All-Digital High Efficiency Power Amplifiers

FEATURES

- HIGH OUTPUT CAPABILITY
- **DDX® Mono-Mode:**
  - **DDX-2240:** 1 x 240 / 200 W, 3Ω / 4Ω, <10% THD
  - **DDX-2200:** 1 x 200 / 200 W, 3Ω / 4Ω, <10% THD
- **DDX® Full-Bridge Mode:**
  - **DDX-2240:** 2 x 120 / 100 W, 6Ω / 8Ω, <10% THD
  - **DDX-2200:** 2 x 100 / 100 W, 6Ω / 8Ω, <10% THD
- **Binary Half-Bridge Mode:**
  - **DDX-2240:** 4 x 45 W, 4Ω, <10% THD
  - **DDX-2200:** 4 x 45 W, 4Ω, <10% THD
- SINGLE SUPPLY (+9V to +40V)
- COMPACT SURFACE MOUNT PACKAGE
- HIGH EFFICIENCY, 90% @ 8 ohms
- THERMAL OVERLOAD PROTECTION
- THERMAL WARNING OUTPUT
- SHORT CIRCUIT PROTECTION

BENEFITS

- COMPLETE SURFACE MOUNT DESIGN
- POWER SUPPLY SAVINGS

APPLICATIONS

- SURROUND SOUND SYSTEMS
- A/V RECEIVERS
- CAR AUDIO
- MINI/MICRO AUDIO SYSTEMS
- DIGITAL POWERED SPEAKERS

1.0 GENERAL DESCRIPTION

The DDX-2240 and DDX-2200 power devices are monolithic, dual channel H-Bridges that can provide audio power up to:

- 120 watts per channel @10%THD, 6Ω (DDX-2240)
- 100 watts per channel @10%THD, 8Ω (DDX-2200)

at very high efficiency.

Each device contains a logic interface, integrated bridge drivers, high efficiency MOSFET output transistors and protection circuitry. Each device may be used in DDX® Mode as a dual bridge or reconfigured as a single bridge with double the output current capability. Alternatively, in Binary Mode, it may be configured as either a dual bridge or (at lower power output) a quad half-bridge or a combination of both types.

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 PWM designs of more than three times the efficiency of typical Class A/B amplifiers with music input signals.

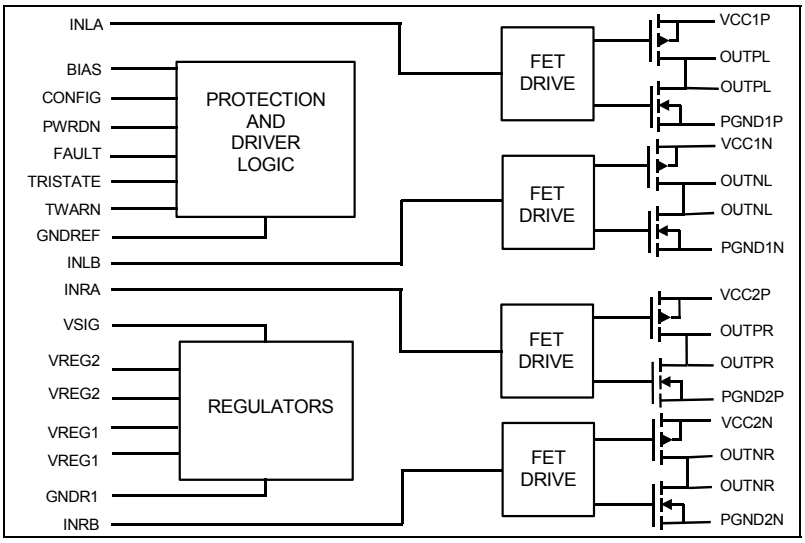


Figure 1. Block Diagram

1.1 Absolute Maximum Ratings [Note 1]

SYMBOL	PARAMETER	VALUE	UNIT
V_{CC}	Power supply voltage	45	V
V_L	Input logic reference	5.5	V
P_{TOT}	Power Dissipation, $T_{heat\text{-}spreader}$ = 25°C [See Figure 4]	50	W
T_j	Operating junction temperature range	0 to +150	°C
T_{stg}	Storage 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.

1.2 Recommended Operating Conditions [Note 2]

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT
V_{CC}	Power supply voltage	9		40	V
V_L	Input logic reference	2.7	3.3	5.0	V
T_A	Ambient Temperature	0		70	°C

Note 2 - Performance not guaranteed beyond recommended operating conditions.

1.3 Thermal Data

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT
$\theta_{J\text{-}C}$	Thermal resistance junction-case (heat spreader)		1	2.5	°C/W
$T_{j\text{-}SD}$	Thermal shut-down junction temperature		150		°C
T_{WARN}	Thermal warning temperature		130		°C
T_{hSD}	Thermal shut-down hysteresis		25		°C

1.4 Electrical Characteristics.

[Refer to circuit in Figure 19] Unless otherwise specified, performance is measured using the DDX-2001 processor, V_{CC} = 39V, VL=3.3V, fsw=384kHz, T_C=25°C, R_L=8Ω.

SYMBOL	PARAMETER	CONDITIONS			MIN	TYP	MAX	UNIT
		V_{CC}	THD+N	R_L				
$P_{O\text{-}DM}$ (DDX® Mono Mode) [Figure 21]	DDX-2240 – Power Per Channel [Note 3] [Note 4]	39V	<10%	3Ω		240		W_{RMS}
			<1%			185		
	DDX-2240 - Power Per Channel [Note 3] [Note 4]	39V	<10%	4Ω		200		
			<1%			160		
	DDX-2200 – Power Per Channel [Note 3] [Note 4]	36V	<10%	3Ω		200		
			<1%			160		
	DDX-2200 - Power Per Channel [Note 3] [Note 4]	39V	<10%	4Ω		200		
			<1%			160		
$P_{O\text{-}DF}$ (DDX® Full Bridge Mode) [Figure 19]	DDX-2240 - Power Per Channel [Note 4]	39V	<10%	6Ω		120		W_{RMS}
			<1%			100		
	DDX-2240 - Power Per Channel [Note 4]	39V	<10%	8Ω		100		
			<1%			80		
	DDX-2200 - Power Per Channel	36V	<10%	6Ω		100		
			<1%			80		
	DDX-2200 - Power Per Channel [Note 4]	39V	<10%	8Ω		100		
			<1%			80		
$P_{O\text{-}Bin}$ (Binary Half-Bridge Mode) [Figure 25]	DDX-2240 - Power Per Channel [Note 4]	39V	<10%	4Ω		45		W_{RMS}
			<1%			35		
	DDX-2200 - Power Per Channel [Note 4]	39V	<10%	4Ω		45		
			<1%			35		

Note 3 – Maximum power limited to < 1 second.
Note 4 - Power Output Limited by Maximum Voltage Limit.

1.4 Electrical Characteristics (continued) [Refer to circuit in Figure 19] Unless otherwise specified, performance is measured using the DDX-2001 processor, V_{CC} = 39V, VL=3.3V, fsw=384kHz, T_C=25°C, R_L=8Ω.

SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
THD+N	Total Harmonic Distortion + Noise, [Note 5]	Po = 1 Wrms		0.09		%
		Po = 70 Wrms		0.20		
SNR	Signal to Noise Ratio, DDX® Mode [Note 5]	A-Weighted		98		dB
	Signal to Noise Ratio, Binary Half-Bridge Mode, [Note 5]			90		
η	Peak Efficiency, DDX® Mode	Po=2 x 100 W, 8Ω		90		%
	Peak Efficiency, Binary Half-Bridge Mode	Po=4 x 45 W, 4Ω		86		
I_{SC}	Speaker Output Short-Circuit Protection Limit per Bridge	DDX-2240	6	7	9	A
		DDX-2200	5.5	7	9	
R_{ds-on}	Power MOSFET output resistance	I_d=1A		150	200	mΩ
g_N	Power Nchannel R_{ds-on} matching	I_d = 1A	95			%
g_P	Power Pchannel R_{ds-on} matching	I_d = 1A	95			%
I_{dss}	Power Pchannel/Nchannel leakage	V_{CC} = 37 V			100	uA
UVL	Under-voltage Lockout Threshold			7		V
I_{PD}	V_{CC} supply current, Power-down	PWRDN = 0		1	3	mA
I_{CC-tri}	V_{CC} supply current, Tri-state	TRISTATE = 0		22		mA
I_{CC}	DDX® mode V_{CC} supply current	2-Channel switching at 384kHz.		98		mA
	Binary mode V_{CC} supply current	4-Channel switching at 384kHz.		111		
t_{on}	Turn-on delay time	Resistive load			100	ns
t_{off}	Turn-off delay time	Resistive load			100	ns
t_r	Rise time	Resistive load			25	ns
t_f	Fall Time	Resistive load			25	ns
V_{IL}	Low logic input voltage: PWRDN, TRISTATE pins	V_L = 2.7V V_L = 3.3V V_L = 5.0V	0.7 0.8 0.85			V
	Low logic input voltage: INLA, INLB, INRA, INRB pins	V_L = 2.7V V_L = 3.3V V_L = 5.0V	1.05 1.35 2.2			
V_{IH}	High logic input voltage: PWRDN, TRISTATE pins	V_L = 2.7V V_L = 3.3V V_L = 5.0V			1.5 1.7 1.85	V
	High logic input voltage: INLA, INLB, INRA, INRB pins	V_L = 2.7V V_L = 3.3V V_L = 5.0V			1.65 1.95 2.8	
I_{IN-H}	High Level Input Current	Pin Voltage = VL		1		uA
I_{IN-L}	Low Level Input Current	Pin Voltage = 0.3V		1		uA
I_{fault}	Output Sink Current, FAULT, TWARN pins	Fault Active		1		mA
P_{Wmin}	Minimum output pulse width	No load	25		40	ns

Note 5 - Performance Characteristics obtained using a DDX-8001/DDX-8229 or DDX-2001 controller.

2.0 DDX-2240 and DDX-2200 Pin Function Description:

2.1 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

2.2 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 or Overtemperature (0=Fault, 1=Normal).
TWARN [Note 6]	28	Thermal warning output (0=Warning T_J >= 130°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 (mono mode) operation for high current.

2.3 Power Outputs for DDX® Mode or Binary Full Bridge Mode [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.

2.4 Power Outputs for Binary Half-Bridge Mode [Note 9]

Pin Name	Pin No.	Description
OUTNR	2, 3	CH4 output, positive reference
OUTPR	8, 9	CH3 output, positive reference
OUTNL	10, 11	CH2 output, positive reference
OUTPL	16, 17	CH1 output, positive reference

Note 9 - Half-Bridge Binary Mode outputs are NOT bridged. All outputs produce signals in phase with the input.

2.5 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 [Note 10]	23	Logic reference voltage.
GNDREF	19	Logic reference ground.
GNDS	1	Substrate ground.
GNDR1	20	Internal regulator ground.

Note 10 - V_L (Logic Reference Voltage) is recommended to be powered and stable prior to Vcc achieving > 7V to assure proper power up sequence. V_L is recommended to remain powered and stable until after Vcc has decayed below 7V during power removal.

3.0 DDX-2240 and DDX-2200 POWER DEVICES

The DDX-2240 and DDX-2200 Power Devices are dual channel H-Bridges that can deliver more than 120/100 watts per channel (<10%THD) of audio output power at very high efficiency. They convert both DDX® and binary-controlled PWM signals into audio power at the load. Each includes a logic interface, integrated bridge drivers, high efficiency MOSFET outputs, and thermal and short circuit protection circuitry. In DDX® mode, 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. In Binary Mode operation, both Full Bridge and Half Bridge Modes are supported. These devices include over-current and thermal protection as well as under-voltage lockout with automatic recovery. A thermal warning status is also provided.

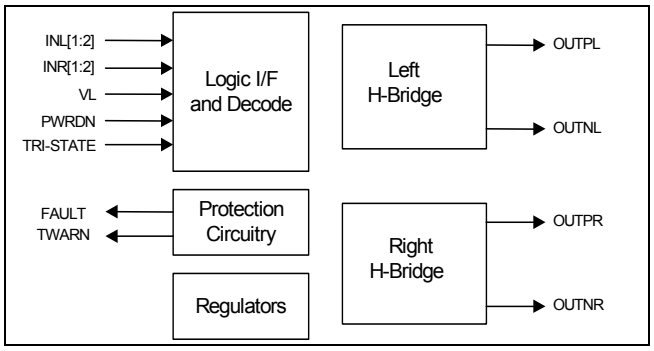


Figure 2 - DDX-2240 and DDX-2200 Block Diagram, Full- Bridge DDX® or Binary Modes

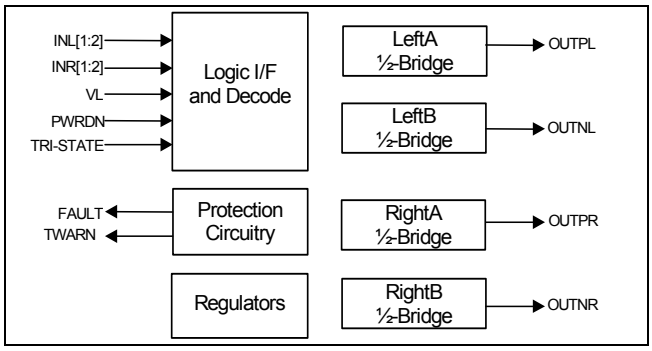


Figure 3 - DDX-2240 and DDX-2200 Block Diagram, Binary Half-Bridge Mode

3.1 Logic Interface and Decode

The DDX-2240 and DDX-2200 power outputs are controlled using one or two logic level timing signals. In order to provide a proper logic interface, the V_L input must operate at the same voltage as the DDX® controller logic supply. VL (Logic Reference Voltage) is recommended to be powered and stable prior to Vcc achieving > 7V to assure proper power up sequence. VL is recommended to remain powered and stable until after Vcc has decayed below 7V during power removal.

3.2 Protection Circuitry

The DDX-2240 and DDX-2200 include protection circuitry for over-current 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 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 19. The FAULT and TRI-STATE pins are shorted together and connected to a time constant circuit comprising R_T and C_T. 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.

3.3 Power Outputs

The DDX-2240 and DDX-2200 power and output pins are duplicated to provide a low impedance path for the device's 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, V_L, is settled.

3.4 Parallel Output/High Current Operation

When using DDX® Mode output, the DDX-2240 and DDX-2200 outputs can be connected in parallel to increase the output current to a load. In this configuration the devices can provide over 240W@3Ω / 200W@4Ω (see Figure 6). This mode is enabled with the CONFIG pin connected to VREG1 and the inputs combined INLA = INLB, INRA = INRB and outputs combined OUTLA = OUTLB, OUTRA = OUTRB.

3.5 ADDITIONAL INFORMATION

3.6 Output Filter

A passive two-pole low-pass filter is used on the DDX-2240 and DDX-2200 power outputs to reconstruct an analog signal. System performance can be significantly affected by the output filter design and choice of components. (See appnote: AN-15, Component Selection for DDX Amplifiers.) A filter design for 6Ω/8Ω loads is shown in the Typical Application Circuit in Figure 19. Figure 21 shows a filter design for 4Ω loads. Figure 25 shows a filter for ½ bridge mode, 4Ω loads.

3.7 Power Dissipation & Heat Sink Requirements

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

The surface mount package of the DDX-2240 and DDX-2200 include an exposed thermal slug on the top of the device to provide a direct thermal path from the integrated circuit to the heatsink. Careful consideration must be given to the overall thermal design. See Figure 4 for power derating.

