PURIFI

PURE SOUND

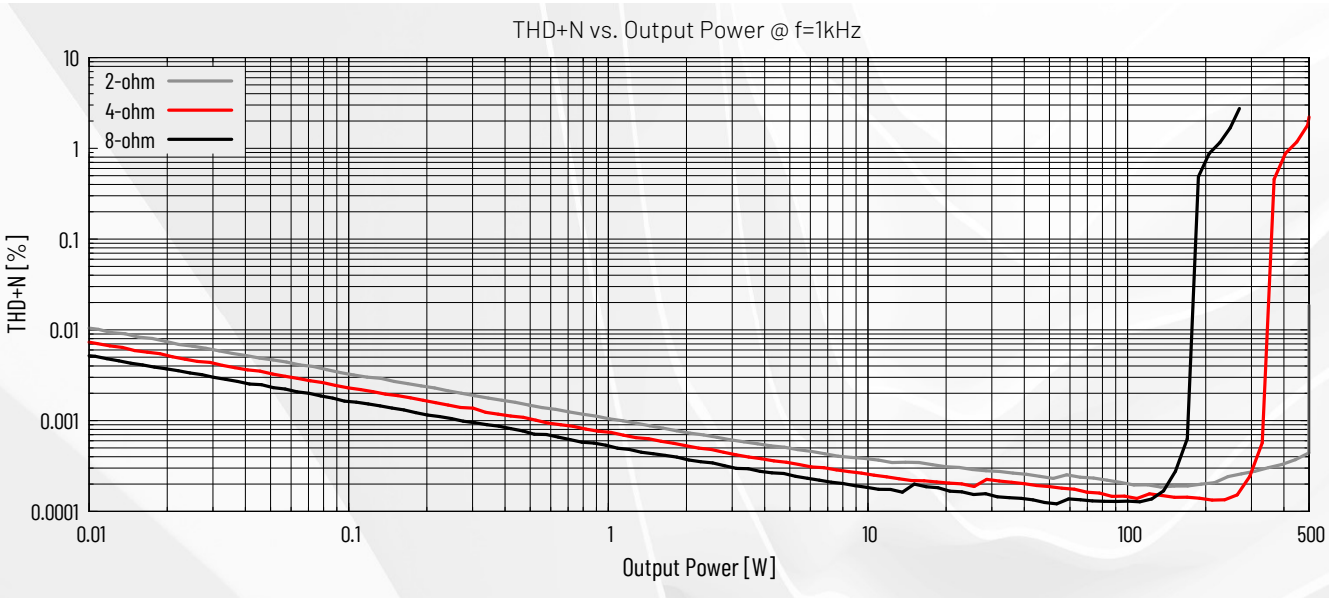
Building a Straight Wire to the Soul of Music

1ET400A
DATA SHEET

- Single-channel, analog-input Class D amplifier module
- Negligible THD and IMD
- Extraordinarily low noise
- Load-invariant response
- Exceptionally clean clipping
- Low losses & high efficiency
- Easy to integrate

KEY SPECIFICATIONS

Output Power	425W @ 1% THD, 4Ω
Output Current	~25A
THD+N	<0.00017% (-116dB) @ 100W, 4Ω, 20-20kHz
Dynamic Range	~131dB(A)
Output Noise	~11.5µV(A)
Gain	12.8dB
Output Impedance	<65µΩ @ 1kHz
Efficiency	>94%
Idle losses (output stage)	~1.7W
Supply	±25V to ±65V DC
Size	82x63x33mm



1 Specifications

1.1 Absolute Maximum Ratings

Referenced to GND unless otherwise noted.

Parameter		Min	Max	Unit
Power Supplies	Power Stage Supply, positive rail voltage (+VP)	-0.3	75	V
	Power Stage Supply, negative rail voltage (-VP)	-75	0.3	V
	Gate Drive Supply, voltage, referenced to -VP (VDR)	-0.3	20	V
	OPAMPs supply, positive rail voltage (+VOP)	-0.3	20	V
	OPAMPs supply, negative rail voltage (-VOP)	-20	0.3	V
	Digital Supply, voltage (VD) (optional use)	-0.3	6	V
I/O's	Analog Inputs (+AIN, -AIN)	-15	15	V
	Logic-level outputs, continuous current (SMPS_OFF, READY)		50	mA
	Logic-level inputs, voltage (/AMPON, SDA, SCL, /FATAL)	-0.3	4.2V	V
	Open-drain, bi-directional, continuous current (SDA)		50	mA
Env.	Ambient temperature	0	100	°C
	Heatsink temperature	0	100	°C
	Relative Humidity, non-condensing		85	%

Stress beyond Absolute Maximum Ratings may cause permanent damage to the Design and associated circuitry. Attempts to operate the Design within Absolute Maximum Rating but outside Recommended Operation Conditions (Table 2) may result in non-functional circuits and erroneous behavior.

Table 1 Absolute Maximum Ratings

1.2 Recommended Operating Conditions

Amplifier operation is permitted only under conditions stated in Table 2.

Referenced to GND unless otherwise noted.

Parameter			Min	Typ[1)]	Max	Unit
Power Supplies						
+VP	Power Stage, positive rail voltage		25	65	70	V
-VP	Power Stage, negative rail voltage		-70	-65	-25	V
VDR	Gate Drive, voltage (must be referenced to -VP)		13.6	15	16.5	V
+VOP	OPAMPs, positive rail voltage		11.4	12	12.6	V
-VOP	OPAMPs, negative rail voltage		-12.6	-12	-11.4	V
VD	Digital, voltage (optional use)		4	5	5.5	V
I/O's						
V_{in_dif}	Analog Inputs, differential rms voltage (pos. to neg. input)		0	11.2[2)]	12	V
V_{in_cm}	Analog Inputs, common-mode voltage		-5	0	5	V
R_L	Speaker Load, resistive		2[3)]	4	∞	Ω
Z_L	Speaker Load, capacitive			0	1	µF
Environmental						
T_A	Ambient temperature		0	25	60	°C
T_{HS}	Heatsink temperature		0	25	75	°C
θ_{HS-A}	Thermal resistance, Heatsink to Ambient		see note[4)]			°C/W
ρ_{FET-HS}	Thermal interface, FET Case to Heatsink	Conductivity[5)]	3	3		W/m-K
t_{FET-HS}		Thickness[5)]		0.5	0.5	mm
-		Dielectric strength	250			V
RH	Humidity, relative (non-condensing)			50	85	%

1) Audio Performance Specs are not guaranteed outside Typ. recommended operating conditions.
2) Corresponds to approximately full rated power in typ. load condition
3) The amplifier is stable into loads <2Ω. Output power into impedances <3.2 Ω may be limited by the Over Current Protection system.
4) The required θ_{HS-A} depends highly on the desired sustained power delivery specification – see section 7.2)
5) Conductivity and thickness can be traded off provided the ratio is 6 or better (i.e., $\rho_{FET-HS} / t_{FET-HS} > 6$)

Table 2 Recommended Operating Conditions

1.3 Audio Characteristics

R_L=4Ω, T_A=25° free operating air, f=1kHz, 20kHz AES17 filter (AP), typical operating conditions (Table 2) unless otherwise noted.

