



# ---Under construction---

## Sanyo ICEpower Amp System 1 LA4930/LV4970

- 2ch Analogue input, ICEpower power amplifier

Version 0.4

### Content

---

Description .....	2
Applications .....	2
Features .....	2
Absolute Maximum Ratings .....	3
Normal Operating Conditions .....	3
Electrical Characteristics Mode 1 (4Ω) .....	3
Electrical Characteristics Mode 2 (8Ω) .....	4
Pin descriptions .....	4
Equivalent circuit block diagram .....	6
Typical Application (2x100W breadboard) .....	11
Interfacing with the chipset .....	14
Protection .....	16
Typical performance .....	24
Packages .....	26

---

Sanyo Semiconductor Company  
1-1-1, Sakata Oizumi-Machi  
Ora-Gun Gunma 370-0596, Japan  
Phone: [81] 276 61 8388, Fax: [81] 276 61 8730  
[www.semic.sanyo.co.jp/index\\_e.htm](http://www.semic.sanyo.co.jp/index_e.htm)

Bang & Olufsen ICEpower a/s  
Gl. Lundtoftevej 1b  
DK-2800 Lyngby, Denmark  
Phone [45] 45 20 36 00, Fax [45] 45 20 36 99  
[ICEpowerinfo@bang-olufsen.dk](mailto:ICEpowerinfo@bang-olufsen.dk), [www.icepower.bang-olufsen.com](http://www.icepower.bang-olufsen.com)

## Description

Sanyo ICEpower Amplifier System 1 is based on the ICEpower analog technology, consisting of unique COM modulation and MECC feedback control techniques, is adopted for the Amplifier System 1 to reach best in class audio performance.

Sanyo ICEpower Amplifier System 1 consists of one LA4930 analogue 2ch controller IC and two LV4970 half bridge driver IC's, which implements up to 150W pr. Channel output with a single ended (bridgeable) output stage operating from dual power supplies. New output stage drive technology, the Intelligent Power Cell (IPC), is adapted to reach state-of-the-art efficiency (95-96% in 8 ohm loading) and idle power consumption (<1W).

The documentation describing the chipset consist of following documents:

- LA4930M datasheet.
- LV4970M datasheet.
- Sanyo ICEpower Amp System 1 LA4930/LV4970.
- Application note.

## Applications

- Car audio
- Home audio
- A/V receiver

## Features

- High audio performance
  - THD+N = 0.005% @ 1W / 1 kHz, THD+N < 0.05% all frequencies and output powers.
  - Idle Noise = 50  $\mu$ V AwtD, typical
  - Bandwidth typical: 80kHz (programmable)
- High undistorted output power
  - Po=100W/ch, THD+N=0.05%, 4 ohm, 1kHz, (Vd,Vs=± 40V)
  - Po2=100W/ch, THD+N=0.05%, 8 ohm, 1kHz, (Vd,Vs=± 50V)
  - Max output = 150W, THD+N = 0.05%, 8 ohm
  - Max output = 200W, THD+N = 0.05%, 4 ohm (SE or BTL mode )
- Total protection scheme
  - Local over current limit at each FET & Output short circuit protection
  - Over voltage protection
  - Optional under voltage protection
  - Thermal protection
  - High frequency / output filter protection.
- Sound quality optimized intelligent input soft clipping.
- Flexibility in MECC control system design provided by external components.

## Absolute Maximum Ratings

Parameter	Symbol	Test Condition	Value	Unit
Maximum Supply Voltage	$V_d, V_{s, \max}$	Operating	$\pm 60$	V
	$V_{dd}, V_{ss}$	Operating	$\pm 4.5 \sim \pm 5.5$	V
	$V_{drive, \max}$	Operating	$V_s + 15$	V
Operating Temperature	$T_{opg}$		$- 40 \sim + 85$	°C
Storage Temperature	$T_{stg}$		$- 50 \sim + 150$	°C

Table 1: Absolute Maximum Ratings,  $T_a=25^\circ\text{C}$

## Normal Operating Conditions

Parameter	Symbol	Test Condition	Value	Unit
Recommended Supply Voltage	$V_d, V_{s, \max}$	Operating	$\pm 25$ to $\pm 56$	V
	$D_{dd}, V_{ss}$	Operating	$\pm 5$	V
	$D_{drive, \max}$	Operating	$V_s + 10$	V

Table 2: Operating Conditions,  $T_a=25^\circ\text{C}$

## Electrical Characteristics Mode 1 (4W)

Parameter	Symbol	Test Condition	Min.	Typ.	Max	Unit
Quiescent Power	$P_q$	Total – All supplies		1		W
LV4970 Power consumption	$P_d$	$V_{drive}$ 1ch		0.25		W
LA4930 Power consumption	$P_c$	$V_{dd}, V_{ss}$ Complete 2ch		0.4		W (2ch)
Efficiency	$\eta$	$P_o = 100\text{W}$		93		%
Input sensitivity	$V_i$			1.85		Vp
Channel Gain Unbalance	$\Delta VG$	1 % ext Resistors		$\pm 0.1$		dB
Output Power	$P_o$	$V_d, V_s = \pm 37\text{V}$ , THD=0.05%		100		W
Output Offset Voltage	$V_n$ offset	$R_g = 0 \text{ ohm}$		3	30	mV
Distortion	THD+N	$P_o = 1\text{W}$ , AES17 LPF		0.005		%
Distortion	THD+N	All frequencies, Powers		<0.05		%
CCIF IMD	IMD	19kHz, 20kHz, -3dB		0.001		%
Power supply Ripple Rejection	PSRR	$V_{dd}/V_{out}$ @1kHz $V_{ss}/V_{out}$ @1kHz $V_d/V_{out}$ @1kHz $V_s/V_{out}$ @1kHz				dB dB dB dB
Output Noise	$V_{NO}$	$R_g = 0$ , A-weighted		50	100	$\mu\text{V}_{rms}$

Table 2: Electrical Characteristics Mode 1,  $T_a=25^\circ\text{C}$ ,  $V_d, V_s = \pm 37\text{V}$ ,  $R_L = 4 \text{ ohm}$ ,  $f = 1\text{kHz}$

## Electrical Characteristics Mode 2 (8W)

Parameter	Symbol	Test Condition	Min.	Typ.	Max	Unit
Quiescent Power	$P_q$	All Supplies		1		W
Efficiency	$\eta$	$P_o = 100W$		96		%
LV4970 Power consumption	$P_d$	$V_{drive} \cdot 1ch$		0.25		W
LA4930 Power consumption	$P_c$	$V_{dd}, V_{ss} \cdot \text{Complete 2ch}$		0.4		W (2ch)
Input sensitivity	$V_i$			1.85		V
Channel Gain Unbalance	$\Delta VG$	1 % ext Resistors	-0.2	$\pm 0.1$	+0.2	dB
Output Power	$P_o 2$	$V_d, V_s = \pm 50 V, THD = 0.05\%$		100		W
Output Offset Voltage	$V_n \text{ offset}$	$R_g = 0$	-30	$\pm 10$	+30	mV
Distortion	THD	$P_o = 1W, \text{AES17 LPF}$		0.003		%
Distortion	THD+N	All frequencies, Powers		<0.05		%
CCIF IMD	IMD	19kHz, 20kHz, -3dB		0.001		%
Channel Separation	$CH_{sep}$	$V_o = 0dBm, R_g = 10k\Omega$		75		dB
Supply Voltage Ripple Rejection	SVRR	$R_g = 0, f_r = 100Hz, V_{ccr} = 0dBm$		70		dB
Output Noise	$V_{NO}$	$R_g = 0, A \text{ weighted}$		50	100	$\mu V_{rms}$

Table 2: Electrical Characteristics Mode 2,  $T_a = 25^\circ C$ ,  $V_d, V_s = \pm 50V$ ,  $R_L = 8 \text{ ohm}$ ,  $f = 1kHz$

