR	8, 9	Right output, positive reference
OUTNR	2, 3	Right output, negative reference

Note 8: DDX outputs are bridged. The outputs OUTPx produce signals in phase with the input.

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**Power Supplies**

Pin Name	Pin No.	Description
VCC [1P, 1N, 2P, 2N]	4, 7, 12, 15	Power
PGND [1P, 1N, 2P, 2N]	5, 6, 13, 14	Power grounds
VREG1	21, 22	Internal regulator voltage requires bypass capacitor.
VREG2	33, 34	Internal regulator voltage requires bypass capacitor.
VSIG	35, 36	Signal Positive supply.
VL	23	Logic reference voltage.
GNDREF	19	Logic reference ground.
GNDS	1	Substrate ground.
GNDR1	20	Internal regulator ground.

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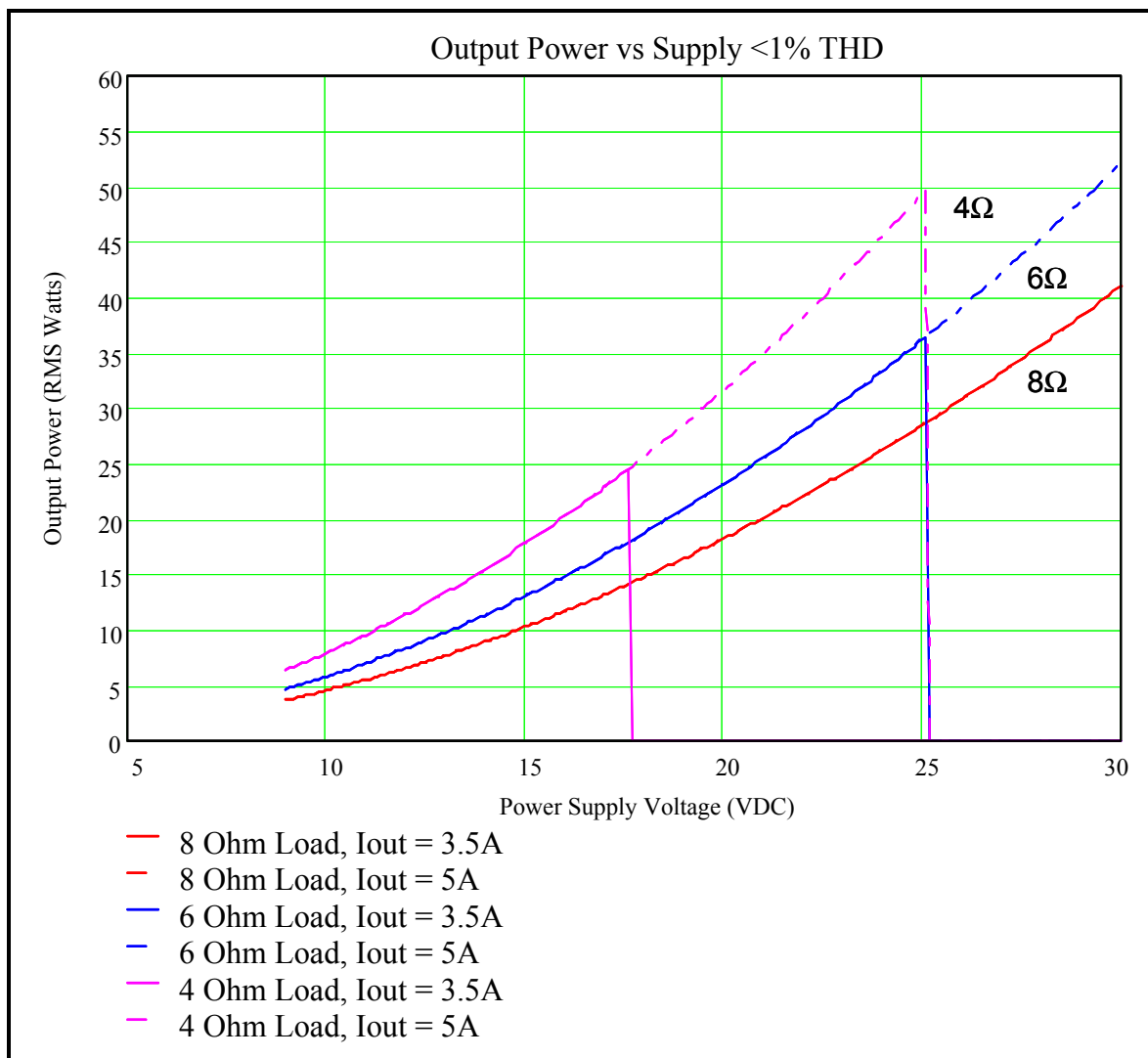