Parameter		Conditions	Min	Typ[1]	Max	Unit
P_O	Output Power, Short term	R_L= 8Ω, 1%THD		227		W
		R_L= 4Ω, 1%THD		425		W
		R_L= 2Ω, 1%THD		450[2]		W
	Output Power, Continuous[3]	-		(as limited by thermal system)		-
THD+N	Total Harmonic Distortion + Noise	P_O=1W, f=1kHz		0.0007		%
		P_O=10W, f=1kHz		0.00026		%
		P_O=100W, f=1kHz		0.00015[4]		%
		P_O=1W, f=20-20kHz		0.0007		%
		P_O=10W, f=20-20kHz		0.00029		%
		P_O=100W, f=20-20kHz		0.00017[4]		%
IMD	Intermodulation Distortion, CCIF	P_O=1W, f=18kHz+19kHz		0.00025		%
		P_O=10W, f=18kHz+19kHz		0.00022		%
		P_O=100W, f=18kHz+19kHz		0.00027		%
	Dynamic Intermodulation Distortion, DIM	P_O=1W, DIM30		0.002[4]		%
		P_O=10W, DIM30		0.002[4]		%
		P_O=100W, DIM30		0.002[4]		%
ICN	Idle Noise, speaker output	A-weighted		11.5		µV
DNR	Dynamic Range	A-weighted, relative 425W, R_L= 4Ω		131		dB
SNR	Signal to Noise Ratio	A-weighted, relative to 425W, R_L= 4Ω		131		dB
BW	Frequency Response, upper -3dB/-6dB	R_L= 8Ω, V_o=2.83V@1kHz (=1W)		60/75		kHz
		R_L=4Ω, V_o=2.83V@1kHz		60/75		kHz
		R_L= 2Ω, V_o=2.83V@1kHz		60/75		kHz
	Frequency Response, lower -3dB	-		(DC coupled)		-
	Frequency Response, flatness	R_L= 8Ω, f= 20-20kHz		±0.01		dB
		R_L= 4Ω, f= 20-20kHz		±0.01		dB
		R_L= 2Ω, f= 20-20kHz		±0.01		dB
		R_L= ∞Ω, f= 20-20kHz		±0.01		dB
	Frequency Response, load variation	R_L= 2 -∞Ω, f= 20-20kHz		±0.01		dB
Z_O	Output Impedance[5]	1kHz, I_{out}=1A		0.07		mΩ
		20-20kHz, I_{out}=1A		<0.65		mΩ

1) Performance depends on physical implementation and system-level circuitry/configuration. Measured data is based on 1ET400A-01B.
2) Power is limited by overcurrent protection system (OCP)
3) Continuous output power depends on properties of the thermal system. Data provided is based on module operating in free air.
4) THD @ 100W and DIM readings limited by analyzer
5) Kelvin measurement on edge connector.

Table 3 Audio Characteristics

1.4 Typical Audio Performance, Graphs

T_A=25° free operating air, 20kHz AES17 filter (AP), typical operating conditions (Table 2) unless otherwise noted.

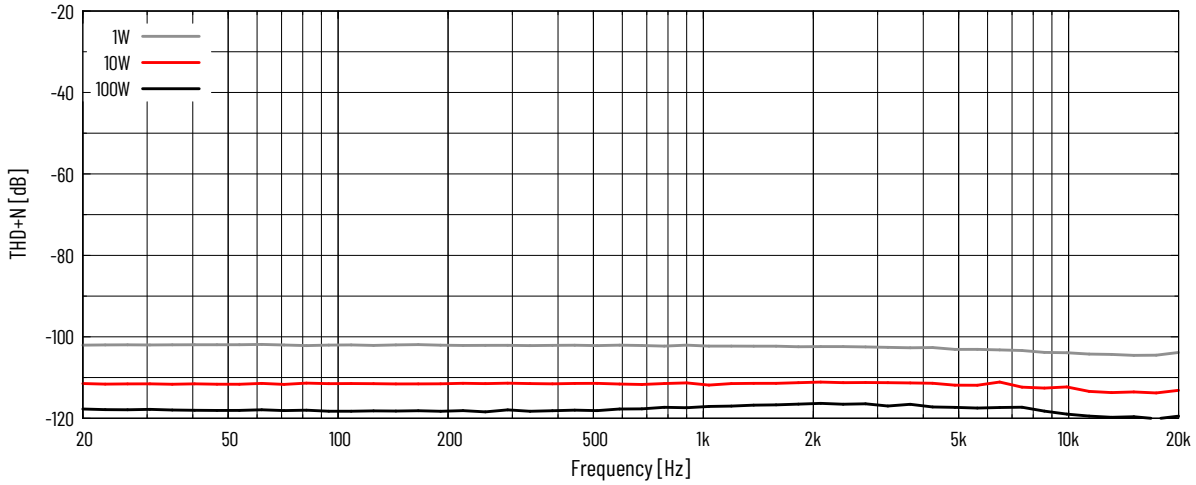


Figure 1 THD [dB] vs. Frequency @ 4Ω

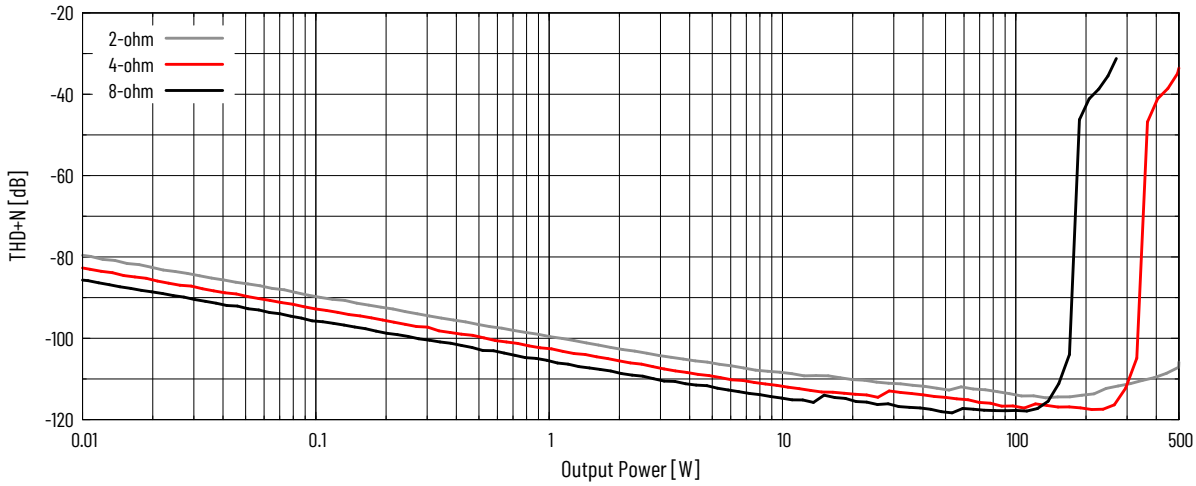


Figure 2 THD+N [dB] vs. Power @ f=1kHz

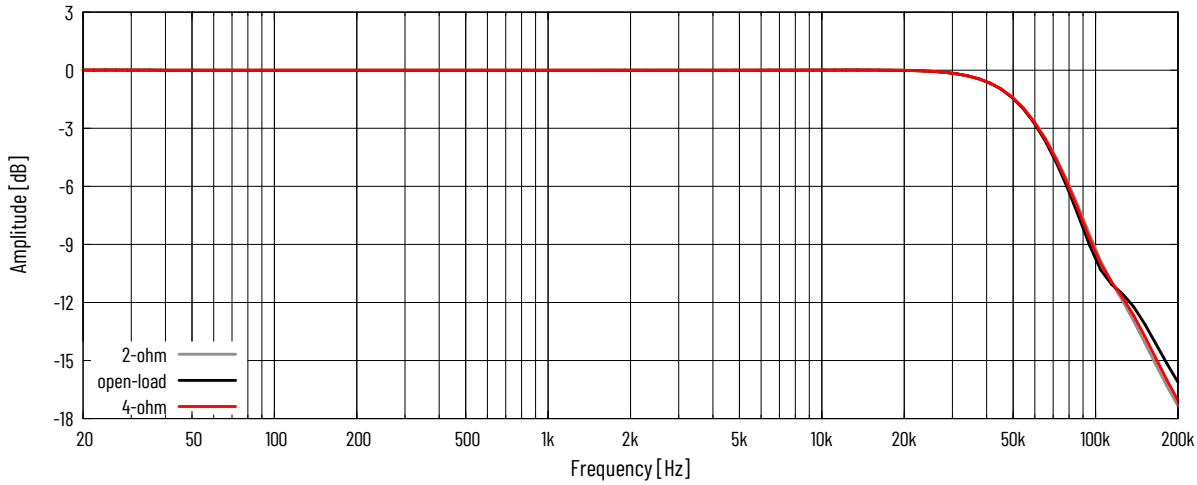


Figure 3 Frequency Response @ V_i=2.83V

T_A=25° free operating air, 20kHz AES17 filter (AP), 16K/48kHz/32x avg. FFT's, Equiripple window, typical operating conditions (Table 2) unless otherwise noted.