## Pin descriptions

LA4930		
Pin	Pin name	Description
1	Vd_check	This is a high impedance input for monitoring the positive power stage voltage. This monitoring controls the soft clipping circuit and the over and under voltage shut down.
2	Vs_check	Same as above for the negative rail.
3	Discharge	This high impedance output generates a current in case of over voltage condition on the power stage voltages ( $V_s/V_d$ ). This current is designed to turn-on a set of discharge transistors.
4	OC_mon	For monitoring the state of the control loop and the average voltage across the zobel resistor, this open collector output will turn on in case of of-limit conditions.
5	Enable	Bi-directional input/output. Input is including hysteresis for glitch free enabling of the system.
6	Thermal	Open collector output for over temperature warning.
7	FB_coil2	Feedback pin for global loop of channel 2.
8	CompA2	Pin for connection of loop shaping components of channel 2.
9	CompB2	Pin for connection of loop shaping components of channel 2.
10	CompC2	Pin for connection of loop shaping components of channel 2.
11	FBpwm2	Feedback pin for inner loop of channel 2.
12	Pwm-_ch2	The first of two balanced high impedance current comparator output. This output is connected via level shift transistors to the driver.
13	Pwm+_ch2	The second of the balanced high impedance current comparator output. When both of these outputs are low (Pwm-_ch2 and Pwm+_ch2) the driver will regard this as a disable. This is the way the disable is communicated to the driver.
14	NC	No connection

15	Zobel2	For estimating the power dissipation in the zobel resistor this input is sensing the zobel voltage via a resistive network. Channel 2.
16	Average2	For the averaging function in ch 2 of the OC monitor a capacitor is connected to this pin.
17	Average1	For the averaging function in ch 1 of the OC monitor a capacitor is connected to this pin.
18	NTC_in	Comparator input for connection of an NTC resistor. When detection a hysteresis current of 100uA is sourced via this pin.
19	Zobel1	Same as pin 15
20	NC	No connection
21	Pwm-_ch1	The first of two balanced high impedance current comparator output. This output is connected via level shift transistors to the driver.
22	Pwm+_ch1	The second of the balanced high impedance current comparator output. When both of these outputs are low (Pwm-_ch1 and Pwm+_ch1) the driver will regard this as a disable. This is the way the disable is communicated to the driver.
23	FBpwm1	Feedback pin for global loop of channel 1
24	CompC1	Pin for connection of loop shaping components of channel 1
25	CompB1	Pin for connection of loop shaping components of channel 1
26	CompA1	Pin for connection of loop shaping components of channel 1
27	FB_coil1	Feedback pin for inner loop of channel 1
28	NC	No connection
29	Vdd	Positive supply pin
30	UVP_en	Enabling of the Under Voltage Protection by connecting to Vdd and disabling by connecting to Vss.
31	Gnd	General ground for protection and all miscellaneous circuits.
32	Vss	Negative supply
33	Gnd_ch1	Audio ground for signal path of channel 1
34	CS1_ch1	Pin for connection of capacitor for the dc servo. This pin is the output of the internal dc servo amplifier.
35	CS2_ch1	Pin for connection of capacitor for the dc servo. This pin is virtual ground.
36	RecOut_ch1	This pin is the ch1 receiver output after an internal series resistor of 1k. By connecting a capacitor to ground a low pass function is obtained. From this pin the signal is internally passed on to the output stage.
37	Vin__ch1-	High impedance audio input. <b>This input is inverting.</b>
38	Agnd_ch1	Input reference for channel 1. This is true non-inverting low impedance (2kohm) input for avoiding ground loop noise.
39	Vin_ch2+	High impedance audio input. <b>This input is non-inverting.</b>
40	Agnd_ch2	Input reference for channel 2. This is true inverting low impedance (1kohm) input for avoiding ground loop noise.
41	RecOut_ch2	This pin is the ch2 receiver output after an internal series resistor of 1k. By connecting a capacitor to ground a low pass function is obtained. From this pin the signal is internally passed on to the output stage.
42	CS1_ch2	Pin for connection of capacitor for the dc servo. This pin is the output of the internal dc servo amplifier.
43	CS2_ch2	Pin for connection of capacitor for the dc servo. This pin is virtual ground.
44	Gnd_ch2	Audio ground for signal path of channel 2

LV4970		
Pin	Pin name	description
1	Sense1_H	This High-Z pin sources 200uA for the use of the over current sensing.
2	Sense2_H	This High-Z pin sinks 100uA. This ensures that the current is equal in the to sense diodes.
3	NC	No Connection
4	NC	No Connection
5	Pwm+	Low-Z non-inverting current input
6	Pwm-	Low-Z inverting current input
7	SS_en	Safe start enabling input.
8	Blanking	Blanking delay is controlled with this pin by connecting a resistor to ground. Shorting the pin to ground the shortest blanking delay is achieved, while leaving the pin open will provide the maximum.
9	Vs	Negative supply voltage
10	L_drive	Driver output for low side power mosfet.
11	V_drive	Positive supply voltage
12	Sense2_L	This High-Z pin sources 200uA for the use of the over current sensing.
13	Sense1_L	This High-Z pin sinks 100uA. This ensures that the current is equal in the to sense diodes.
14	High_Re	Reference pin for the floating high side driver. This pin is connected to the half bridge output.
15	H_Drive	High side driver output.
16	Vboot	Bootstrap voltage. Floating supply voltage pin for highside driver.

## Equivalent circuit block diagram

### System

Figure 1 shows the basic configuration of the chipset realizing a two channel single ended stereo amplifier.