Figure 2. Output Power vs. Supply Voltage for Stereo Bridge.

Figure 2 shows the full-scale output power (0dB FS digital input with unity amplifier gain) as a function of Power Supply Voltage for 4, 6, and 8 Ohm loads. Output power is constrained for higher impedance loads by the over-voltage protection limit of the DDX-2060 IC and by the over-current protection limit for lower impedance loads. The minimum threshold for the over-current protection circuit is 3.5A (at 25 °C) but the typical threshold is 5A. Solid curves depict the worst case output power capability constrained to a 3.5A current limit. Dashed curves depict typical output power capability of the device. Of course, the output power curves assume proper thermal management of the power device's internal dissipation.

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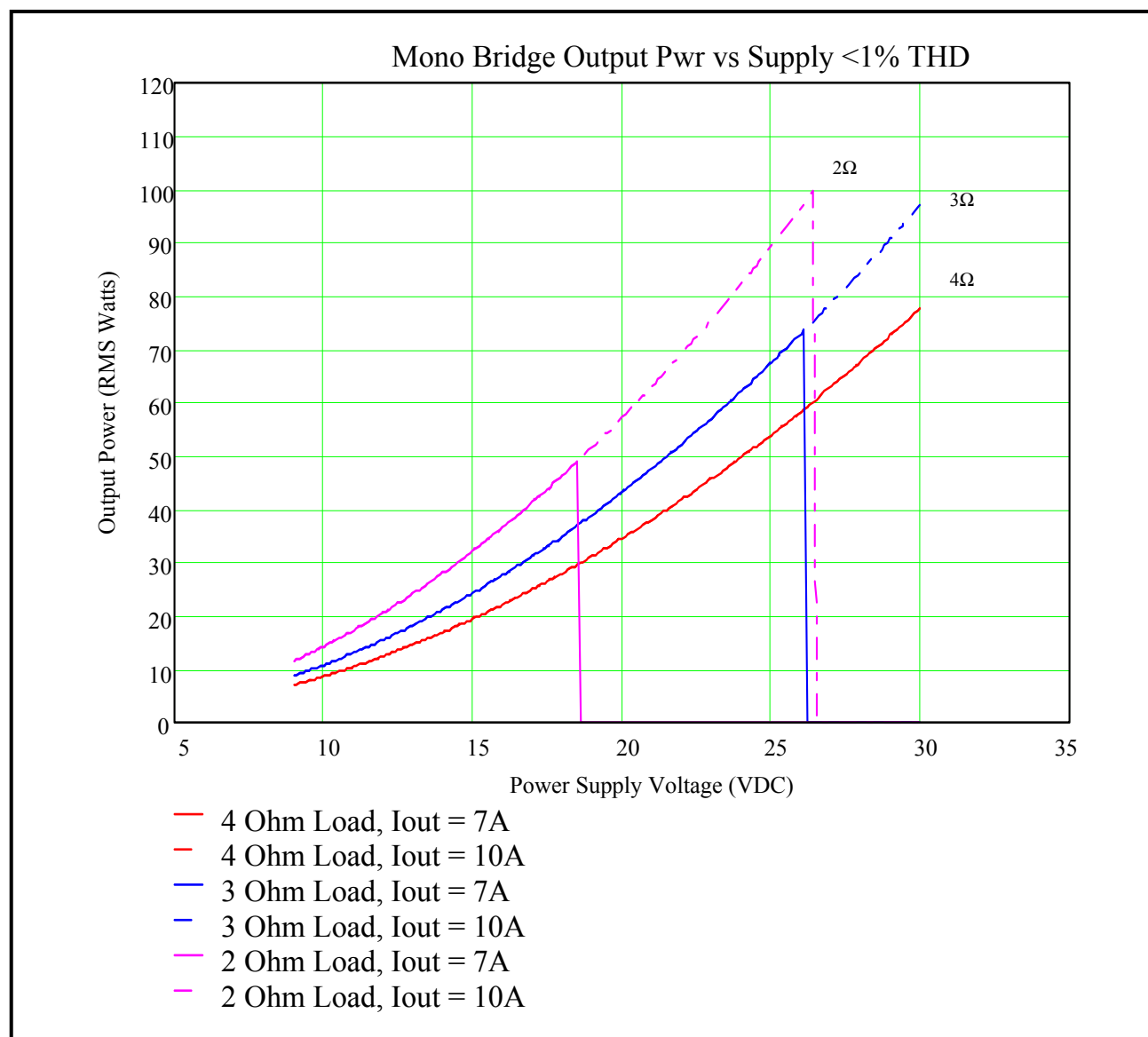