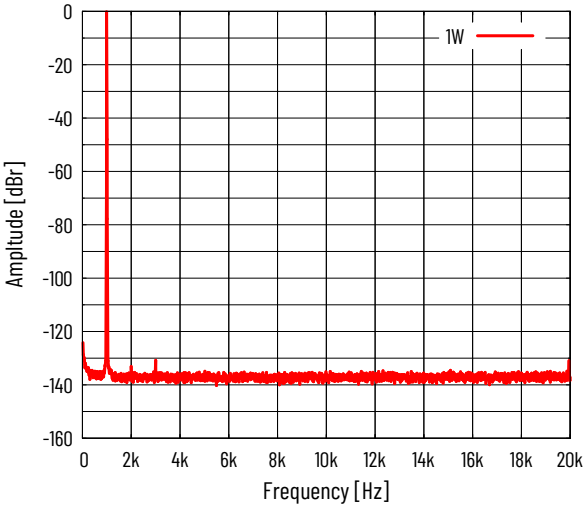


Figure 4 Frequency Spectrum (FFT) @ 1kHz, 1W, 4Ω

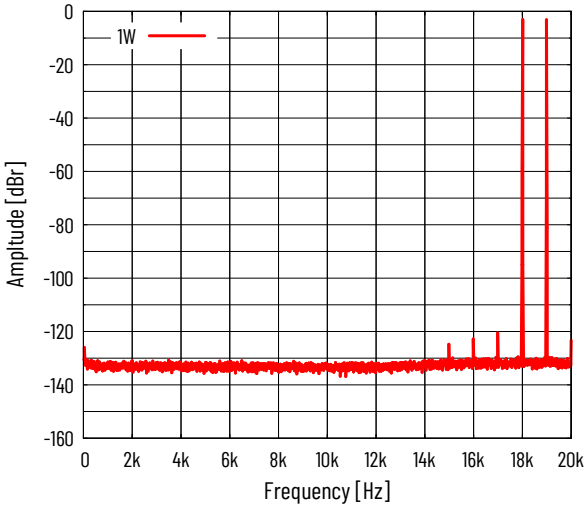


Figure 5 Intermodulation Distortion @ 18+19kHz, 1W, 4Ω

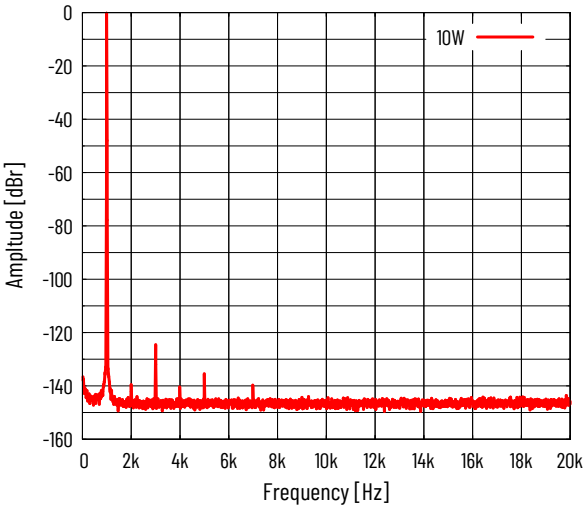


Figure 6 Frequency Spectrum (FFT) @ 1kHz, 10W, 4Ω

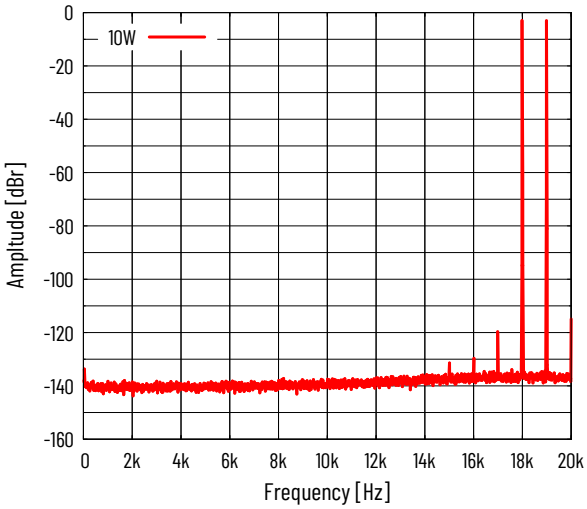


Figure 7 Intermodulation Distortion @ 18+19kHz, 10W, 4Ω

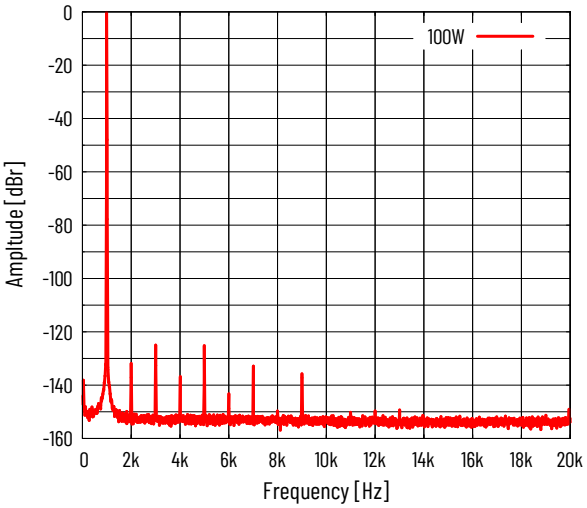


Figure 8 Frequency Spectrum (FFT) @ 1kHz, 100W, 4Ω

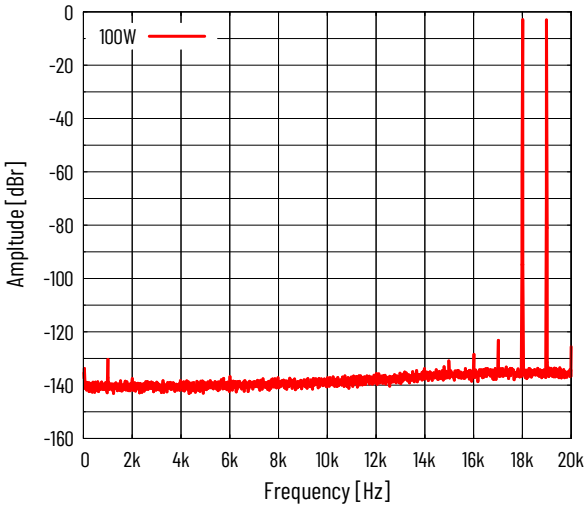


Figure 9 Intermodulation Distortion @ 18+19kHz, 100W, 4Ω

T_A=25° free operating air, 20kHz AES17 filter (AP), typical operating conditions (Table 2) unless otherwise noted.