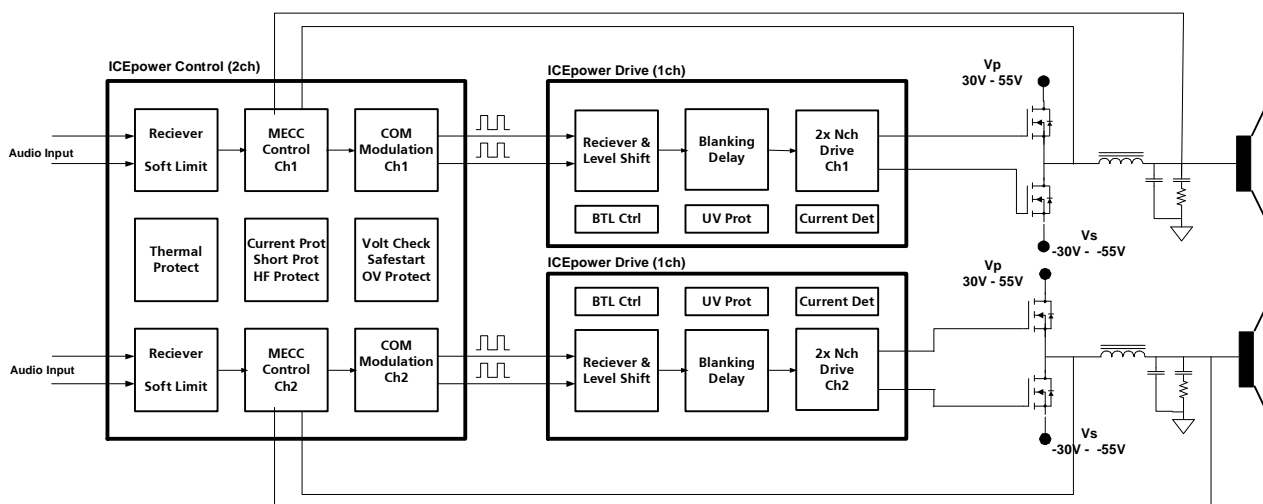


Figure 1 Simplified system diagram

## LA4930 (Control)

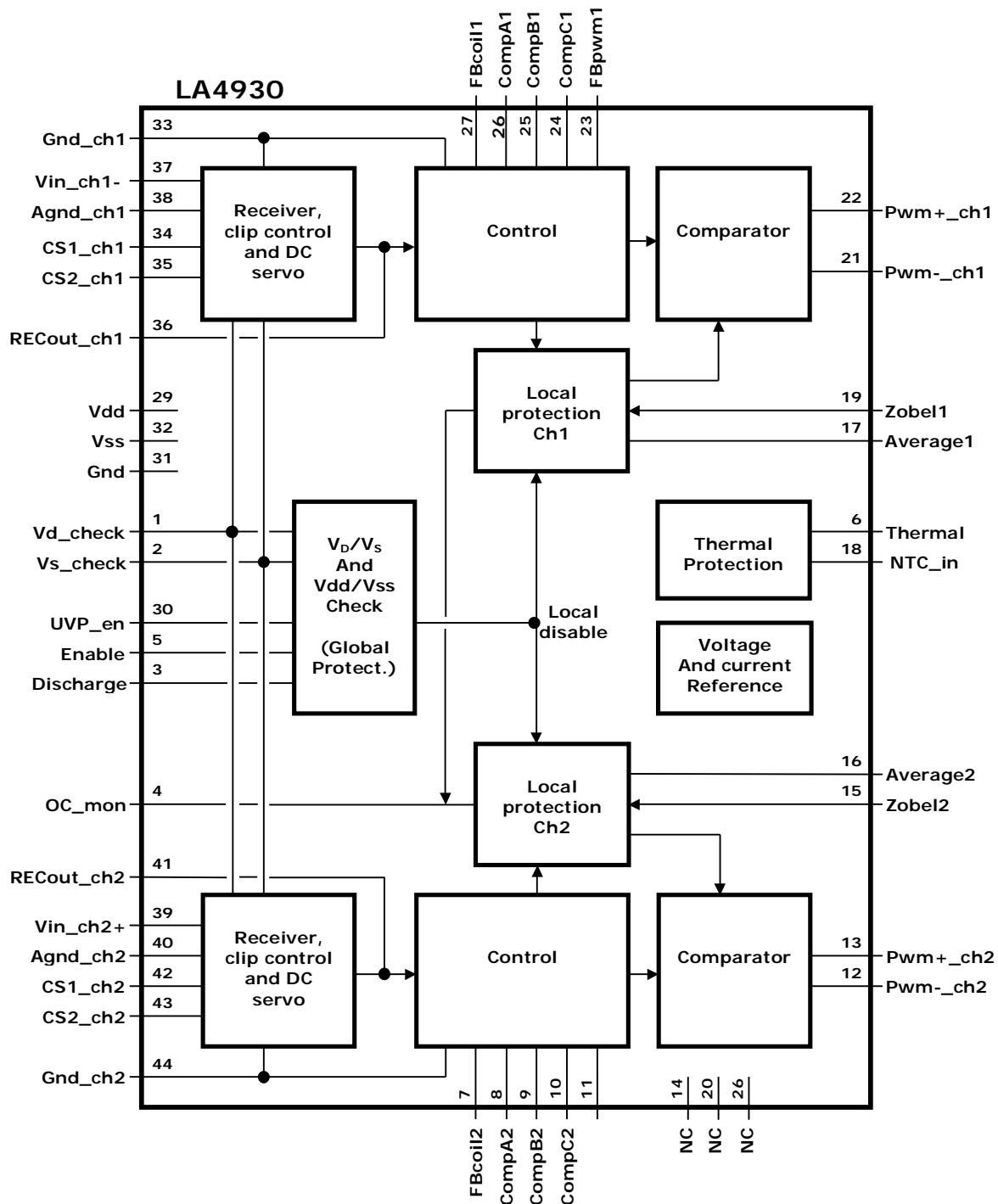


Figure 2 Block diagram of the LA4930 control chip

Block diagram of the LA4930 is shown in Figure 2. Therol chip consist of fundamentally of receiver sections control or feedback section, comparator and local and global protection.

### *Receiver*

The receiver is a versatile input engine with a broad range of features.

- The receiver has a high impedance input terminal for applying single ended signal, it also have a low impedance reversed input terminal for rejecting ground noise. For obtaining good channel separation the ground connections for the analog circuits of each channel has been pinned out separately.
- The receiver has a soft clipping circuit that performs a controlled clipping according to the voltage applied to the output stage. The clipping level will always be  $V_d \cdot 0.875$  for the positive waves and equally  $V_s \cdot 0.875$  for the negative waves. This feature secures that the control system is never saturated during normal operation and eliminates clipping with recovery time, which produce a very harsh clipping sound. The clipping circuit has a soft clipping characteristics producing is very pleasant clipping sound.
- For the recommended schematics the input clip level is always 1.86Vp no matter what voltage applied to the output stage. The design procedure of the control system will result in a gain, which always provides the standard clip level.
- A dc servo is built in the receiver to secure low pop noise during start-up.
- Lowpass filtering.
- Channel inversion for better use of buffer capacitors in power supply.

### *Control*

In this block all feedback circuitry is gathered.

- Feedback before and after filter. This means less coil requirements and better frequency response.
- Flexible loop control for various properties set by external components.
- Easy to use table recommendations available in application note.

### *Comparator*

This is where the analog signals enter the PWM domain and following features are included.

- Fast low power comparator.
- Differential output for fast and noiseless level shift without excessive power dissipation in the level shift.
- Enable signal coded into the 2 outputs.

### *Protection*

It is here beneficial to distinguish between the local protection features and the global protection features. Local protection refers to a protection feature, which are measuring and acting on the same channel only. Where as the global protection measures on shared items and act globally via the enable bus.

The local protection (zobel protection and OC detection) consists of:

- Zobel protection to protect against excessive power dissipation in the zobel resistor.
- Saturation detection referred to as OC protection.
- DC protection on output.

When a local protection feature is acting the OC monitor bus is pulled down. Both channels share the same bus and are connected internally by open collectors. The channel is shut down by disabling the comparator output.

The Global protection features:

- Under/over voltage of the power stage ( $V_d/V_s$ )
- Under voltage of the control supply voltage ( $V_{dd}/V_{ss}$ )

The global protection act directly on the enable bus and the enable bus state is forwarded by the global protection to the local protection blocks. The local protection are now shut down the amplifier.

In the case of multi channel systems, sharing the same enable bus all chipset are shutdown.



## Thermal protection

Finally a thermal warning function is included. This function basically works independently and is connected via an open collector to the thermal bus. This function is a simple over temperature indication including hysteresis, which can be adjusted by external components.

## LV4970

This chip is a driver for the driving the power mosfet output stage. The driver is a half bridge driver including Blanking delay, over current detection and a balanced current input for interfacing via level shift transistors to the LA4930 control chip.

Together with the output stage we have the intelligent power cell, which features a full protection scheme with a minimum of external components.