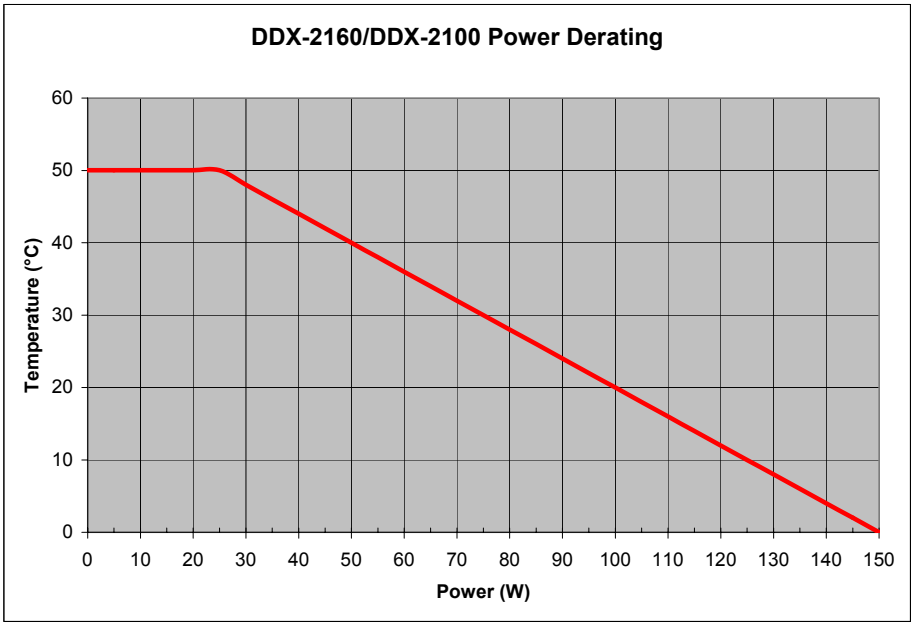


Figure 4 –Power Derating Curve (Typical)

For additional thermal design considerations, see: AN19, Power Device Thermal Calculator.

For additional design considerations with binary mode operation, see application note: AN-16, Applying the DDX-8000/DDX-8228 in Binary Mode.

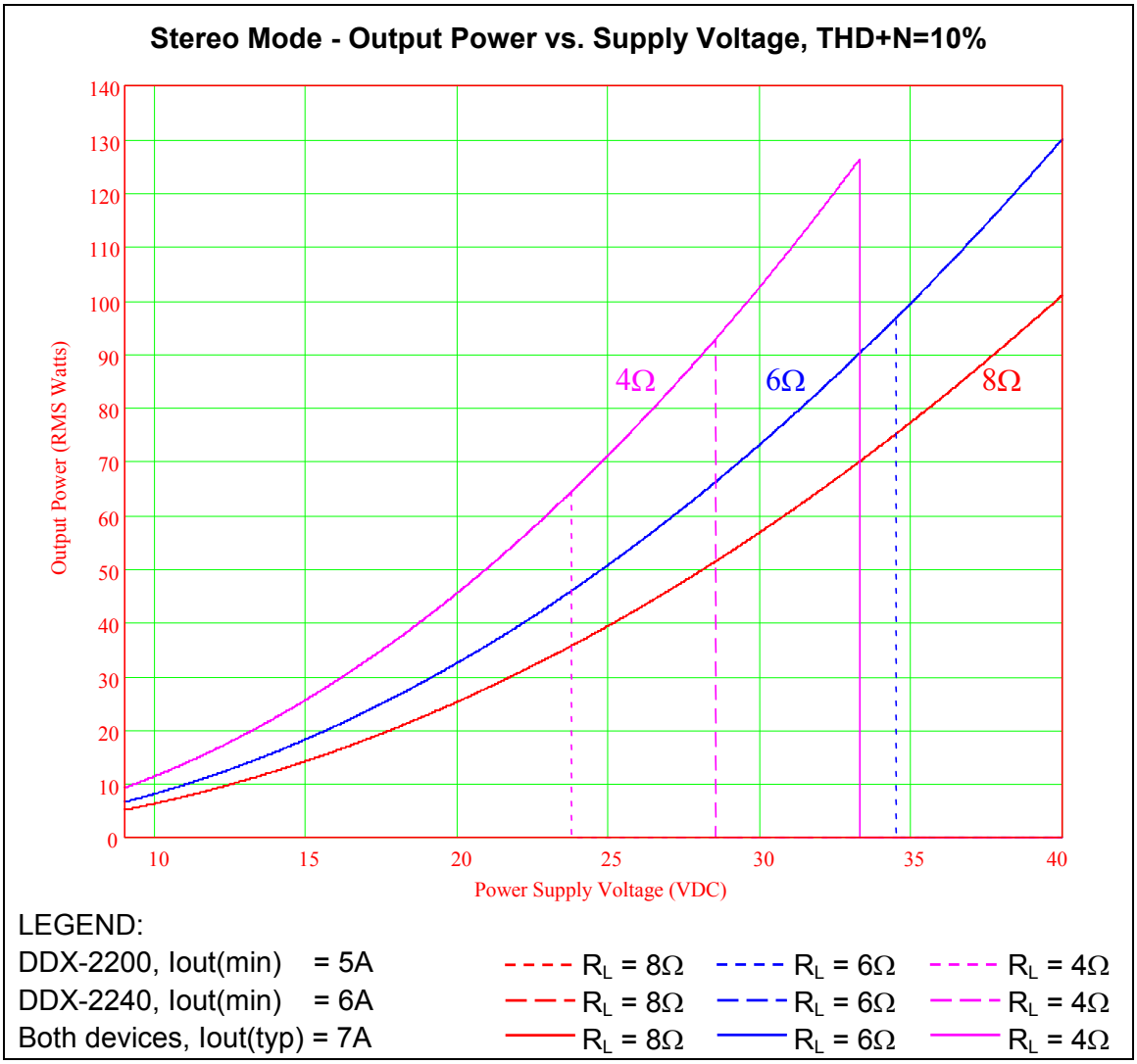


Figure 5. Output Power vs. Supply Voltage for Stereo Bridge.

Figure 5 shows the 10% THD output power as a function of Power Supply Voltage for 4, 6, and 8 Ohm loads in either DDX® Mode or Binary Full Bridge Mode. Output power is constrained for higher impedance loads by the maximum voltage limit of the DDX-2240 and DDX-2200 ICs and by the over-current protection limit for lower impedance loads. The minimum threshold for the over-current protection circuit is 6/5.5A (at 25 ºC) but the typical threshold is 7A. Solid curves depict typical output power capability of each device. Dotted and dashed curves depict the output power capability constrained to the minimum current specification of for the DDX-2240 and DDX-2200, respectively. The output power curves assume proper thermal management of the power device's internal dissipation. See Figure 4.