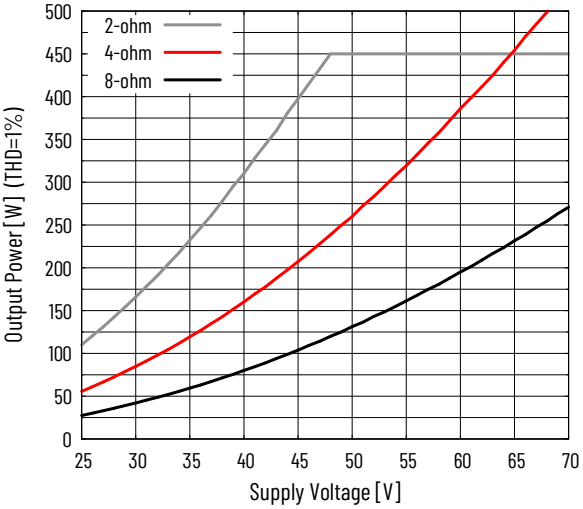


Figure 10 Output Power vs. VP @ 1% THD

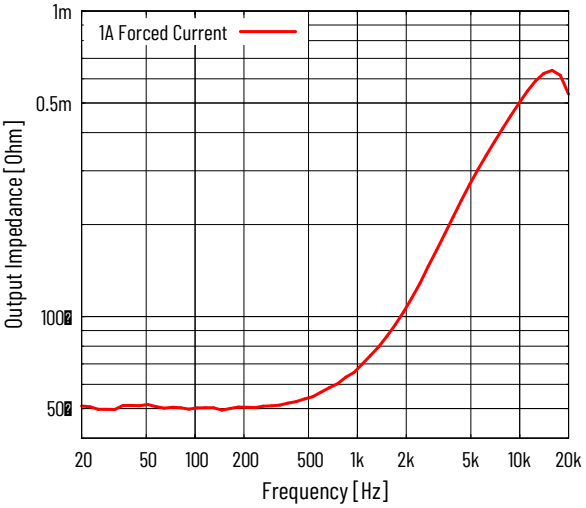


Figure 11 Output Impedance vs. Frequency

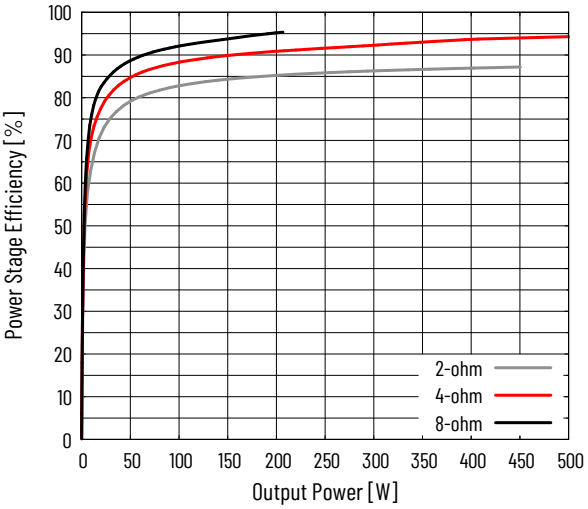


Figure 12 Power Stage Efficiency vs. Output Power

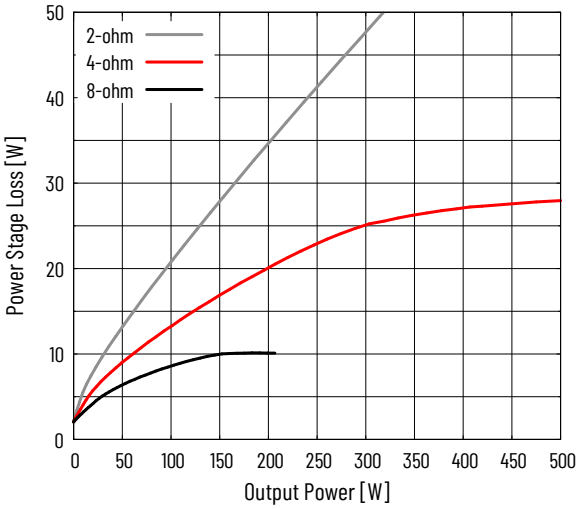


Figure 13 Power Stage Loss vs. Output Power (one channel)

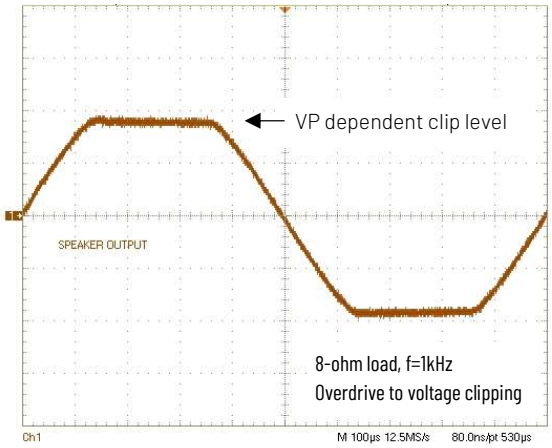


Figure 14 Voltage Clipping/Recovery (behavior)

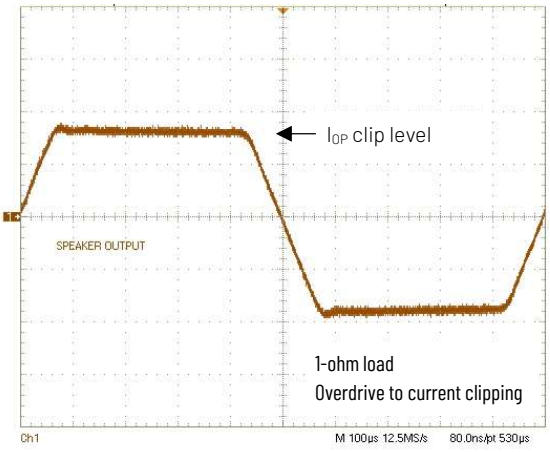


Figure 15 Current Clipping/Recovery (behavior)

1.5 Electrical Characteristics

Typical operating conditions (Table 2) unless otherwise noted.

Parameter		Conditions			Min	Typ[1)]	Max	Unit
Current Consumption & Efficiency								
$\lvert I_{VP} \rvert$	Power Stage supply, current	(+VP,-VP), Idle				13		mA
I_{DR}	Gate Drive supply, current	(VDR), Normal operation				35		mA
$\lvert I_{OP} \rvert$	OPAMPs supply, current	(+VOP, -VOP), Normal operation				27		mA
I_{VD}	uC and logic supply, current	(VD), Normal operation				10		mA
η	Efficiency	R_L= 8Ω				95		%
		R_L= 4Ω, Full rated power				94		%
Audio Inputs & Output								
R_{in}	Input impedance	Differential, pos. to neg. input				4.4		kΩ
		Single-ended, input to GND				2.2		kΩ
A_V	Voltage Gain	V_o/V_i				12.8		dB
$V_{in\_1\%THD}$	Differential input voltage	To get 1% THD @ R_L= 4Ω, VP=±65V [1)]				9.6		V_{rms}
CMRR	Common Mode Rejection Ratio	Audio input, 1kHz				>60		dB
PSRR	Power Supply Rejection Ratio	Forced 1Vrms f≤1kHz ripple, either rail				>90		dB
$\lvert V_{o\_DC} \rvert$	Speaker Output, DC offset	Grounded analog inputs				<10		mV
f_s	Switching frequency	Idle (indicative)				500		kHz
		Positive clipping				>50		kHz
		Negative clipping				0		Hz
Logic Control Signals								
V_{IH}	High level input threshold	(/AMPON)			2.7			V
V_{IL}	Low level input threshold						0.65	V
V_{IH_I2C}	High level input threshold	(SDA)			2.3			V
V_{IL_I2C}	Low level input threshold						1	V
V_{OH_I2C}	High level output voltage	(SDA)	Open-drain	I=6mA	2.6			V
V_{OL_I2C}	Low level output voltage			I=10mA			0.6	V
I_{OL_I2C}	Low level sink current						10	mA
V_{IH_SCL}	Open collector input	(SCL)			1.65			V
V_{IL_SCL}							0.5	
I_{IH_SCL}							0.001	mA
I_{IL_SCL}							1	
I_{OOC}	Open collector output	(/FATAL)					10	mA
V_{OOC}							65	V
V_{OH}	High level output voltage	(READY, PSUDIS)			VD-0.7			V
V_{OL}	Low level output voltage						0.6	V
Protection Systems								
I_{OCP}	Overcurrent Protection, threshold	Current limit				25		A
f_{DCP}	DC Protection, Speaker terminal	Detection filter corner frequency				2.5		Hz
$\lvert V_{DCP} \rvert$		Voltage limit, low-pass filtered signal				12		V
T_{OTP}	Thermal Protection, Heatsink	Over-temperature				75		°C
T_{UTP}		Under-temperature				0		°C
$\lvert OVP_{VP} \rvert$	Overvoltage Protection, threshold	(+VP, -VP)				75		V
OVP_{DR}		(VDR)				15.5		V
$\lvert OVP_{OP} \rvert$		(+VOP, -VOP)				20		V
$\lvert UVP_{VP} \rvert$	Undervoltage Protection, threshold	(+VP, -VP)				20		V
UVP_{DR}		(VDR)				9.5		V
$\lvert UVP_{OP} \rvert$		(+VOP, -VOP)				11		V