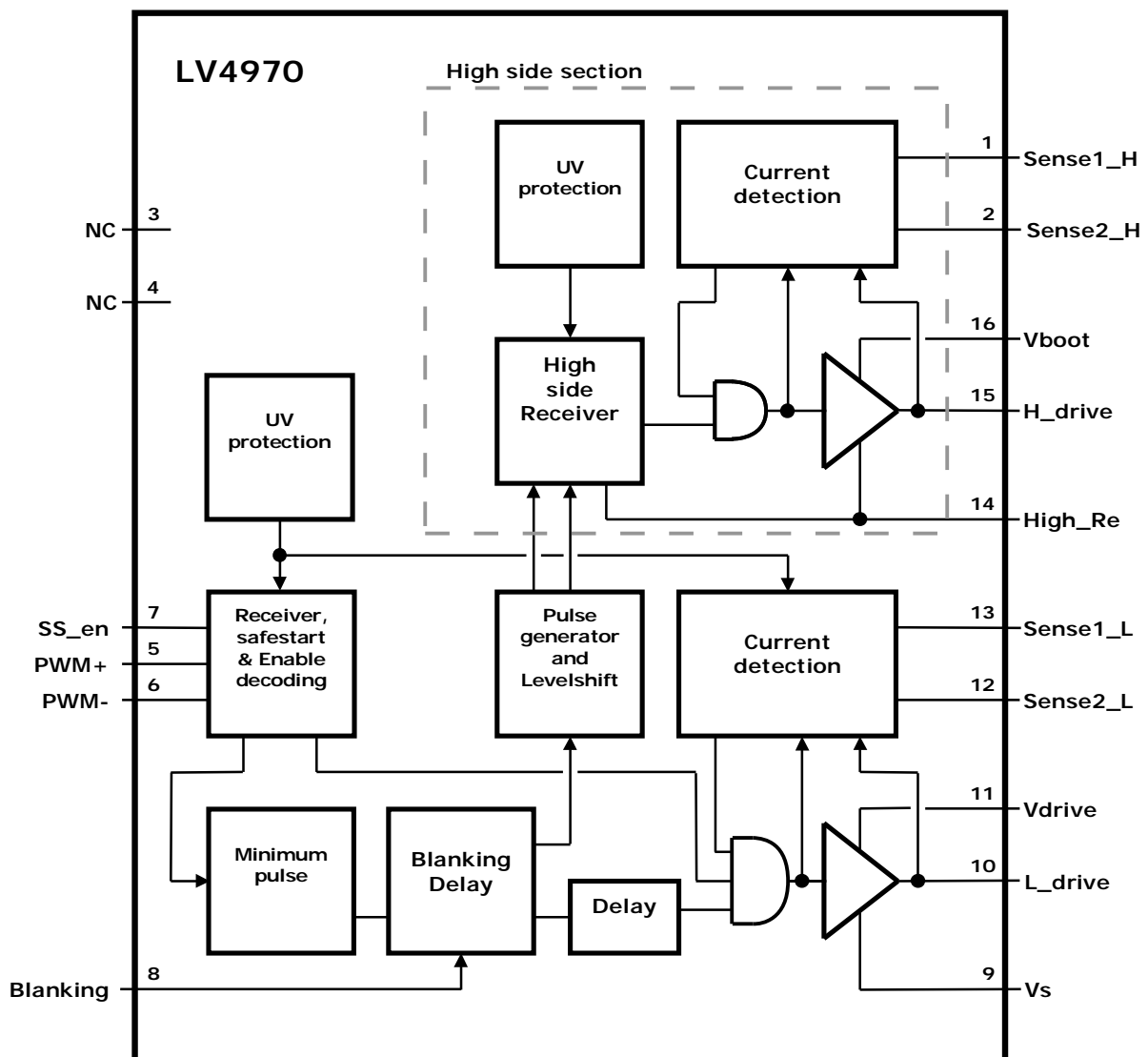


Figure 3 Block diagram of the LV4970 driver

## Receiver

The input signals are fed to the receiver as balanced current pulses via pins PWM- and PWM+. The receiver has also a logical input to enable the safe start feature. This will ensure that the low side power mosfet is always on

for 2 $\mu$ s after power-up or after enabling. With this feature enabled, the bootstrap capacitor will always be charged in a controlled way during start-up. The receiver outputs the PWM as a normal voltage mode logic PWM signal together with the decoded enable signal.

#### ***Minimum pulse***

The PWM signal now reaches the minimum pulse circuit, which ensures that the minimum pulse length will not exceed 200ns typically. If a pulse occurs with less duration than 200ns, the pulse will be prolonged to 200ns.

#### ***Blanking delay***

Next is the blanking delay which provides the blanking delay to prevent shoot-through currents in the output stage, here the PWM signal is split into a high-side signal and a low-side signal. The low-side PWM signal is now delayed in order to match the delay in the high-side in low-side. Finally the low-side PWM signal is AND'ed with the protection signals and then connected to the output driver.

#### ***Pulse generator and level shift***

From the blanking delay block the high-side PWM signal is converted into a set and reset pulse and level shifted to the high-side section of the die.

#### ***High side receiver***

The high-side receiver features a patented low impedance input circuitry with common mode rejection for fast, reliable and efficient level shift. The high-side driver also contains an under-voltage protection. The high-side PWM signal is now AND'ed with the Over Current detection and connected to the High-side driver.

#### ***The OC protection***

The over-current detection circuit is basically the same in the high-side and low-side and it works by measuring the voltage across the MOSFETs during the on-time. The timing for detecting the on-time is done by evaluating the signals before and after the driver stage. In case of detection the driver is shutdown for 1.25 $\mu$ s causing the amplifier to enter a current mode oscillation, where the output stage will act as a current generator while the control system is trying to force an output current larger than the limit. In effect the output current will be limited in the same way as most conventional class-AB output stages but here we are still operating in class-D with high efficiency.

Even though the current limitation mode is class-D the power dissipation in the output stage is relatively high (typ. 4-8W) and therefore a time limit is built in before shutdown. The current limitation mode is determined in the control chip by detecting saturation of the control system. This condition will typically be allowed in 100ms to 500ms enough for avoiding shutdown during peak currents during high music output power.

#### ***Output drive***

The output stage is designed to drive the MOSFETs with a  $Q_g$  less than 40nC directly. The 40nC case will lead to a power dissipation of approximately 350mW in the driver package.







The typical application schematic is described in details in application note: [Anxxx](#) This application notes contains detailed description of the customer breadboards which in standard versions are available in three different voltages: +/-33, +/-40 and +/-56Volt.

## Interfacing with the chipset

### Diagnostics

Three busses offer monitoring/control of the status of the amplifier. The busses are open collector type and must be pulled up by a resistor of 10K to Vdd. The busses are:

- Enable bus –enabled when high
- OC monitor –low when overload
- Thermal monitor –low when to high temp.

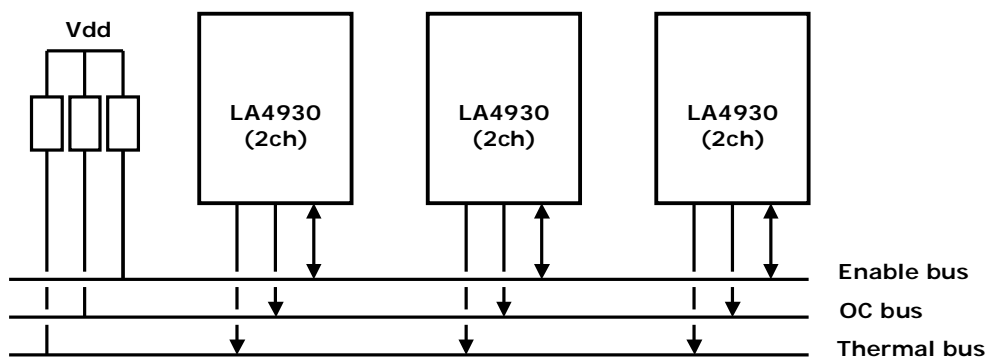


Figure 5 Multichannel bus structure

Common for all busses are that both channels share the same bus. Regarding the thermal monitor this means that there is only one circuit for thermal detection for both channels. In case of multi channel systems the up to 5 chipset can share the 3 busses by simply connecting all the monitor pins to the busses as seen in Figure 5. The pull-up resistor should remain 10k in this case. It is of course also possible to split up the monitor pins if more selective monitoring is required.

The enable bus is a bi-directional bus for externally shutting down the amplifiers. On the other hand the LA4930M can also pull down the bus internally. In case of voltage protection unit detects wrong power supply, it will pull down the bus internally. This will ensure that all amplifiers will shut down the same time in case of supply failure; this only goes for the situations where the enable bus is shared.

The monitor inputs of the LA4930 are CMOS compatible inputs and outputs. The following table shows the thresholds.