Figure 3. Mono Bridge Output Power vs Supply <1% THD.

Figure 3 depicts the output power as a function of power supply voltages for loads of 2, 3, and 4 Ohms. The same notes from Figure 2 apply except output current is 7A minimum, 10A typical. for a mono bridge. Solid curves depict the worst case minimum and dashed curves depict typical performance.

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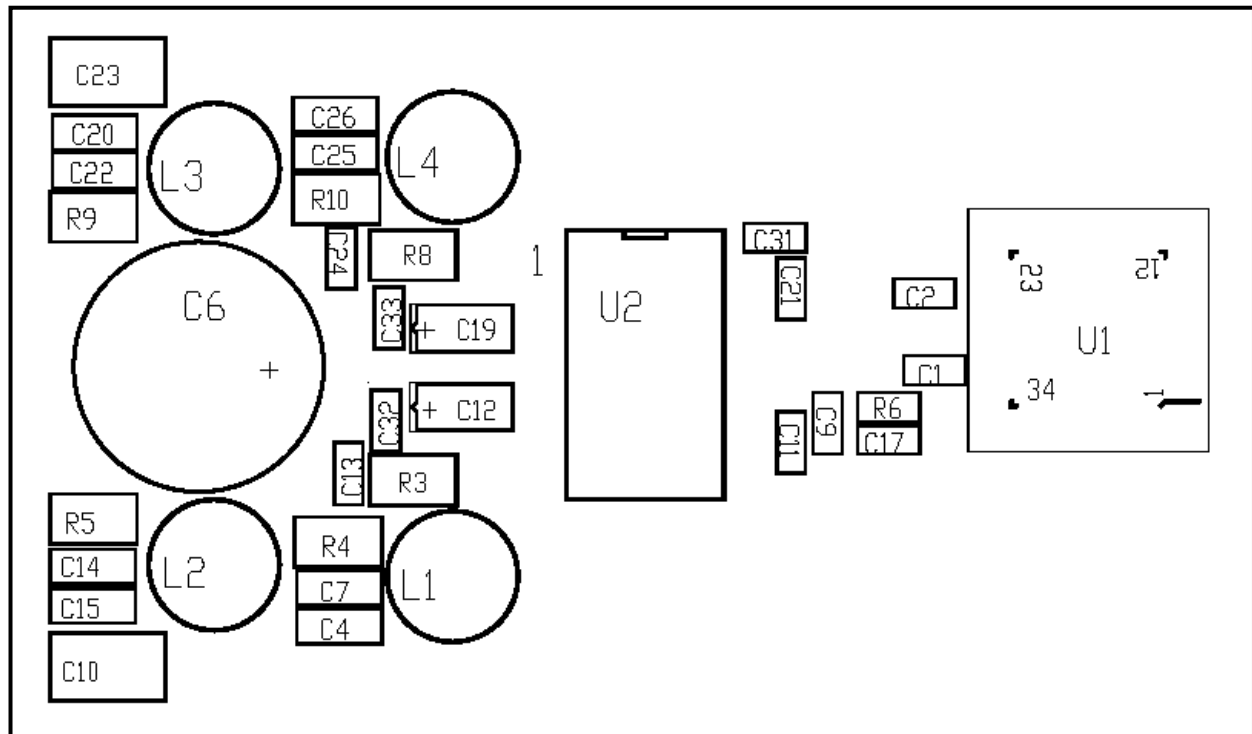
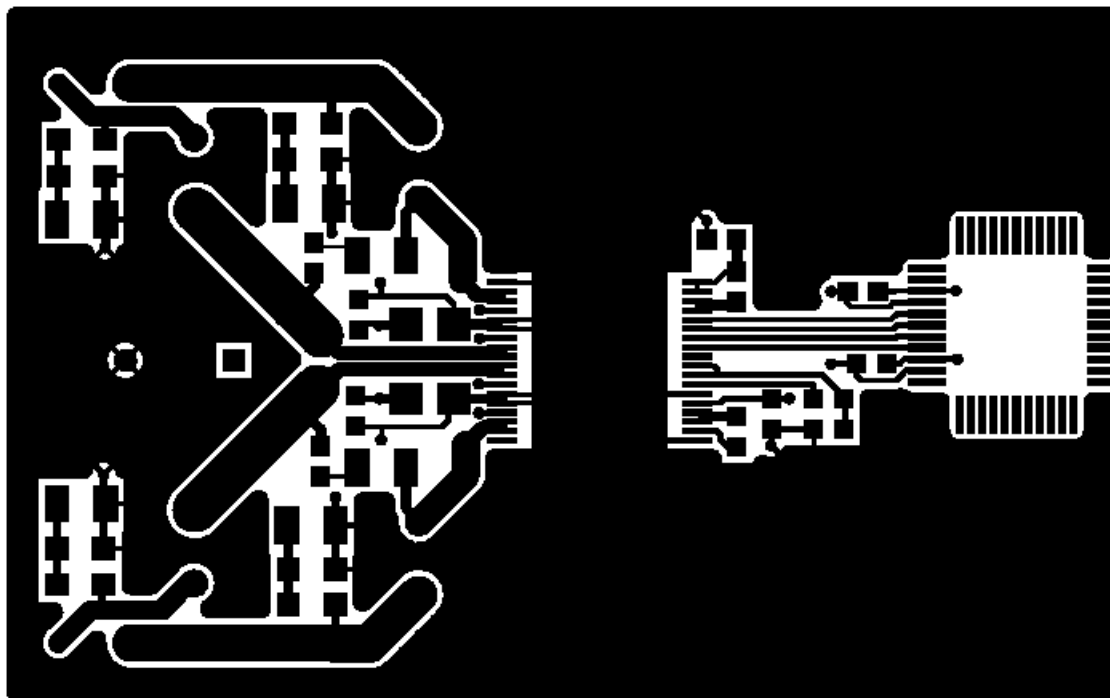