1) Performance depends on physical implementation and system-level circuitry/configuration. Data provided is based on module operating in free air.

Table 4 Electrical Characteristics

1.6 Timing Characteristics

Typical operating conditions unless otherwise noted.

Parameter		Conditions	Min	Typ[1)]	Max	Unit
Control Signals						
/AMPON	Mute time	Pin asserted high to Amp output HiZ		1		ms
	Un-mute time	Pin asserted low to Amp output LoZ		1.25		ms
READY	Start delay	Supplies stable to READY asserted high		1.25		ms
/FATAL	Amplifier failure to signal assertion	Failure to /FATAL low		40		ms
PSUDIS	PSU off signal	DC failure to PSUDIS high		40		ms
HS/ADDR	Mode Selection	Power-up to Mode latched		10		ms
Protection Systems						
t_{OCP}	OCP Mute cycle duration	OCP event to reenable outputs		>300		ns
OLP	Overload Protection, threshold	Ratio of OCP cycles to non-OCP cycles		12		%
t_{OLP}	OLP Mute cycle duration	OLP even to reenable outputs		1		s
t_{DCP}	DCP Mute cycle duration	DCP even to reenable outputs		1		s

1) Performance depends on physical implementation and system-level circuitry/configuration. Data provided is based on module operating in free air.

Table 5 Timing Characteristics

1.7 Mechanical Characteristics

Parameter		Conditions	Min	Typ	Max	Unit
SIZE	Length			82		mm
	Width			63		mm
	Height			33	36	mm
Mounting	Threaded standoff, heatsink-PCB, M3	Height		6		mm
	Threaded stud, heatsink-FET-PCB	Length		13		mm
	Spacer, FET-PCB, M3	Height		3		mm
	Threaded standoff	Diameter		M3		-
		Available thread depth			4	mm
		Torque			0.5	Nm

Table 6 Mechanical Characteristics

2 Introduction

1ET400A is a single-channel, ultra-high performance, analog-input Class D Amplifier module capable of over 400W of power at an audio quality level that sets the standard for power amplifiers of any operating class. Its compact size and high reliability makes it fit a broad range of applications, while its audio quality makes it the undisputable choice for applications where all the premium is on sound quality.

PURIFI's continuing research into nonlinear control theory has produced the first mathematically exact large-signal model of self-oscillating amplifier controllers. This breakthrough allows complete optimization of the feedback circuit and improves performance by at least an order of magnitude over existing implementations. The amplifier module further incorporates a comprehensive protection system that makes it tremendously robust and easy to integrate.

These circuits and methods provide many practical and audible benefits:

- ***High loop gain (>75dB) in the entire audio band***
  - *This figure corresponds to an unprecedented 110MHz Gain-Bandwidth Product and produces consistent ultra-high performance across the audio spectrum unmatched by audio amplifiers of any technology or operating class.*
- ***Negligible intermodulation distortion (IMD)***
  - *A very good measure for how well an amplifier handles complex signals. Sonically low IMD means a highly resolved and stable stereo image across the whole spectrum, even during very complex and busy passages.*
- ***THD remains extremely low at any frequency and any power level*** *right until clipping*
  - *Translates into a total lack of sonic signature, and an ability to reproduce any type of music without preference for genre or production style.*
- ***Negligible output noise***
  - *No audible noise. Deep black silences and a generous and detailed sound even at very low playback volumes.*
- ***High power supply rejection ratio (PSRR)***
  - *The module places no particular demands on the power supply quality. A simple off-the-shelf unregulated SMPS will not degrade audio performance.*
- ***Load-invariant frequency response and negligible output impedance***
  - *The amplifier handles difficult loudspeakers with ease, including those that challenge most other amplifiers.*
- ***Controlled, second-order low-pass response***
  - *Very flat audio-band response with a sensible, 60kHz bandwidth.*
  - *Reduced sensitivity to out-of-band noise from DACs, reducing the requirements on the DAC reconstruction filter. This leaves a shorter signal path between DAC and loudspeaker.*
  - *Problem-free operation with outboard DACs over which you may have no control.*
- ***Very low idle losses and reduced electromagnetic interference (EMI)***
  - *The enormous loop gain allows relaxed timing of the power MOSFETs without degrading audio performance.*
  - *Idle losses are minimized.*
  - *Very little to no effort needed to pass regulatory tests.*
- ***Exceptionally clean clipping and clipping-recovery*** *in both voltage and current domains*
  - *Clips cleanly and recovers immediately without "overhang". Current limiting is equally instantaneous and glitch free. This guarantees the smallest amount of audible artefacts when pushed into clipping or overload protection.*
- ***Overall implementation/integration ease*** *saves save time and cost for the system integrator*
  - *Architecture completely eliminates heterodyning in multichannel applications.*

3 Overview

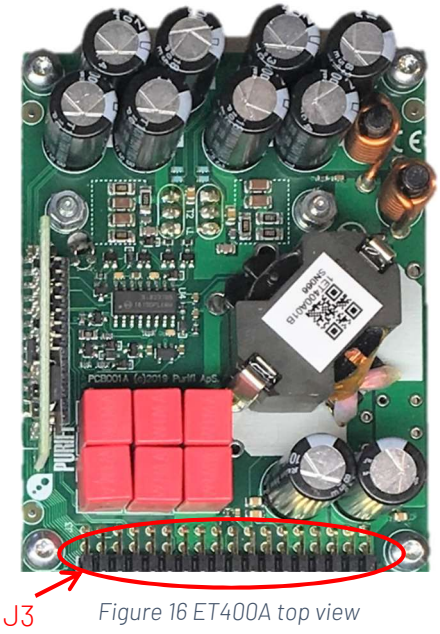
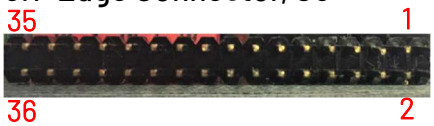


Figure 16 ET400A top view

3.1 Edge Connector, J3



Pin	Signal	Rating	I/O	Description
Power Supplies				
1, 2	+VP	Table 2	P	Power Stage Supply, positive rail
3,4,5 6,7,8	GND		-	Ground
9,10	-VP		P	Power Stage Supply, negative rail
11	VDR		P	Gate Drive Supply, referenced to -VP
12	VD		P	(option use) External Voltage supply to on-board 3.3V regulator
26	+VOP		P	OPAMPs, positive rail
25	-VOP		P	OPAMPs, negative rail
27	GND		-	Ground
I/O's				
13,14,15, 16,18	OUT-	Table 2	O	Speaker Output, negative (internally connected to GND)
17	VFBLF-		I	Feedback sense input, negative
19	VFBLF+		I	Feedback sense input, positive
20,21,22, 23,24	OUT+		O	Speaker Output, positive
28,33,34	NC		-	Not connected
29	IN+		I	Analog Input, positive
30	IN-		I	Analog Input, negative
31	HS/ADDR		I	Mode/I2C Address Selection; set by one 1% resistor.
32	PSUDIS /AMPON		O I	PSU off control signal (SW Mode), or Amplifier Disable (HW Mode) – *pull low to enable Amp*
35	SDA READY		I O	I2C Data (SW Mode), or Amplifier Ready (HW Mode) – "all good for operation" when high
36	SCL /FATAL		I O	I2C clock (SW Mode), or Amplifier "error/fail" (HW Mode) – *signal goes low on error*