	Low threshold Typical	High thresh. Typical	Hysteresis Typical	V <sub>OUT</sub> Low max.	V <sub>OUT</sub> High Typical.	
	V <sub>T-</sub>	V <sub>T+</sub>	V <sub>HYS,typ</sub>	V <sub>OL,max</sub>	V <sub>OH,typ</sub>	
Enable	2.18	2.76	0.6	0.2	Vdd	[V]
OC	-	-	-	0.2	Vdd	[V]
Thermal	-	-	-	0.2	Vdd	[V]

The detailed detection conditions of the monitor pins are described in the protection section.

### Audio Input

In Figure 6 the input circuitry is shown. For each channel there are 3 input terminals the Vin signals which are the main high impedance inputs, the Agnd inputs that can be seen as a ground sense or a low impedance balancing input and finally the true ground references (Ref\_chx).

The channel inversion is made in these input stages

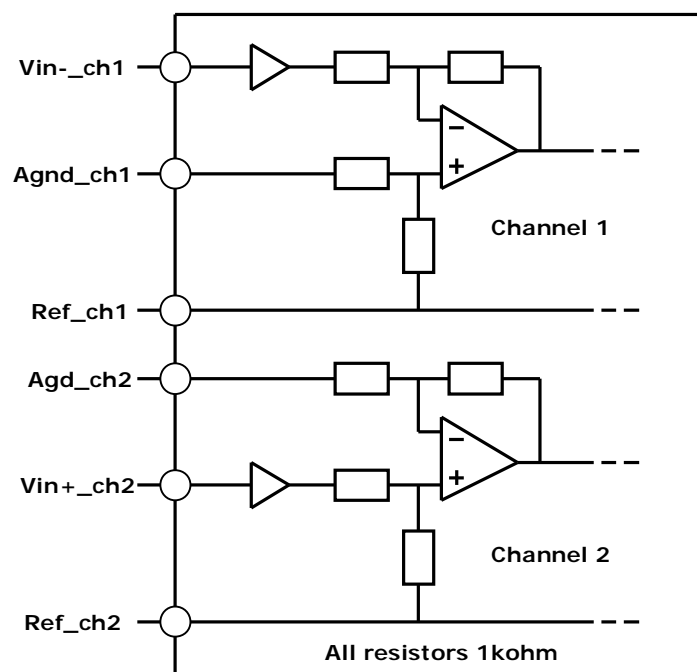


Figure 6 input interfaces

This configuration allows for protecting the audio signal against ground loops and thereby hum and crosstalk can be reduced. The recommended way of inter connection is shown in Figure 7.

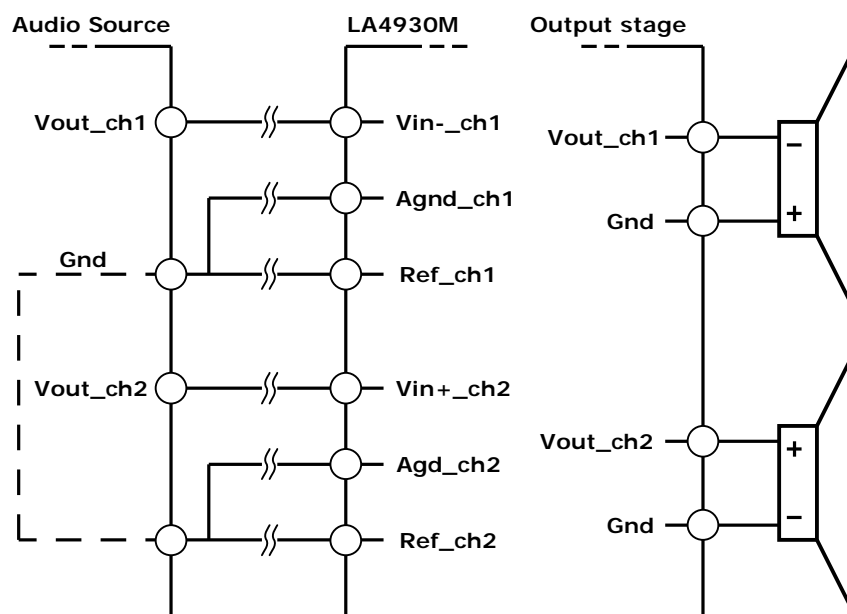


Figure 7 Input/output connections

As seen in **Figure 6** the channel inversion is carried out here by inserting the signal on the opposite input of the internal differential amplifier. It is important to remember that channel 1 is inverting and channel 2 is non inverting.

## Audio Output

To maintain zero phase through the system the speaker wires of channel 1 must be reversed at the speaker terminals as shown in Figure 7.

Because of the channel inversion bridging is easily obtained, simply connect as illustrated in Figure 8.

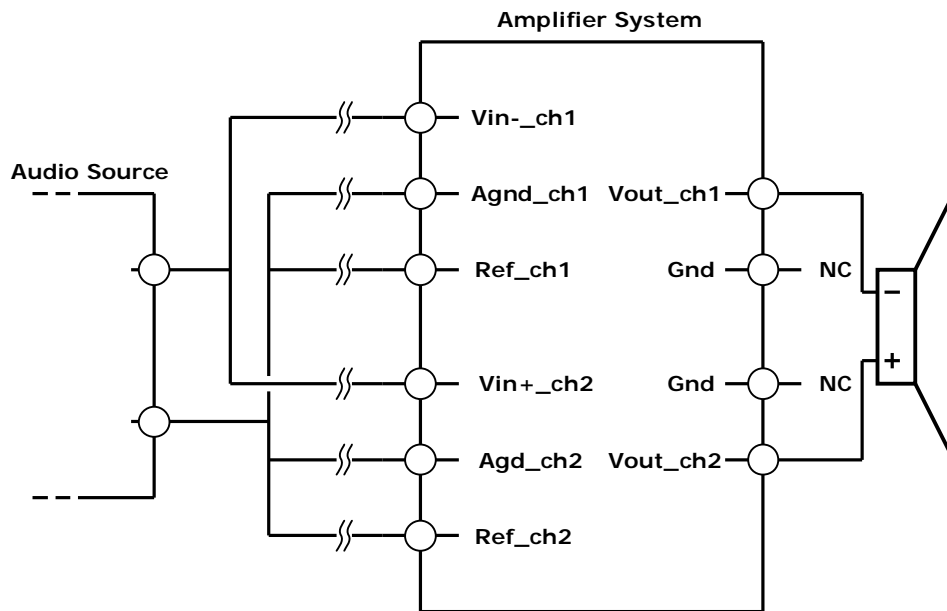


Figure 8 Bridging

## Protection

The chipset is developed to form a simple inexpensive stand-alone amplifier system with only a few external components required yet including a full protection scheme.

Together the chipset offer following protection items:

- Analog type current limitation
- Thermal indication
- Clipping control
- Zobel protection
- Saturation protection
- Supply voltage protection

In the following a 40V customer breadboard has been used for measurements and explanations.

### Analog type current limitation

The driver has a unique feature that measure the voltage drop across each mosfet during the ON-state. This circuit is an integrated part of the high side and low side drive of the driver chip and work completely independent. Internally in the driver, references of 1.4 volt are compared to the voltage drop across the mosfets via the diode networks. The 2 diodes (Dsense) are provided with a matched bias of 100uA each, for canceling out the forward drop voltages. For adjusting the threshold of detection, resistors are inserted to add a voltage offset to the detected voltage. This means that if 10k are inserted a voltage drop of 1V is obtained and the resulting threshold is reduced from 1.4V to 0.4V. The current is calculated using the voltages and the Ron of the used power mosfet.

In case of detection the mosfet is turned off and it is kept turned of for approx. 1.25uS. This means that in case of overload, the amplifier enters a new current mode self-oscillating state. In Figure 9 a situation of current



limitation is shown. The amplifier is loaded with 1 ohm and a single cycle of 5kHz is applied and when the voltage reaches 15V corresponding to 15A, the amplifier enters the current limitation state. The switching frequency of the current limitation state is about 300kHz at this output voltage.