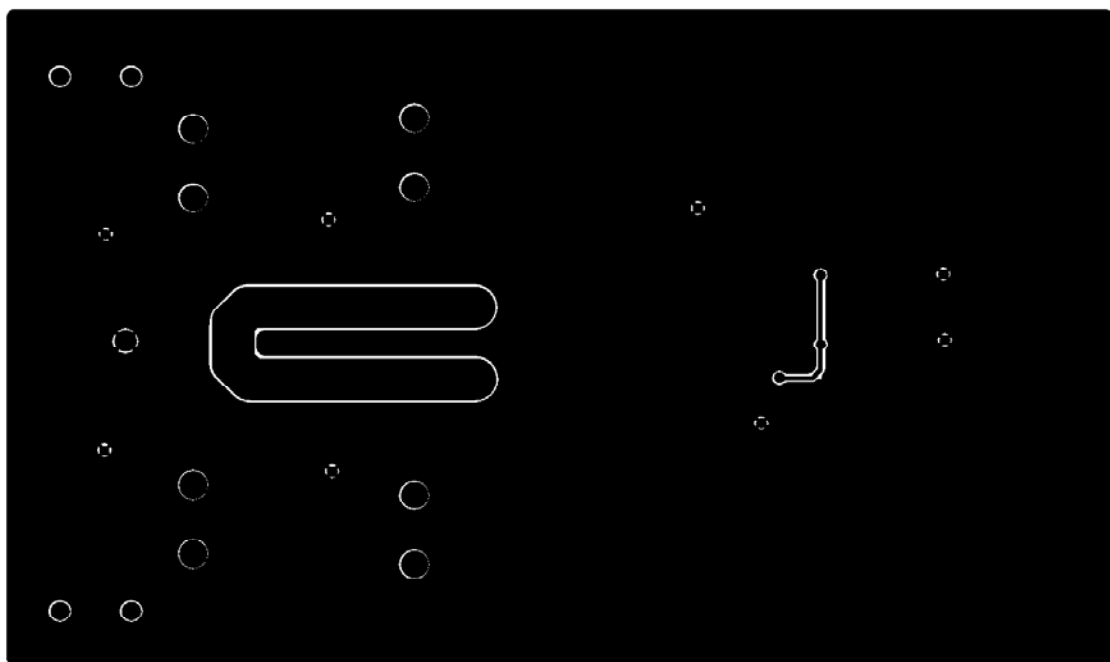
Figure 6. Silkscreen Layer

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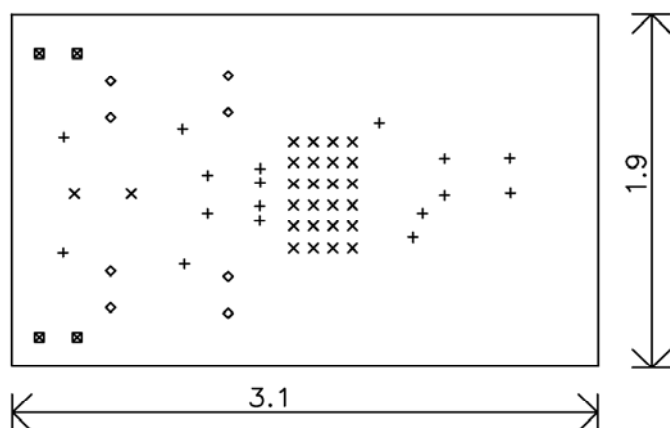