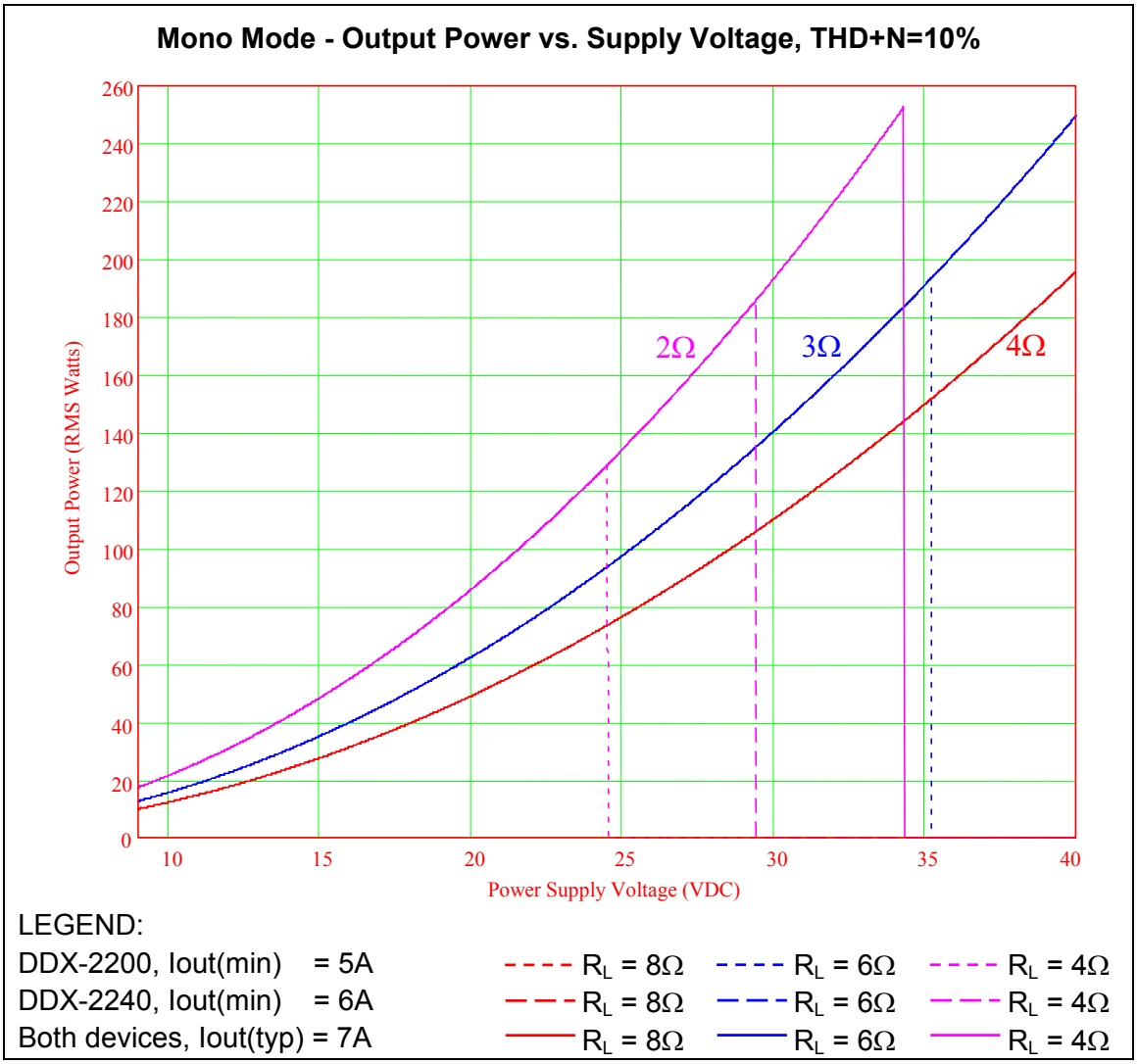


Figure 6. Mono Bridge Output, DDX® Mode Only, Power vs Supply <1% THD.

Figure 6 depicts the mono mode output power as a function of power supply voltages for loads of 2, 3, and 4 Ohms. The same current limit observations from Figure 5 apply, except output current is 11A/12A minimum, 14A typical in mono bridge configuration. Solid curves depict typical performance and dotted and dashed curves depict the minimum current limit for the DDX-2240 and DDX-2200, respectively. Again, the output power curves assume proper thermal management of the power device's internal dissipation. See Figure 4.

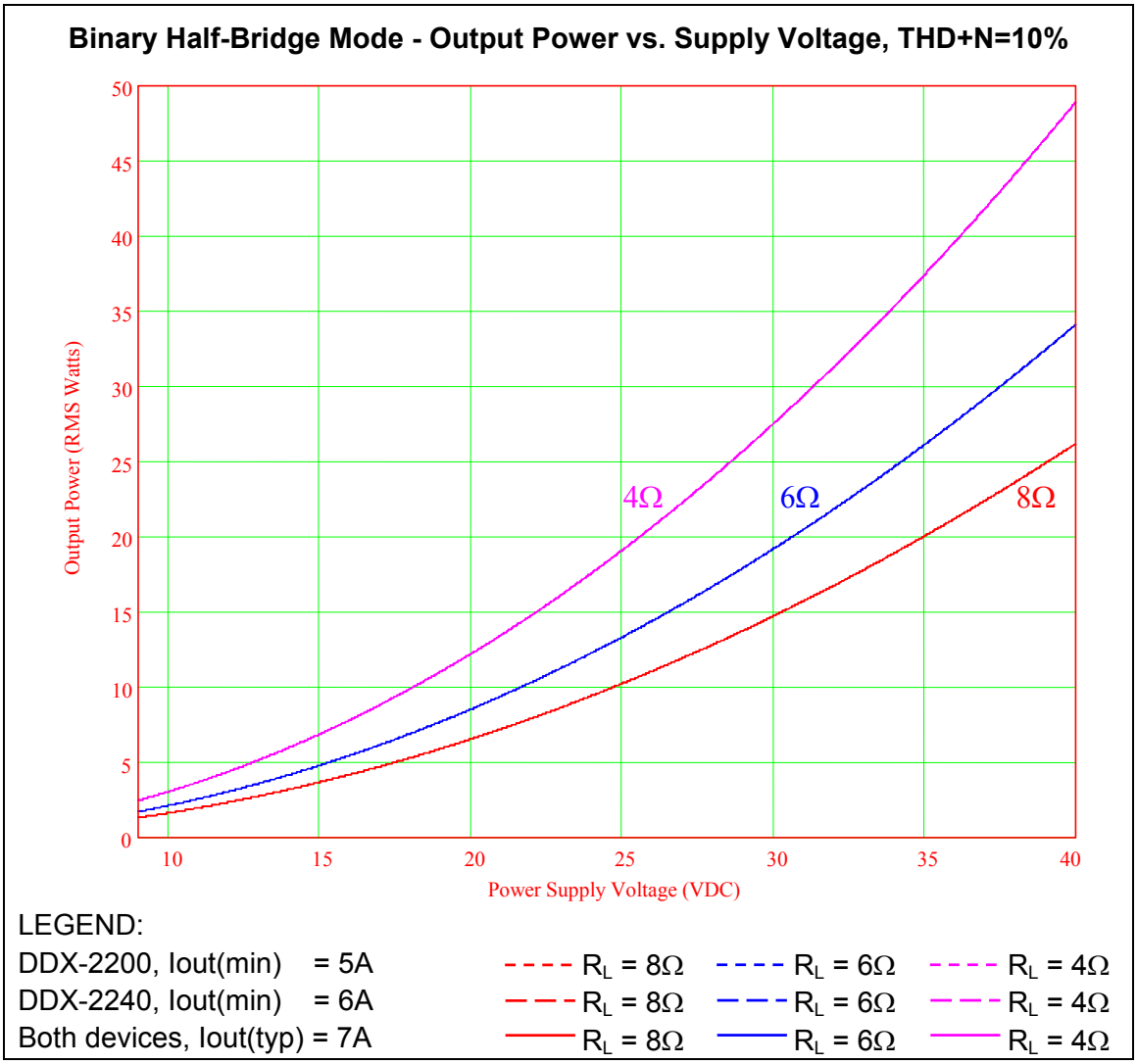


Figure 7. Half-Bridge Binary Mode Output Power vs Supply <1% THD
(NOTE: Curves taken at f = 1 kHz and using a 330uF blocking capacitor.)

Figure 7 depicts the output power as a function of power supply voltages for loads of 4, 6, and 8 Ohms when the DDX-2240 and DDX-2200 are operated in a half-bridge Binary Mode. Solid curves depict typical performance and dotted and dashed curves depict the minimum current limit for the DDX-2240 and DDX-2200, respectively. Once again, the output power curves assume proper thermal management of the power device's internal dissipation. See Figure 4.

3.8 Typical Stereo Mode Performance Characteristics, V_{CC} = 40V using a DDX-2001 controller

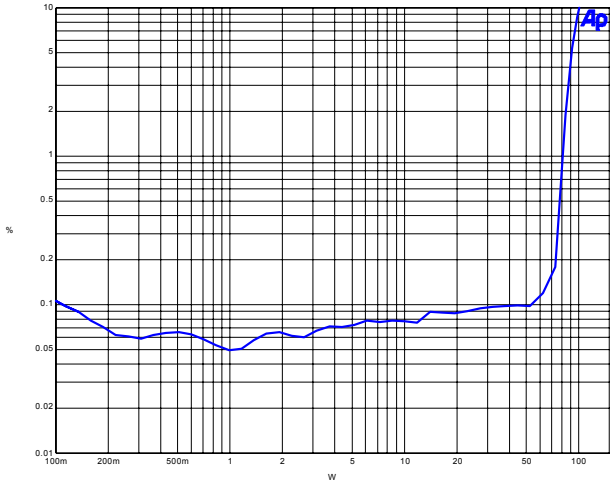


Figure 8. THD+N vs. Output Power @ 1kHz, R_L = 8Ω. [Note 11]

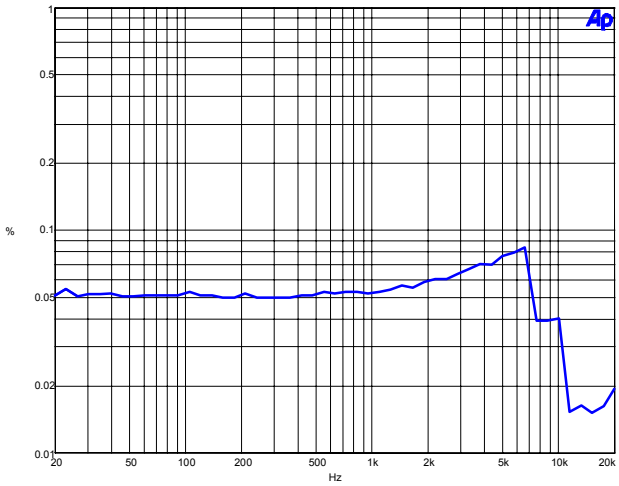


Figure 9. THD+N vs. Frequency, 1W, R_L = 8Ω. [Note 11]