Figure 9 5Khz into 1 ohm load

This unique feature provides a continuous transition between normal voltage mode and current mode like the behavior of an analog system.

When the amplifier enters the current mode the voltage mode control loop is overruled and the control chip will saturate **but not shutdown**. Figure 10 illustrates this by applying first a 10Vp cycle where there is no current limitation and then a cycle including current limitation. The other trace is the virtual ground pin of the modulator amp.



Figure 10 Shot of saturation of control sys.

It can be seen on virtual ground trace that it clearly saturates when the amplifier enters current limitation. This is an important point because detecting saturation in this way is actually used internally in the chip as a mean of detecting over current and other overload situations.

It is very important to realize that there is no direct communication between the driver and control chip in the case of the amplifier entering current limitation. When the control chip is detecting the current limitation situation, it is solely detected from saturation of the loop.

There is build in a time limit of the over current situation, which is described in the saturation protection section.

## Thermal indication

With this class-D amplifier system efficiencies of up to 96% can be reached this means that very powerful amplifiers of 2X150W amplifiers can be realized using only PCB cooling. In normal condition the thermal detection will not act if the mechanical system is well designed, even with an output of 2x150W clipped music. Since the thermal indication is not expected during normal situations the thermal detection is a simple over temperature detection.

Even though the efficiency is very high there are situations where the temperature can exceed maximum.

The worst situation is a wrong loading of 1-3 ohm with full voltage swing. In this case the current limitation will only act for short periods and the time limit for current limitation may not be reached. This means that the output stage will dissipate a considerable amount of power and will eventually overheat and the thermal detection will act. In the case of short circuit (0.6 ohm) the current detection will limit the current in most of the time when applied a music signal. The time out of the current limitation will be reached fast and the amplifier will be shut down.

The thermal characteristics of course depend of the mechanical system and it is recommended to read the application note of the costumer breadboard where information on thermal design of PCB is written.



Figure 11 NTC voltage and thermal bus

The detection voltage is -2.5V and a hysteresis current of 100uA sinked when exceeding (more negative) this point. By adequate NTC and resistor values the performance can be set for the application.

## Clipping Control

A part from great benefit for sound quality the clipping control is also a part of the protection scheme in two ways:

First it protects the system from saturated clipping and resulting recovery effects. This ensures that no matter the input signal the amplifier will always work in linear mode and never enter saturation when working in normal condition. This is a very important point for the saturation protection, which is explained later.

Secondly it prevents the switching frequency to drop below approx. 100kHz because the modulation index is limited to 0.875. This protect against miss behavior of the zobel protection.

Figure 12 illustrates the clipping behavior in this case the clipping level is 35V ( $40V \cdot 0.875$ ).

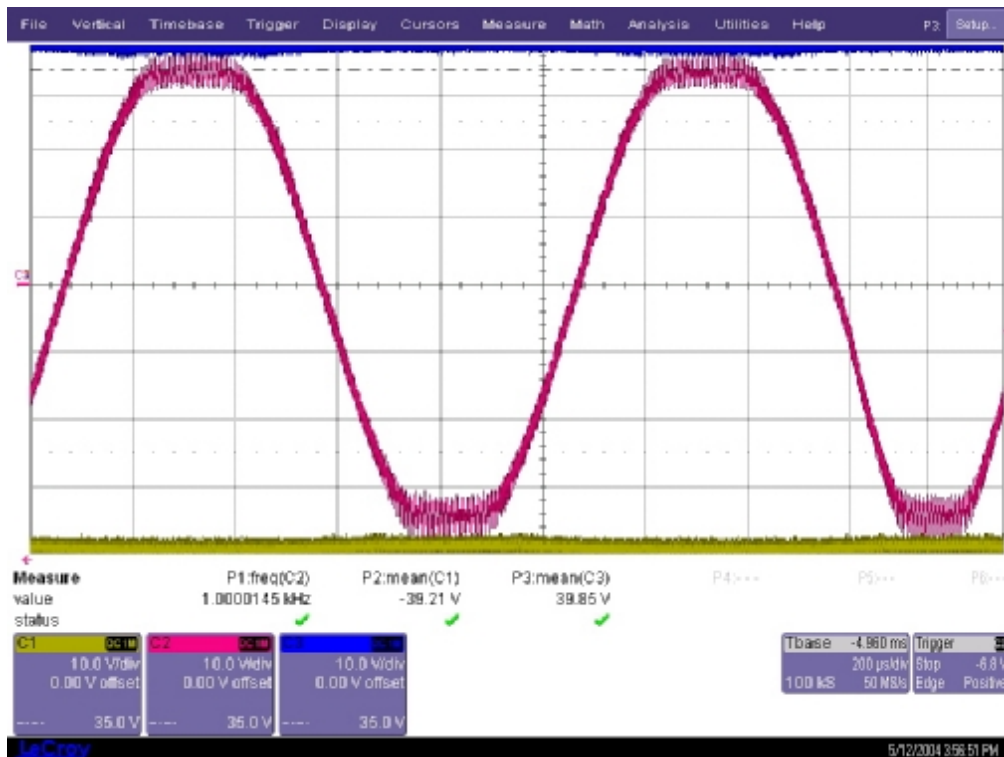


Figure 12 Clipping at 1kHz 80W/8ohm

For setting the clipping levels the control chip must sense the supply voltage for the output stage ( $V_d/V_s$ ) this is done via a resistive voltage divider. This voltage divider is shared with the voltage check in order to safe external components.

Normally the clipping limits are set to  $\pm 1.86V_p$  in the receiver of the control chip. The gain of the power stage is then set according the supply voltage to achieve a clipping limit of 0.875 of the supply voltage. Clipping control of the input signal is carried out by comparing the voltage divider output (pin  $V_d\_check$  and  $V_s\_check$ ) with the input signal and the output of the receiver is not allowed to exceed these voltages numerical.

## Saturation protection

This protection feature is detecting if the amplifier is in normal mode by detecting the voltage across the inputs of the modulator opamp. Under normal operation the measuring point is virtual ground but if the output stage enters current limitation or some element in the loop fails, the loop will saturate and the virtual ground can no longer be maintained. The detection of the saturation is integrated using the  $C_{AVE}$  in order to secure that only a high amount of detections over time can lead to shutdown. The size of the capacitor determines the over-current time limit before shutdown and the parallel resistor sets the time before restart. The voltage across the Average capacitors are compared to a reference voltage of -2.5V and when the voltage becomes more negative than this reference the channel is shutdown and the OC bus is pulled low. As shown in Figure 13 the channel is restarted again when the average voltage has reached -1V.