*Figure 7. : P. C. Board, Top (Component Side)*



*Figure 8. P. C. Board, Bottom (Solder Side)*

**Specifications are subject to change without notice.**



All Dimensions in Inches

DRILL CHART				
SYM	DIAM	TOL	QTY	NOTE
+	0.015		17	
◇	0.031		4	
x	0.040		26	
◇	0.046		8	
TOTAL			55	

Figure 9. Drill Diagram

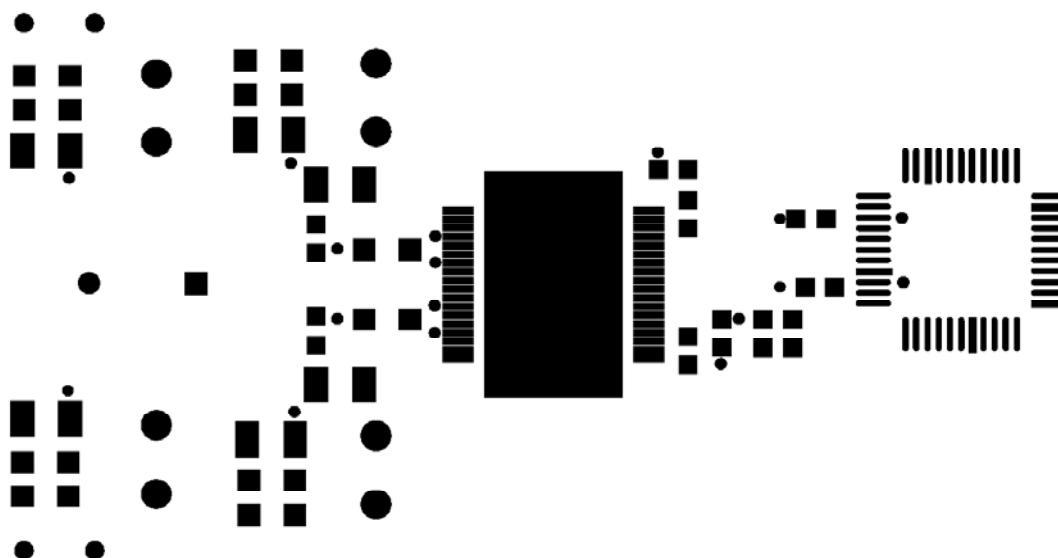


Figure 10. Solder Mask

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## DDX-2060 POWER DEVICE

The DDX-2060 Power Device is a dual channel H-Bridge that can deliver over 35 watts per channel of audio output power at very high efficiency. It converts DDX controlled PWM signals to power at the load. The DDX-2060 includes a logic interface, integrated bridge drivers, high efficiency MOSFET outputs and over-voltage, thermal and short circuit protection circuitry. Two logic level signals per channel are used to control high-speed MOSFET switches to connect the speaker load to the input supply or to ground in a bridge configuration, according to Apogee's patented damped ternary PWM. The DDX-2060 includes over-current, thermal, and over-voltage protection and under-voltage lockout with automatic recovery. A thermal warning status is also provided.

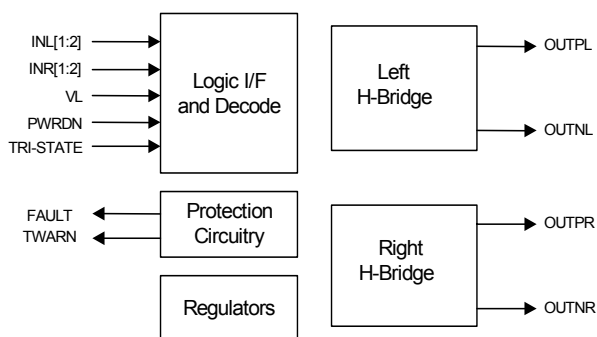


Figure 9: DDX-2060 Block Diagram

### Logic Interface and Decode

The DDX-2060 power outputs are controlled using two logic level timing signals. In order to provide a proper logic interface, the VL input must operate at the same voltage as the DDX controller logic supply.

### Protection Circuitry

The DDX-2060 includes protection circuitry for over-current, over-voltage, and thermal overload conditions. A thermal warning pin TWARN is activated low (open-drain MOSFET) when the IC temperature exceeds 130°C, in advance of the thermal shutdown protection. When a fault condition is detected (logical OR of over-current,