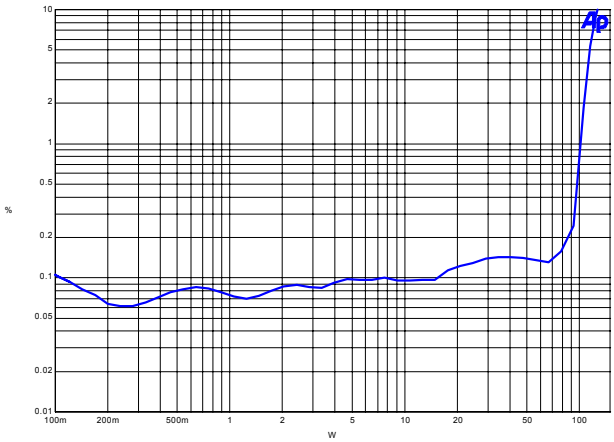


Figure 10 - THD+N vs. Output Power @ 1kHz, R_L = 6Ω. [Note 11]

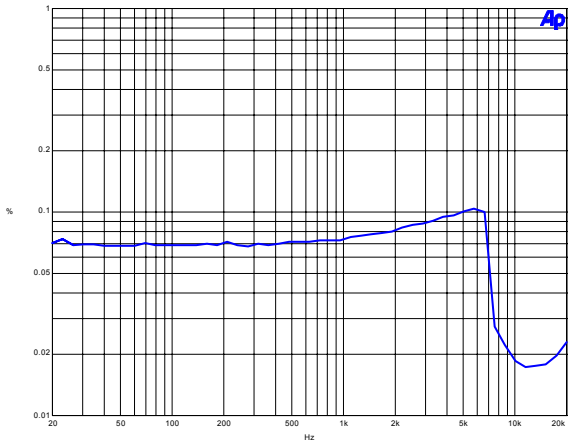


Figure 11 - THD+N vs. Frequency, 1W, 40V, R_L = 6Ω. [Note 11]

Note 11 – Measured using CRC (0x02) OM1..0 = '11' and CSZ4..0 = '01000'