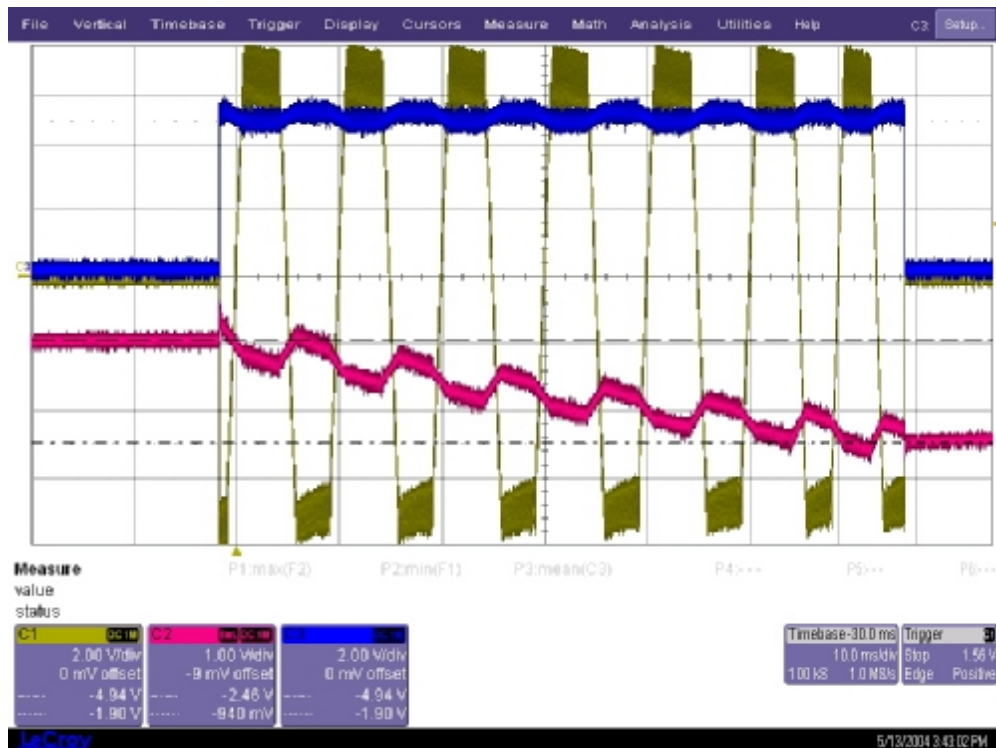


Figure 13 Picture 100Hz into 0.5 ohm

Because the far most common cause of detection is short circuit of the output, this detection output has been named Over Current. But this bus is also used by the zobel protection as explained later. This I done for minimizing the external components and pin count.

Additionally this protection provides good safety because nearly all critically components are included in the loop and component failure will lead to shut down.

## Zobel protection

This protection feature is sharing the integrator formed by the  $C_{AVE}$  capacitors and therefore also causes the voltage to increase across the  $C_{AVE}$  when a large voltage is detected over the zobel resistor. Because of the sharing of one integrator and comparator the time constants for the attack time of the zobel protection OC time limit are tied together. This time constant should reflect the thermal time constants of the mechanical system typically 100ms – 1000ms.

It is important to understand that the zobel protection is an optional feature for saving cost on the zobel resistor. It is possible to use very small power ratings of the zobel (<1W) even for a 150W amplifier if the zobel protection is setup correctly. It is not possible in this configuration to output full output power at 20kHz but all kinds of music can be played even at hard clipping without the zobel detection is shutting down.

In applications where full output power at high frequency is required the zobel detection network  $R_{ZSENSE1}$  and  $R_{ZSENSE2}$  can simply be removed and the input left open. Now the zobel is not operating and the zobel resistor must then be adequate sized for the application.

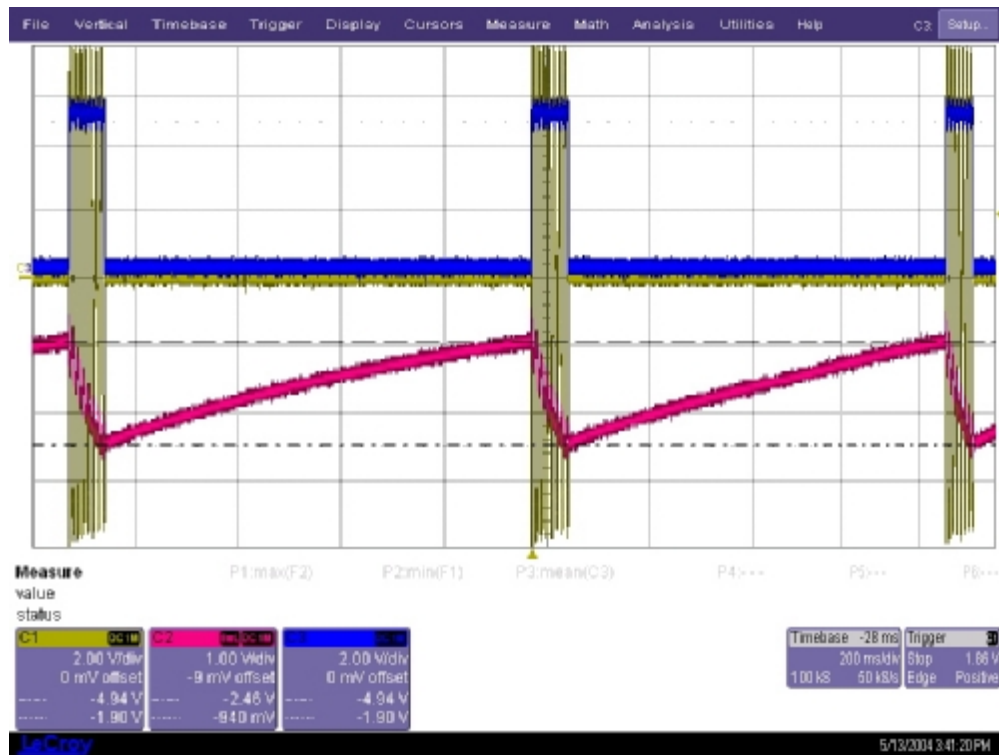


Figure 14 Picture of 75W/20kHz hike up

As Figure 14 shows how the zobel protection response to full output power 75W/20kHz signal. As seen this condition is allowed for approximately 100msec and the amplifier enters the hike up mode. Below 20W/20kHz the zobel protection will not shutdown.

## Supply voltage protection

In the control chip there is build in under/over voltage detection of the power stage supplies (Vd/Vs) and also a under voltage lockout of the Control supply voltages (Vdd/Vss).

The over voltage protection is mainly to protect against supply pumping. A short explanation of supply pumping in a single ended class-d power stage:

Considering a class-b output stage powered by  $\pm 20\text{V}$  and the output voltage is  $10\text{ V}_{\text{DC}}$  into a  $10\text{ ohm}$  load. The output current is now  $1\text{A}$  and the power dissipation in the amplifier and load is then  $10\text{W}$  each. In the class-b situation the current in the negative supply is zero and the power dissipation is caused by having voltage and current present at the same time.

Now if we have a class-d power stage including output filter the output current would be still be  $1\text{A}$  but the high side current would be  $0.75\text{ A}_{\text{RMS}}$  because the voltage swing requires a modulation index of  $0.75$ . Since the class-d theoretically has an efficiency of  $100\%$ , the output stage must pump energy back in the negative supply to preserve the energy. The current pumped back is  $0.25\text{ A}_{\text{RMS}}$  and for a negative output current the pumping will occur at the positive supply.

Since most power supplies are not uni-directional the pumping result in voltage peaks on the supplies especially at low frequencies. This is shown in Figure 15. Where the supply rails is jumping from  $\pm 40\text{V}$  up to approx.  $\pm 48\text{V}$ . The maximum pumping occurs when the output voltage is half of the rail voltage so therefore the maximum pumping is not seen at full output swing but when the average of the waveform is half the rail voltage.