over-voltage, and thermal), an internal fault signal acts to immediately disable the output power MOSFETs, placing both H-bridges in a high impedance state. At the same time an open-drain MOSFET connected to the FAULT pin is switched on. There are two possible modes subsequent to activating a fault. The first is a SHUTDOWN mode. With FAULT (pull-up resistor) and TRI-STATE pins independent, an activated fault will disable the device, signaling low at the FAULT output. The device may subsequently be reset to normal operation by toggling the TRI-STATE pin from High to Low to High using an external logic signal. The second is an AUTOMATIC recovery mode. This is depicted in the application circuit in Figure 4. The FAULT and TRI-STATE pins are shorted together and connected to a time constant circuit comprising R6 and C17. An activated FAULT will force a reset on the TRI-STATE pin causing normal operation to resume following a delay determined by the time constant of the circuit. If the fault condition is still presented, the circuit operation will continue repeating until such time as the fault condition is removed. An increase in the time constant of the circuit will produce a longer recovery interval. Care must be taken in the overall system design so as not to exceed the protection thresholds under normal operation.

### Power Outputs

The DDX-2060 power and output pins are duplicated to provide a low impedance path for the devices bridged outputs. All duplicate power, ground and output pins must be connected for proper operation. The PWRDN or TRI-STATE pins should be used to set all MOSFETs to the Hi-Z state during power-up until the logic power supply, VL, is settled.

### Parallel Output/High Current Operation

The DDX-2060 outputs can be connected in parallel to increase the output current to a load. In this configuration the device can provide over 70W into 4Ω (see Figure 3). This mode is enabled with the CONFIG pin connected to VREG1 and the inputs combined INLA = INLB,

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INRA = INRB and outputs combined OUTLA = OUTLB, OUTRA = OUTRB.