3.9 Typical Mono Mode Performance Characteristics, V_{CC} = 40 VDC, R_L = 4Ω.

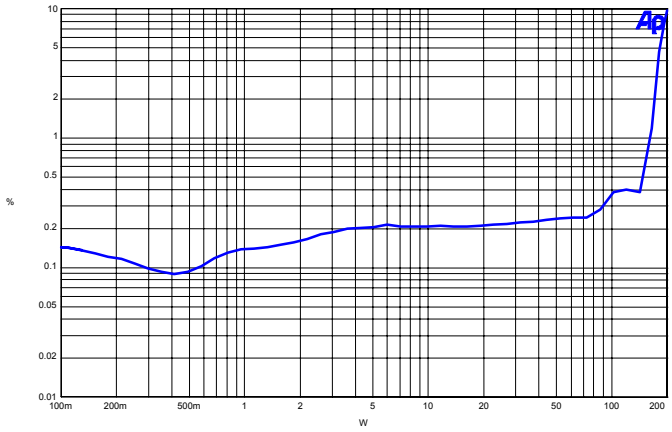


Figure 12 - THD+N vs. Output Power @ 1kHz

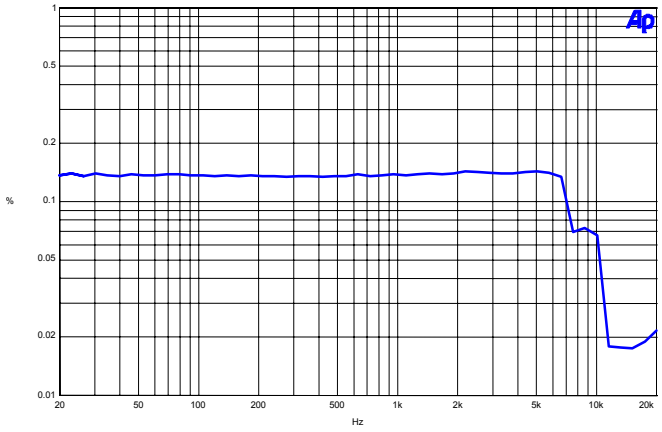


Figure 13 - THD+N vs. Frequency, 1W

3.10 Typical Binary Half-Bridge Mode Performance Characteristics, V_{CC} = 40 VDC, R_L = 4Ω.

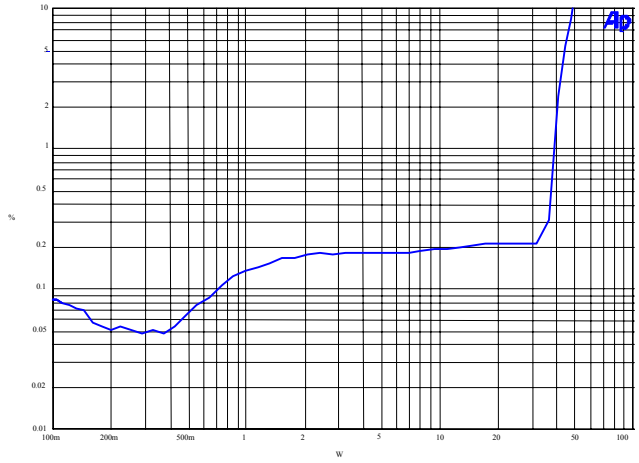


Figure 14 - THD+N vs. Output Power @ 1kHz

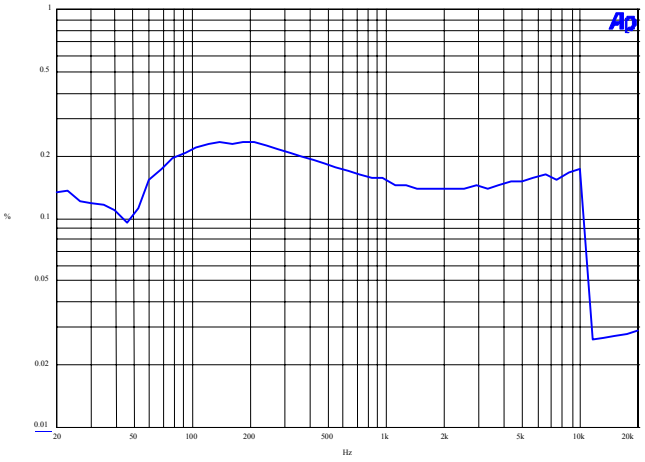


Figure 15 - THD+N vs. Frequency, 1W

3.11 Typical DDX-Mode Performance Characteristics at VCC = 40V, R_L = 8Ω, THD+N < 10%.

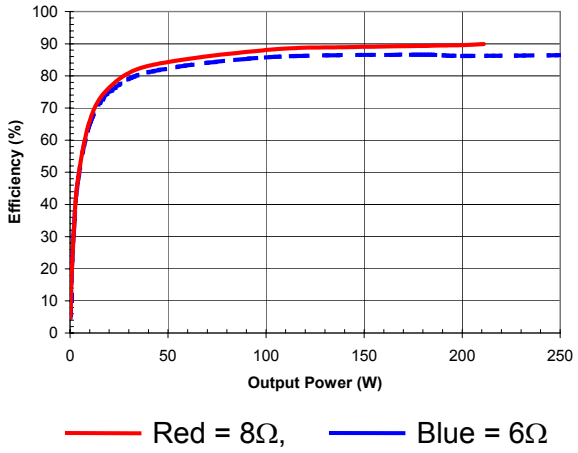


Figure 16 - Typical Efficiencies vs. Power

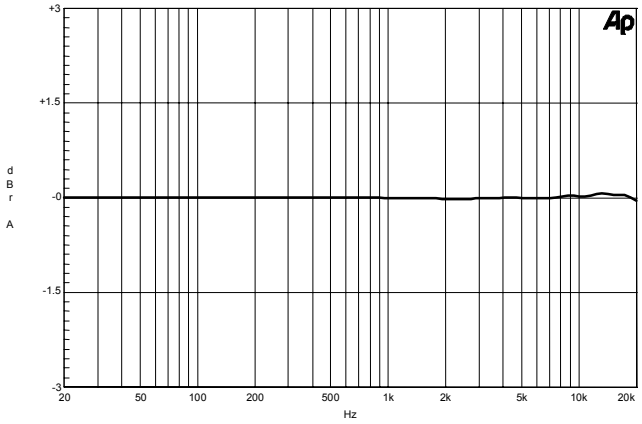


Figure 17 - Typical Frequency Response

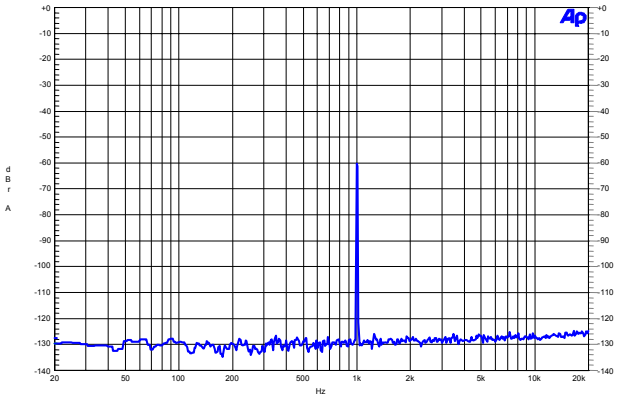


Figure 18 - Typical FFT @ -60 dB,
using a DDX-2001 controller

4.0 APPLICATION REFERENCE DESIGNS.

Apogee can provide reference designs for most applications.
Contact Apogee Technical Support for more information.

4.1 STEREO MODE

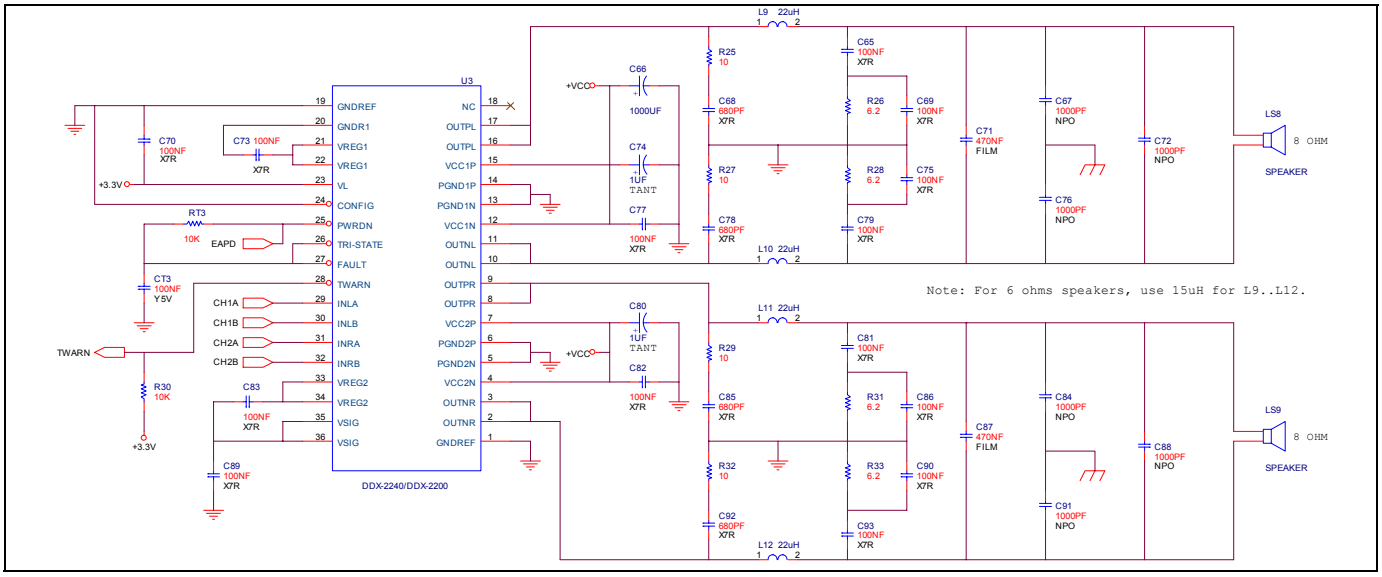


Figure 19 - DDX® Stereo Mode Audio Application Circuit

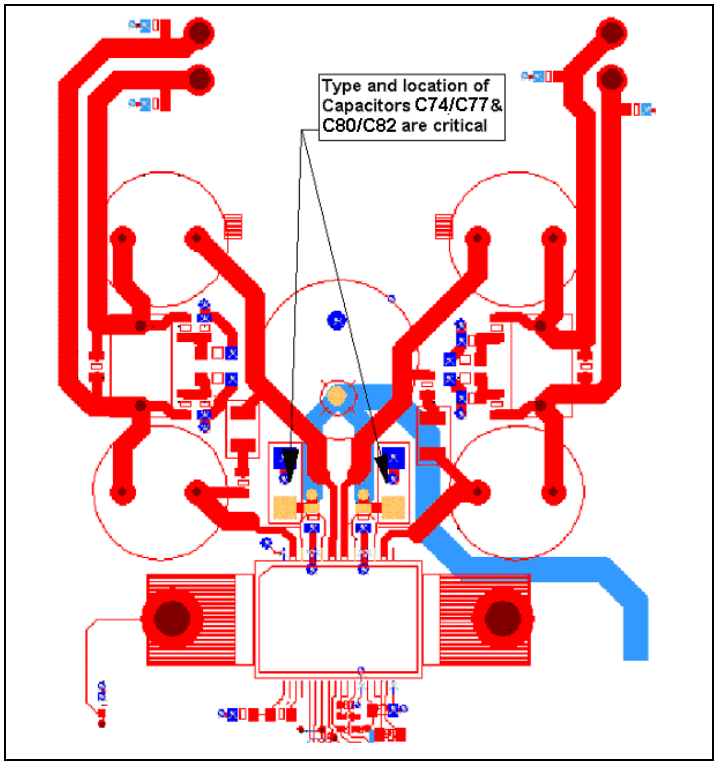


Figure 20 - Sample DDX® Stereo Mode Layout

Specifications are subject to change without notice.