Table 7 Edge Connector, J3

4 Power Supply, Control Signals & I/O's

4.1 Power Supply

Refer to below figure showing required power supplies and how to connect these to 1ET400A:

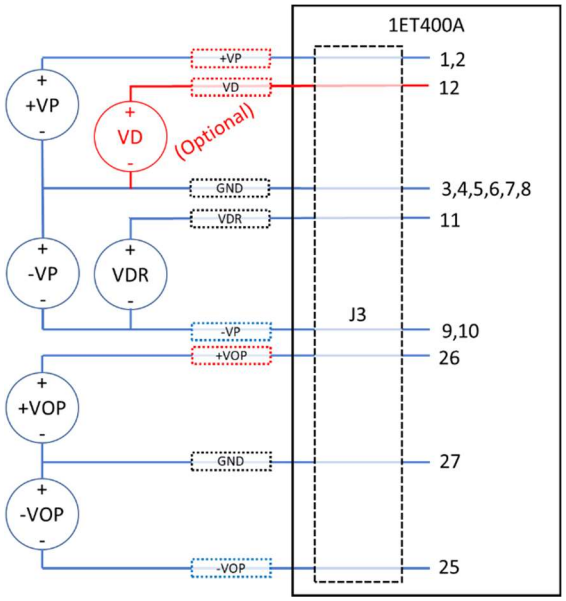


Figure 17 Power Supplies

Voltage, current and power ratings are described in detail in Table 2 Recommended Operating Conditions and Table 4 Electrical Characteristics.

4.1.1 Power Stage Supply (+VP, -VP)

1ET400A requires a ground-centered split-rail supply for the amplifier output stage.

Multiple factors need to be considered when determining capabilities of this supply, e.g., peak/continuous audio power requirements, nominal/minimum (speaker) load, thermal constraints and time constants/durations etc.

Refer to Figure 10 to determine required DC voltage based on desired nominal output power.

For a given supply voltage and output power specification, the power supply peak power and peak current can be estimated:

$$P_{psu\_peak} = 2\frac{P_{out\_rms}}{\eta} \quad ; \quad I_{psu\_peak} = \frac{P_{psu\_peak}}{VP}$$

The supply should be designed such that each rail has enough thermal headroom to drive full peak power for a minimum of one half-period of the lowest desired audio frequency or as otherwise required for continuous power delivery as determined by the system integrator. The 1ET400A design limits power delivery only if OCP or OTP events are triggered and in practice, especially in multichannel applications, the power supply often is the limiting factor for sustained power delivery.

Although 1ET400A includes over- and under-voltage protection (OVP/UVP) the power supply designer should pay close attention to managing "supply pumping". As example, by either ensuring that the supply can sink current or by utilizing enough electrolytic energy storage to keep rail voltages within recommended operating range in all use situations. In a stereo/multichannel application it is recommended to alternate the phase of channels such that PSU rails are loaded as balanced as possible. However, this alone is not enough remedy to always avoid supply pumping and it is the responsibility of the system integrator to define and ensure adequate levels of caution.

4.1.2 Gate Drive Supply (VDR)

1ET400A requires an external supply for the gate drive circuitry. It is essential that the supply is designed as a floating rail, that must be referenced to -VP.

VDR directly feeds the low-side gate driver; the design utilizes boot-strap circuitry to create a rail relative to high-side driver.

4.1.3 OPAMPs Supply (+VOP, -VOP)

1ET400A requires an external ground-centered split-rail supply for the modulator and general analog low-power circuitry. There are no particular design constraints outside of normal audio design best-practice.

4.1.4 (optional) Digital Supply (VD)

The design includes a 3.3V regulator running of +VOP and therefor do not require an external power supply for the digital section. Connect VD to an external 5V supply if you want to avoid powering the uC from the op amp supplies, or if you want to be able to communicate with the module via I2C when the op amp supplies are powered down.

4.1.5 Power Supply Sequencing

1ET400A monitors all supplies with exception of the optional VD supply and prevents operation unless all supply voltages are within preset safe thresholds.

4.2 Control Signals

4.2.1 PSUDIS & /AMPON

Signals share the same physical net and adapts function according to Operation mode (refer to section 5).

The net is tied directly to a microcontroller GPIO pin and has a 27kΩ pull-up to 3.3V.

4.2.2 SCL & /FATAL

Signals share the same physical net and adapts function according to Operation mode (refer to section 5).

The signal is connected to the collector of a transistor which has the emitter tied to a uC GPIO pin and the base tied permanently to 3.3V via a 3.3kΩ resistor.

As SCL, the transistor will level-shift the incoming signal to levels suitable for the uC.

As /FATAL, the transistor will pass output from the microcontroller and function as open-collector output.

4.2.3 SDA & READY

Signals share the same physical net and adapts function according to Operation mode (refer to section 5).

The net is tied directly to a microcontroller GPIO pin.

As SDA, the signal is a bi-directional (open-drain) I/O and complies with the general I2C specification in terms of levels and timing.

As READY, the signal is configured as CMOS-level compliant logic output.

4.3 Audio Inputs & Output

4.3.1 Audio Input (IN+, IN-)

1ET400A has a differential analog input.

The behavior of the input can be described as equivalent to a traditional differential, op-amp configuration with gain and input resistance as listed in Table 4.

For best performance specs the overall amplifier gain is kept reasonably low. If desired, a separate gain stage can be implemented upstream to 1ET400A. It is up to the system integrator to specify the properties of any pre-gain/signal-conditioning circuitry as well as test how it affects the rest of the system.

Adjusting the 1ET400A input resistors voids all performance specifications and should therefore be avoided.

Amplifier clipping is a function of supply voltage (VP), amplifier gain and audio input voltage. As example, in nominal operating conditions (see table) a balanced analog input of 9.6Vrms sine is required for the output to produce a signal with ~1% THD indicating the point where the amplifier is close to clipping.

4.3.2 Speaker Output (OUT+, OUT-)

1ET400A has a single-ended ground-centered speaker output.

The system integrator might notice that the OUT- terminal is connected to GND as part of the Design and be tempted to route the negative speaker terminal to GND elsewhere in the system. This, however, should be avoided as the internal feedback connections sense the voltage between OUT+ and OUT- terminals. If the negative speaker terminal is connected elsewhere, The Design cannot correct for voltage differentials between OUT- and the negative speaker terminal. Best performance is achieved by treating the speaker outputs as a balanced pair when routing the PCB traces from the boundaries of 1ET400A Design to the location of the speaker terminals at the system level.

Similarly, bridging two 1ET400A Designs will result in performance degradation as the circuit is not configured to sense the voltage differential that exists between the (now unused) OUT- terminals of the two 1ET400A Designs. Bridging is therefore not recommended. All operation and performance specs are void in this configuration.

5 Operating Modes & Status Reporting

1ET400A can operate in two modes:

1. HW Mode: all control via pins (HW interface)
2. SW Mode: enables I2C control (I2C interface)

Modes are selected via resistor value programming, please see Table 8

5.1 Mode Selection (HS/ADDR Settings)

The programming resistor most be connected between the HS/ADDR pin and GND.
Setting of the HS/ADDR signal defines operation mode and I2C address per following table:

Mode	I2C Address	Resistor: HS/ADR to GND
Hardware Mode	-	∞ (not populated)
Software Mode	0x50	0
	0x51	1K9
	0x52	3K9
	0x53	6K8
	0x54	10K
	0x55	12K
	0x56	18K
	0x57	22K
	0x58	27K
	0x59	33K
	0x5A	47K
	0x5B	56K
	0x5C	82K
	0x5D	120K
	0x5E	190K
	0x5F	390K

*) Resistors must be 1% or better.