#### **ADDITIONAL INFORMATION**

##### **Output Filter**

A passive two-pole low pass filter is used on the DDX-2060 power outputs to reconstruct an analog signal. System performance can be significantly affected by the output filter design and choice of components. A filter design for  $8\Omega$  loads is shown in the Typical Application Circuit in Figure 4.

##### **Power Dissipation/Heat Sink Requirements**

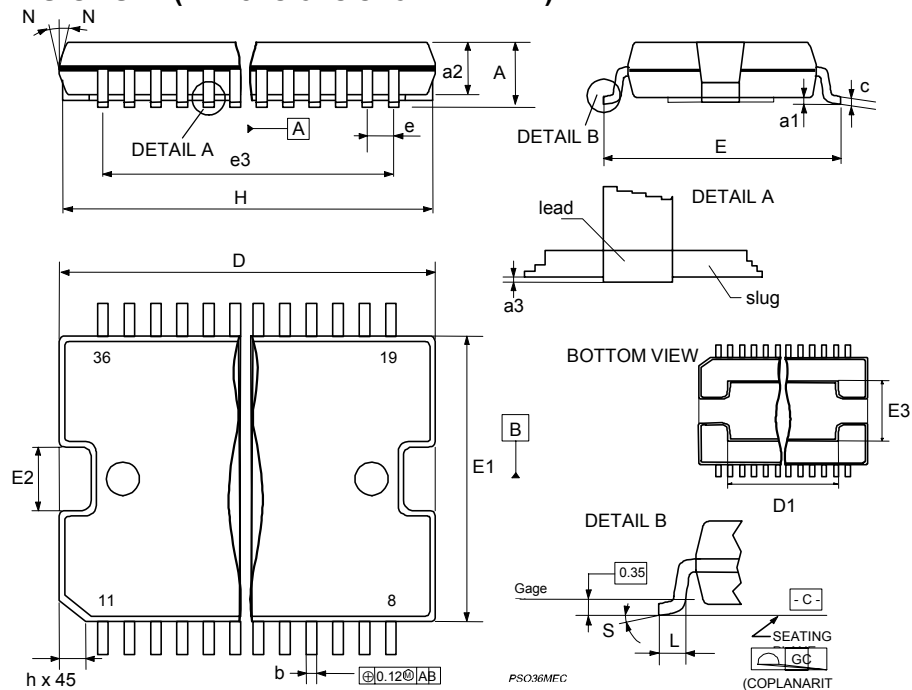
The power dissipation of the device will depend primarily on the supply voltage, load impedance, and output modulation level.

The DDX-2060 surface mount package includes an exposed thermal pad on the bottom of the device to provide a direct thermal path from the integrated circuit to the PCB. This pad must be soldered to a low thermal impedance path at circuit ground potential for proper operation, e.g. a PCB ground plane. For continuous duty rated applications, careful consideration must be made to the overall thermal design.

For additional thermal design considerations, see  
[http://www.apogeeddx.com/DDX\\_Thermal\\_Considerations.PDF](http://www.apogeeddx.com/DDX_Thermal_Considerations.PDF)

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**PHYSICAL DIMENSIONS (Dimensions shown in mm)**


DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			3.60			0.141
a1	0.10		0.30	0.004		0.012
a2			3.30			0.130
a3	0		0.10	0		0.004
b	0.22		0.38	0.008		0.015
c	0.23		0.32	0.009		0.012
D (1)	15.80		16.00	0.622		0.630
D1	9.40		9.80	0.370		0.385
E	13.90		14.50	0.547		0.570
e		0.65			0.0256	
e3		11.05			0.435	
E1 (1)	10.90		11.10	0.429		0.437
E2			2.90			0.114
E3	5.80		6.20	0.228		0.244
E4	2.90		3.20	0.114		0.126
G	0		0.10	0		0.004
H	15.50		15.90	0.610		0.626
h			1.10			0.043
L	0.80		1.10	0.031		0.043
N	1		0°(max.)			
S	8		°(max.)			

(1): "D" and "E1" do not include mold flash or protrusions  
 - Mold flash or protrusions shall not exceed 0.15mm (0.006 inch)  
 - Critical dimensions are "a3", "E" and "G".

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