4.2 MONO MODE.

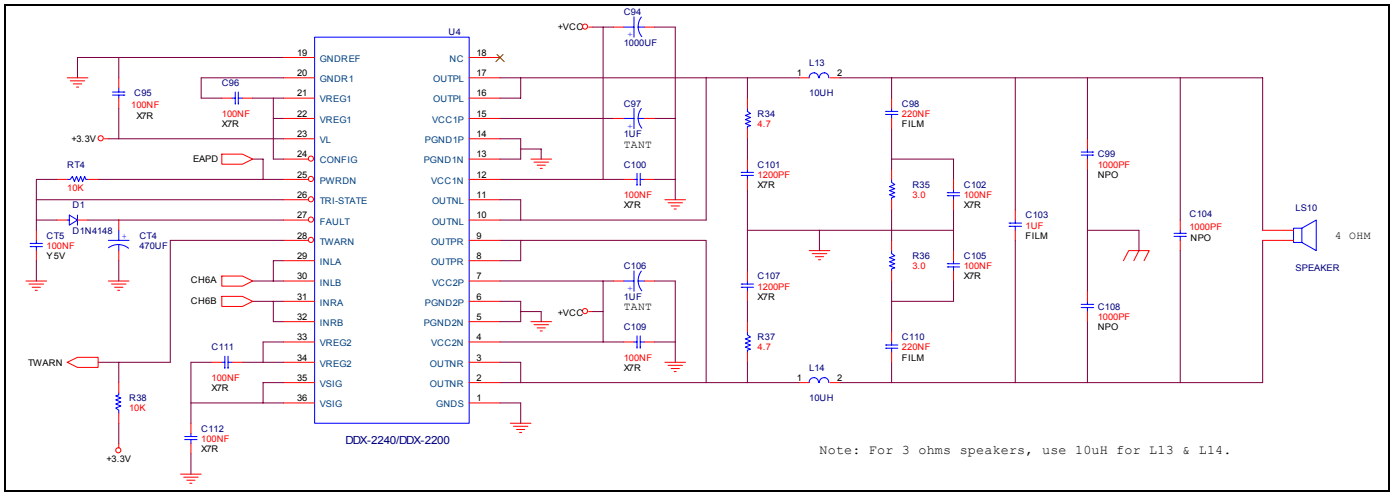


Figure 21 - DDX® Mono Mode Audio Application Circuit

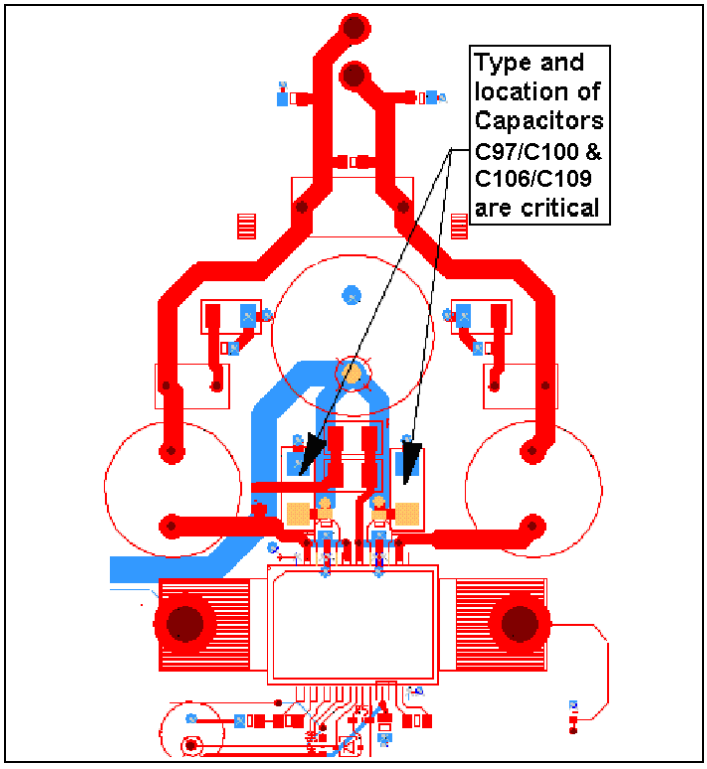


Figure 22 - Sample DDX® Mono Mode Layout

4.3 BINARY MODE, 2.1 CHANNEL.

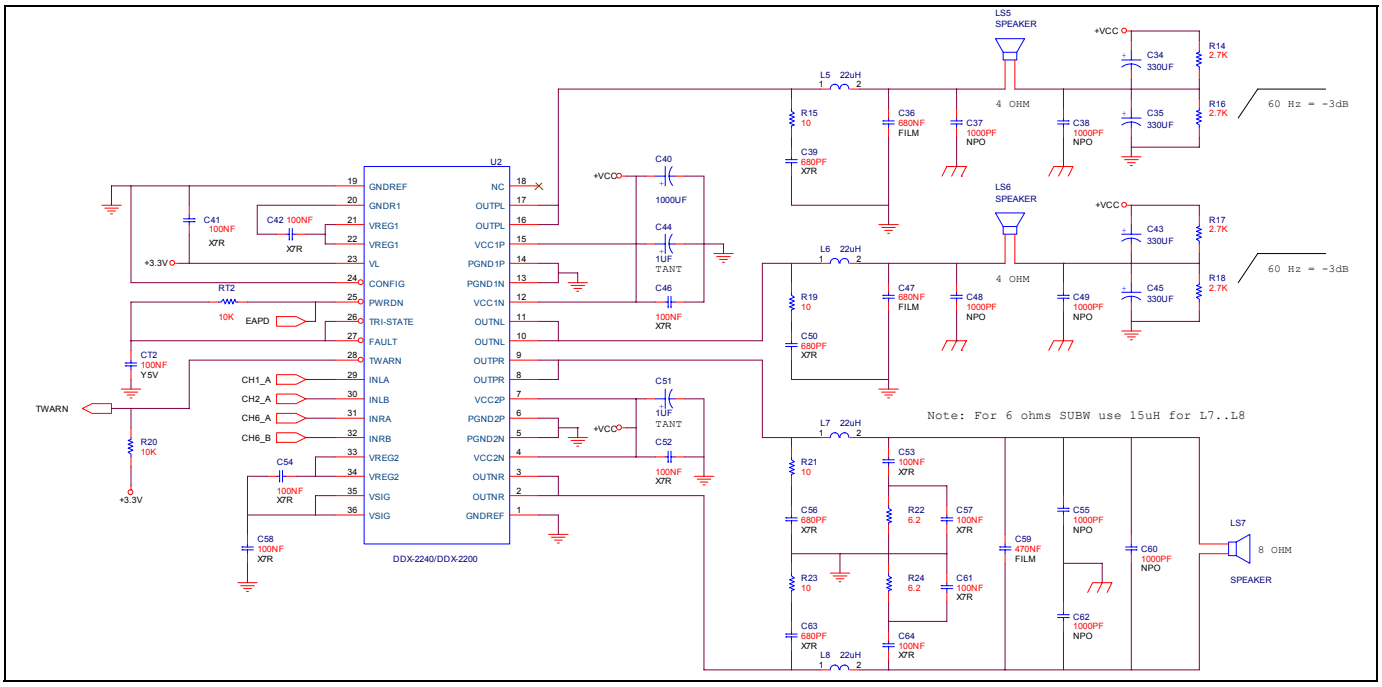


Figure 23 - Binary Mode, 2.1 Channel Audio Application Circuit

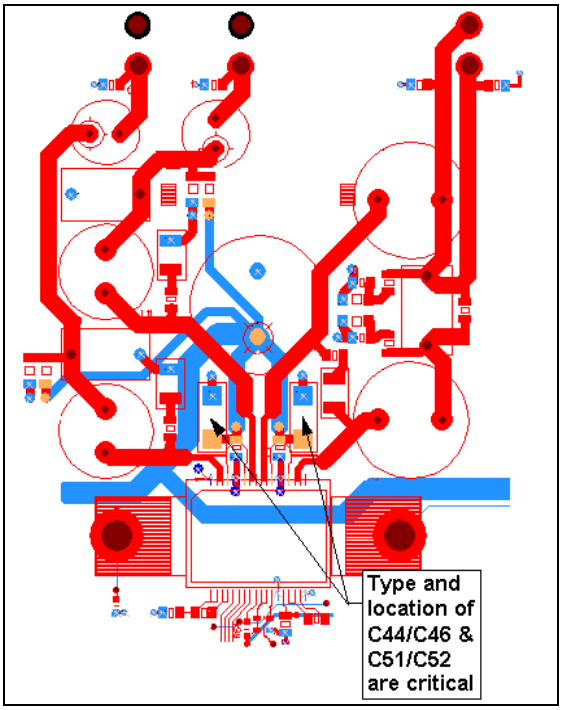


Figure 24 - Sample Binary Mode, 2.1 Channel Layout

4.4 BINARY MODE, 4 CHANNEL.

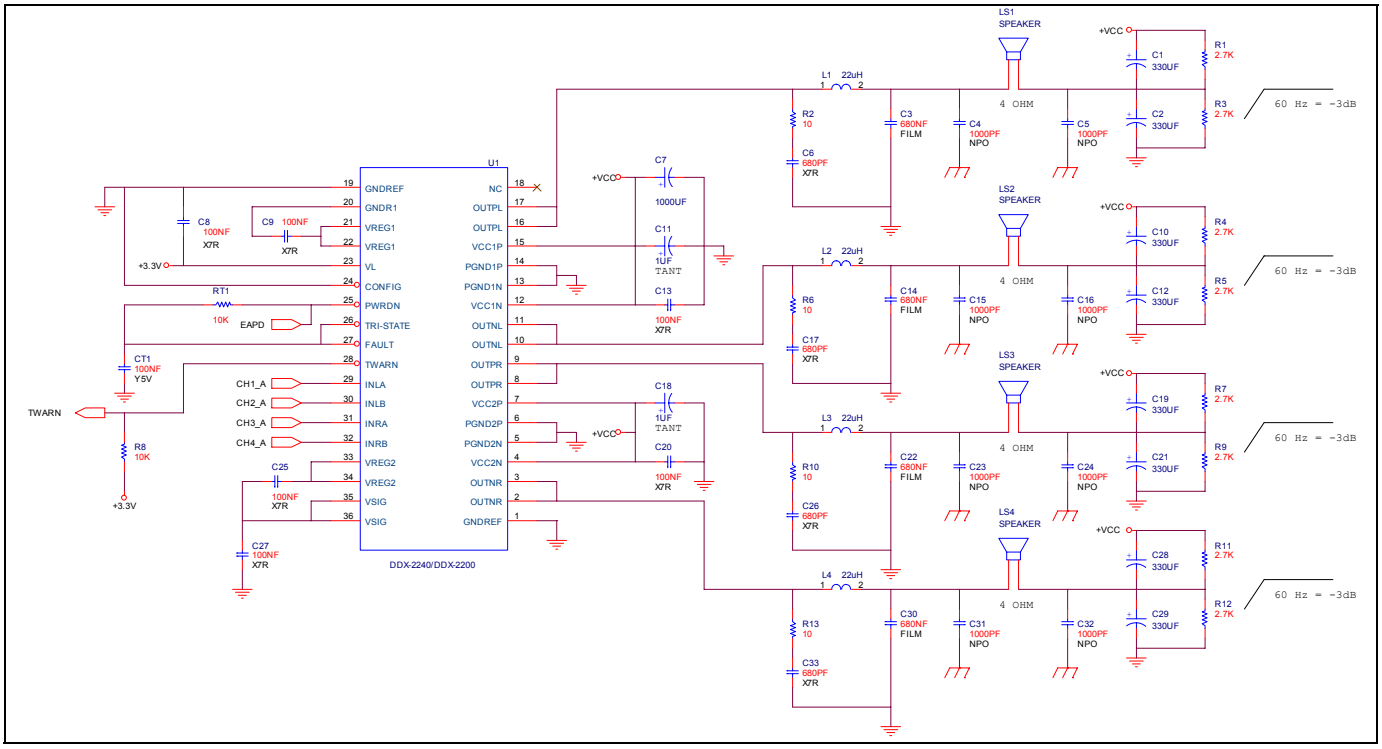


Figure 25 - Binary Mode, 4-Channel Audio Application Circuit

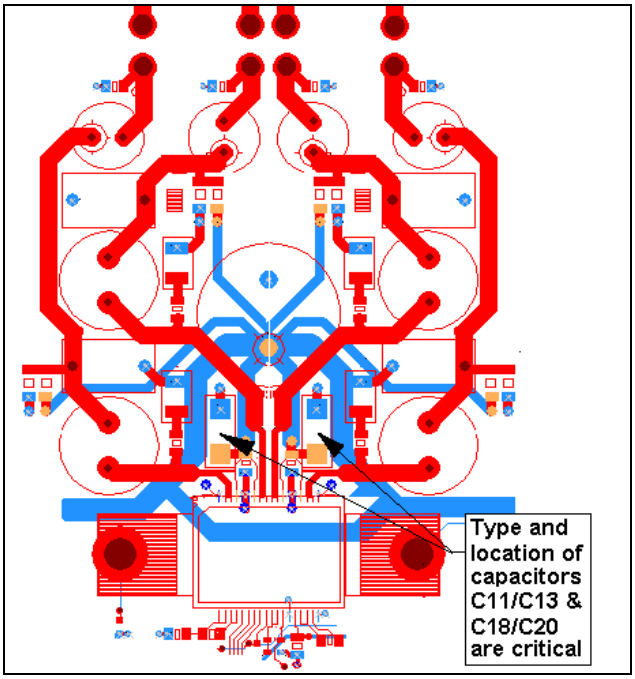
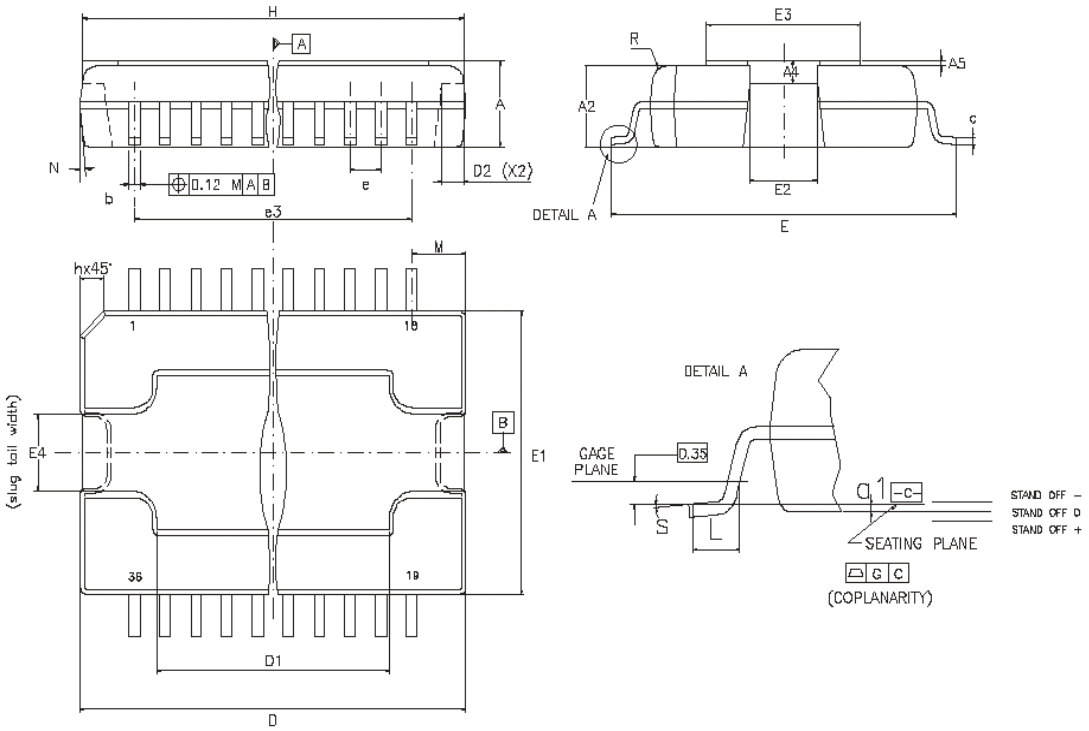


Figure 26 - Sample Binary Mode, 4 Channel Layout

5.0 PACKAGE INFORMATION

5.1 Package Outline Drawing

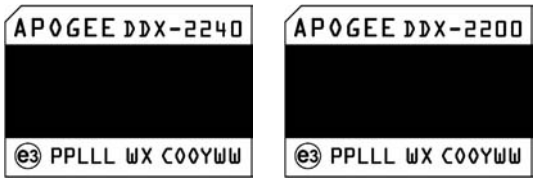


Reference Dimension	DATA BOOK mm			DATA BOOK inc		
	TYP	MIN	MAX	TYP	MIN	MAX
A	-	3.25	3.5		0.128	0.138
A2	-	-	3.3			0.130