Table 8 Mode Selection via HS/ADDR

5.2 HW Modes

In HW Mode the channel controller monitors and operate all available circuits for environmental checks (Over/Under-voltage, Temperature) and all protection circuits (Current limiting, Overload protection, DC protection, Frequency protection and Bootstrap refresh).

Status and control information are accessible via three signals (nets):

NET	Signal	Rating	I/O	Description
J3,32	/AMPON	Table 2	I	Amplifier Disable – *pull low to enable Amp*
J3,25	READY		O	Amplifier Ready – "all good for operation" when high
J3,36	/FATAL		O	Amplifier "error/fail" – *signal goes low on error*

Table 9 Status/Control signals in HW Mode

5.3 SW Mode

The main feature of the SW Mode is access via I2C to a vast amount of status and control information.

I2C is accessed via SCL, SDA.

In addition to status/control information accessible via I2C, one hardwired output signal (PSUDIS) is available.

Pin	Signal	Rating	I/O	Description
J3,32	PSUDIS	Table 2	O	PSU off control signal
J3,35	SDA		I	I2C Data
J3,36	SCL		I	I2C clock

Table 10 Status/Control signals in SW Mode

5.3.1 PSUDIS (GPIO)

PSUDIS is essentially a GPIO which can be configured via the I2C register. Per default, GPIO is set to echo the AmpFail flag and is intended to be used to control the power supplies on and off.

It is possible to force the GPIO (i.e., SMPS_OFF) high or low via the I2C register – this enables control of the power supplies via the amplifier I2C interface.

GPIODir	DPIOVal	GPIOAmpFail	Description
0	0	0	GPIO is forced low
0	1	0	GPIO is forced high
1	x	0	Reserved
x	x	1	GPIO echos the AmpFail flag

Table 11 PSUDIS (GPIO) mapping

5.4 I2C Register Map

Reg	Name	Data type	R/W	Description
0x00	Channel count	High Nibble	R	1 = module has one active channels
	Product Type	Low Nibble	R	1 = amplifier module
0x01 0x02	Power	Integer	R	0x01 0x90 — 0x0190 = 400 (dec) = "~400W" module
0x03	Version	High Nibble	R	Hardware revision number
	Revision	Low Nibble	R	Hardware sub-revision number
0x04 0x05	Serial	Integer		Serial number (convert hex to dec to get serial number)
0x06	Firmware	High Nibble	R	Firmware revision number
		Low Nibble	R	Firmware sub-revision number
0x07	OC limit	Unsigned short	R	Overcurrent Protection threshold
0x08	Reserved	-	-	
0x09	Reserved	Bits 7-4	-	
	GPIOAmpFail	Bit 3	W	Set to make pin high when AmpFail is high, and Hi-Z otherwise
	GPIODir	Bit 2	W	Set low for using GPIO feature
	GPIOVal	Bit 1	W	GPIO pin value
	AmpEnable	Bit 0	W	Request to turn on amplifier
0x0A	Reserved	Bits 7-3	-	
	ICLIP	Bit 2	R	Flags that current limiting has happened since this flag was last read
	VCLIP	Bit 1	R	Flags that at clipping has happened at least once since this flag was last read
	AmpReady	Bit 0	R	Power stage is switching and passing signal
0x0B	Reserved	Bit 7	-	
	AmpFail	Bit 6	R	Flags that DC at the output persisted after turning the power stage off
	OverTemp	Bit 5	R	Temperature too high.
	MinVOPOver	Bit 4	R	Negative op-amp supply too high.
	PlusVOPOver	Bit 3	R	Positive op-amp supply too high.
	VDROver	Bit 2	R	VDR too high.
	MinHVOver	Bit 1	R	Negative high-voltage supply too high.
	PlusHVOver	Bit 0	R	Positive high-voltage supply too high.
0x0C	Reserved	Bits 7-6	-	
	UnderTemp	Bit 5	R	Temperature too low.
	MinVOPUnder	Bit 4	R	Negative op-amp supply too low.
	PlusVOPUnder	Bit 3	R	Positive op-amp supply too low.
	VDRUnder	Bit 2	R	VDR too low.
	MinHVUnder	Bit 1	R	Negative high-voltage supply too low.
	PlusHVUnder	Bit 0	R	Positive high-voltage supply too low.
0x0D	Reserved	Bits 7-2	-	
	OverloadError	Bit 1	R	Power stage is temporarily turned off after a sustained overcurrent event
	DCError	Bit 0	R	Power stage is temporarily turned off after DC was detected on the output.
0x0E	PlusHV	Unsigned short	R	Measured positive high-voltage rail in volts
0x0F	MinHV	Unsigned short	R	Measured negative high-voltage rail in volts
0x10	VDR	Unsigned short	R	Measured VDR in decivolts.
0x11	Temperature	Signed short	R	Measured temperature in °C
0x12	DC	Signed short	R	Measured output DC in volts
0x13 0x14	Fsw	Unsigned int	R	Measured switching frequency in units of 250Hz.
0x15	PlusVOP	Unsigned short	R	Measured positive op amp supply, in decivolts
0x16	MinVOP	Unsigned short	R	Measured negative op amp supply, in decivolts
0x17... 0x1F	Reserved	-	-	

Table 12 I2C Register Map

6 Protection System

1ET400A is protected from overload and failure by means of several protection circuits. All systems are continuously active while the amplifier is powered and operating.

6.1 Environmental checks

Environmental checks denote circuits that monitor operating conditions maintained or affected by external sources or influences such as power supply voltages and ambient/system temperatures.

Environmental checks are enabled in both HW Mode and SW Mode.

6.1.1 Over/Under-Voltage Protection, +VP, -VP, VDR, +VOP, -VOP

The high voltage supply rails (Power Stage Supply) must be within certain thresholds for safe operation. If supply levels are outside min-to-max thresholds denoted in table below the Amplifier power stage output is brought immediately into high-impedance state (HIZ).

In HW Mode an OVP/UVP condition asserts the READY signal low. It is recommended that the system host monitors this signal.

In SW Mode OVP/UVP states are reported in the I2C register with a great deal of associated information available, please refer to the I2C register map for details.

6.1.2 Temperature Protection, Backplate

1ET400A utilize circuitry to monitor the temperature of the required aluminum back plate (used for cooling the FET's) and take appropriate action conditions are outside recommended operating range.

An OTP/UTP condition brings the amplifier output into high-impedance state (stop switching). Normal operation automatically resumes once temperatures return within the tolerable range and no involvement from user or system host controller is required.

In Hardware Mode an OTP/UTP condition asserts the READY signal low for as long as the temperature is out of tolerable range. It is recommended that the system host monitors this signal.

In Software Mode OTP/UTP status and actual measured temperature are reported in the I2C register, please refer to the register map for additional information.

6.2 Overcurrent Protection (OCP)

Each amplifier channel is protected against short- and long-term high-current overload.

A system monitors the output stage current and abruptly engages a *protection cycle* (*OCP cycle*) if a pre-set overcurrent threshold is exceeded. During a *protection cycle* the power stage output is flipped, i.e., if the overcurrent event concerns the high-side FET the half-bridge output will be force low, and reversely, if the overcurrent event concerns the low-side FET the half-bridge will be forced high. The duration of a *protection cycle* is approximately ~300nS or until the output current has decreased below a safe threshold. The combined behavior of the OCP circuit is comparable to a current-limiter function.