A4	-	0.8	1		0.032	0.039
A5	0.2	-	-	0.008		
a1	-	0.030	-0.040		0.001	-0.002
b		0.22	0.38	0.000	0.009	0.015
c	-	0.23	0.32		0.009	0.013
D	-	15.80	16.00		0.623	0.631
D1	-	9.40	9.80		0.371	0.386
D2	1	-	-	0.039		
E	-	13.9	14.5		0.548	0.572
E1	-	10.9	11.1		0.430	0.438
E2	-	-	2.9			0.114
E3	-	5.8	6.2		0.229	0.244
E4	-	2.9	3.2		0.114	0.126
e	0.65	-	-	0.026		
e3	11.05	-	-	0.436		
G	-	0	0.075		0.000	0.003
H	-	15.5	15.9		0.611	0.627
h	-	-	1.1			0.043
L	-	0.8	1.1		0.032	0.043
M	-	-	-			
N	-	-	10deg			
R	-	-	-			
s	-	-	8deg			

1: "D" and "E1" do not include mold flash or protrusions
Mold flash or protrusions shall not exceed 0.15 mm (0.006") per side
2: No intrusion allowed inwards the leads

5.2 Marking Configuration

Packages with Date Code (YWW) = 514 & after



LEGEND:

PPLLLWX	Traceability Coding
COO	Country Of Origin
Y	Assembly Year
WW	Assembly Week
e3	Pb-Free (RoHS Compliant) (no symbol if not Pb-Free)