Extended current-limiting can result in triggering of the Overload Protection (refer to section 6.3).

Following a *protection cycle,* normal operation is automatically resumed and no involvement from user or system host controller is required.

OCP is enable in all modes of operation (SW Mode, HW Mode).

OCP is reported in the I2C register (ICLIP) when operating in SW Mode.

6.3 Overload Protection (OLP)

To safeguard the Module against continuous operation at the OCP threshold (current-limiting) a circuit keeps track of OCP cycles as function of time. If the amplifier is running in current-limiting more than approximately 12% over time *an OLP mute cycle* is triggered. In events of continuous OCP the OLP triggers after approximately 10ms. During a *mute cycle* the output stage is disabled (left in high-impedance state) approximately 1 second.

Following a *mute cycle,* normal operation is automatically resumed and no involvement from user or system host controller is required.

OLP is enabled in all modes of operation (SW Mode, HW Mode).

OLP is reported in the I2C register (OverloadError) when operating in SW Mode.

6.4 DC Protection (DCP)

The amplifier audio signal channel is capable of passing DC signals, i.e., the audio channel does not include any form of low-cut (high-pass) filtering. To protect the speaker against potentially harmful DC signals 1ET400A includes a circuit that monitors the speaker output and disables the power stage should certain conditions be exceeded. The speaker output signal is low-pass filtered with a corner frequency below the audible range and if the filtered signal exceeds a preset threshold a DCP *mute cycle* is triggered (Table 4).

Following a *mute cycle,* normal operation is automatically resumed only if the DC is reduced within safe thresholds. If so, no involvement from user or system host controller is required. However, if DC persist at the end of the *mute cycle*, the power stage is latched off and will stay off until the user or system host controller takes deliberate action to restart operation.

DCP is enabled in SW Mode and HW Mode.

DCP-latch-off condition is reported in the I2C register (AmpFail) when operating in SW Mode. Note that a DCP *mute cycle* is not reported.

It is recommended to frequently poll the AmpFail flag and control the power supply accordingly. Alternatively, program the GPIO pin to output the state of AmpFail flag and use that to shut down the power supply in case of a failure.

In HW Mode, DCP-latch-off condition asserts /FATAL signal low. It is recommended that the /FATAL signal is used to switch off the power supplies.

7 Mechanical Specifications & System Considerations

7.1 Module Dimensions

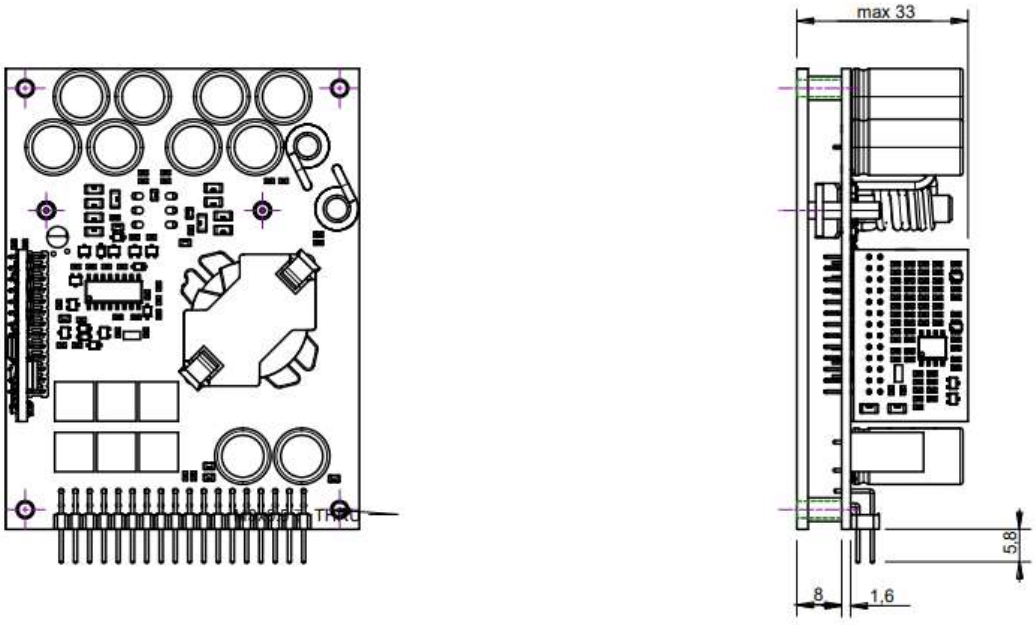


Figure 18 Dimensions

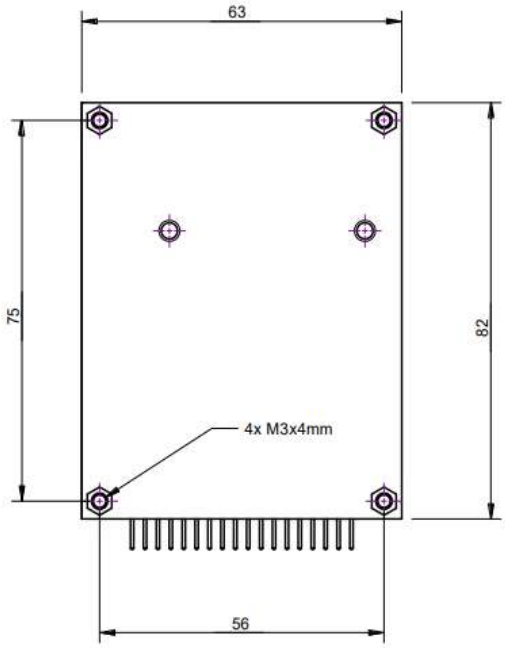


Figure 19 Bottom-side mounting holes

7.2 Thermal Requirements

While 1ET400A has very low idle losses and high overall efficiency, adequate cooling is essential for sustained power delivery. Careful considerations must be given to design of the thermal system in order to achieve desired output power specifications.

It is recommended to mount the module on a heatsink, e.g., an adequately design aluminum chassis.

7.3 Mechanical Requirements

With regard to mechanical robustness of the end application it is the reasonability of the system integrator to specify process, materials, locations, etc. for e.g., gluing of critical components which may be required and to prove/document short- and long-term performance and reliability. The system integrator must ensure integrity of mounting method and materials used related to fixation of the module. It is recommended to thoroughly test the final product for robustness against, e.g., shock and vibration.

7.4 Compliance Testing

1ET400A is designed with considerations for compliance of the end application. However, it is the responsibility of the system integrator to ensure any form of design-for-compliance and associated testing/certification which may be required.

8 Revision History

Rev	Date	Description	ID
(0.90)	2019-05-24	Pre-release version (preliminary)	CNN
(1.00)	2019-10-10	Release version	CNN

Table 13 Revision History

1 MODULE Use Restrictions and Warnings: 1.1 MODULES ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS. 1.2 User must read and apply the user guide and other available documentation provided by PURIFI ApS regarding the MODULE prior to handling or using the MODULE. 1.3 Safety-Related Warnings and Restrictions: 1.3.1 User shall operate the MODULE within PURIFI ApS's recommended specifications and environmental considerations stated in the specification or other available documentation provided by PURIFI APS, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the MODULE may cause personal injury or death, or property damage. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the MODULE and/or interface electronics. Please consult the MODULE documentation prior to connecting any load to the MODULE output. During normal operation, even with the inputs and outputs are kept within the specified allowable ranges, some circuit components may have elevated case temperatures. When working with the MODULE, please be aware that the MODULE may become very warm. If there is uncertainty as to the ratings and specifications, please contact PURIFI ApS prior to connecting interface electronics including input power and intended loads. 1.3.2 MODULEs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the MODULE by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the MODULE and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the MODULE by User or its employees, affiliates, contractors or designees. 1.4 User assumes all responsibility and liability to determine whether the MODULE is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the MODULE and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the MODULE consistent with all applicable international, federal, state, and local requirements.

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