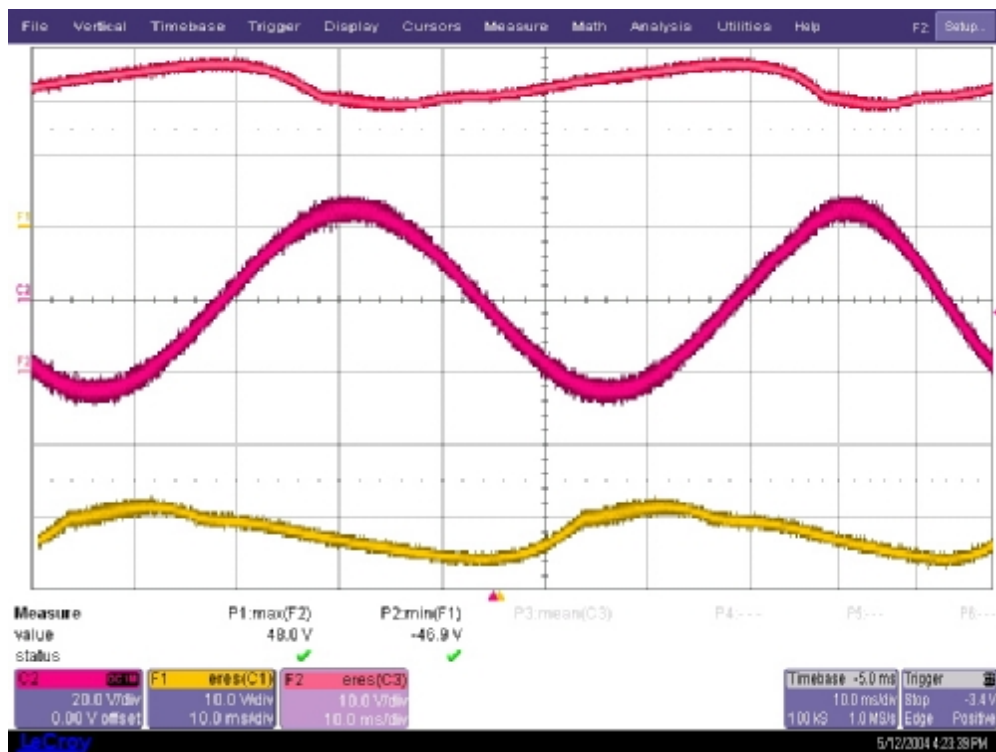


Figure 15 Supply pump at  $20\text{Hz}/30\text{W}/8\text{ ohm}$

The normal way of dealing with this problem is to add sufficient capacitance in the power supply. As rule of thumb it takes  $2 \times 1000\mu\text{F}$  to output  $100\text{W}$  in  $8\text{ ohm}$  when the amplifier is supplied with  $\pm 50\text{V}$ . The supply pumping will be less than  $25\%$  in this case for a  $20\text{Hz}$  sine.

The over voltage threshold in the standard recommendations is set to be  $135\%$  of the nominal supply voltage. In the case of detection the amplifier is shut down and a discharge feature activates. This feature enables a discharge sequence of the supply capacitors. This prevents a very long shutdown time because in the case amplifier shutdown the current draw on Vd/Vs is close to zero and the overcharged capacitors may not have a discharge path.

The under voltage protection of the Vd/Vs is an optional feature to secure a controlled start up, which can be disabled by connecting UVP\_EN to Vss.

In applications where this feature is disabled it is important to consider that the driver and level shift needs minimum Vs voltage of -9V to operate correctly.

The supply voltages are sensed through a voltage divider and compared to a set of fixed internal voltage references and the resulting thresholds can be calculated as:

$$V_{UV,disable} = \frac{R_{VCHK1} + R_{VCHK2}}{R_{VCHK2}} \cdot \frac{V_{REF}}{2}$$

$$V_{UV,enable} = \frac{R_{VCHK1} + R_{VCHK2}}{R_{VCHK2}} \cdot \left( \frac{V_{REF}}{2} + 0.3 \right)$$

$$V_{OV,disable} = \frac{R_{VCHK1} + R_{VCHK2}}{R_{VCHK2}} \cdot V_{REF}$$

$$V_{OV,enable} = \frac{R_{VCHK1} + R_{VCHK2}}{R_{VCHK2}} \cdot (V_{REF} - 0.18)$$

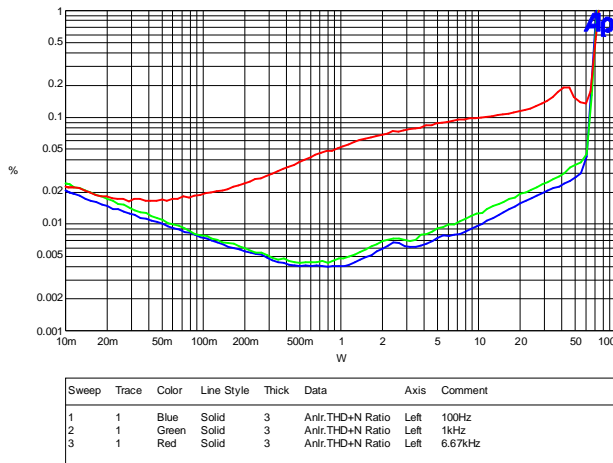
An important circumstance is that the clipping circuit shares the voltage divider network for analyzing the supply voltages in order to clip the input signal. This sharing ties the input clip level together with the voltage detection meaning that the input clip level cannot be freely set to any value.



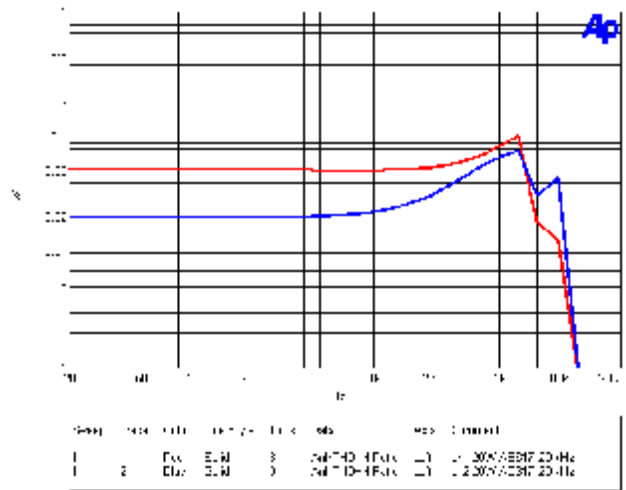
Figure 16 Over Voltage shut down with bus state

## Typical performance

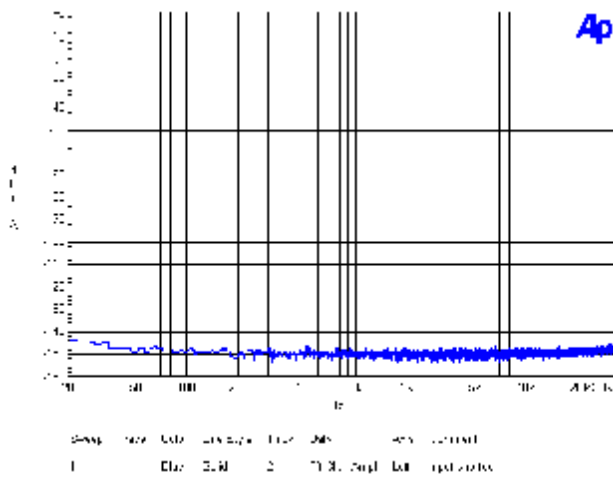
Following measurements have been carried out on the customer breadboard version 1.0.



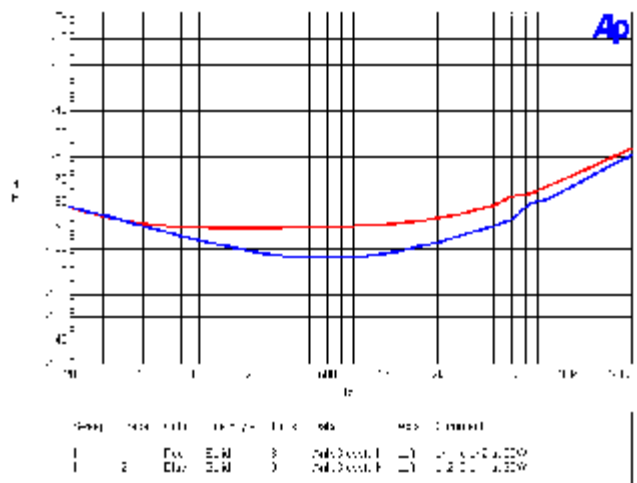
Graph 1 showing THD+N at different frequencies



Graph 2 showing THD+N versus frequency



Graph 3 Noise floor. 0dB refers to clip level.



Graph 4 crosstalk at 20W/8 ohm



Graph 5 Efficiency in 8 ohm

Graph 6

Graph 7

Graph 8

## Packages

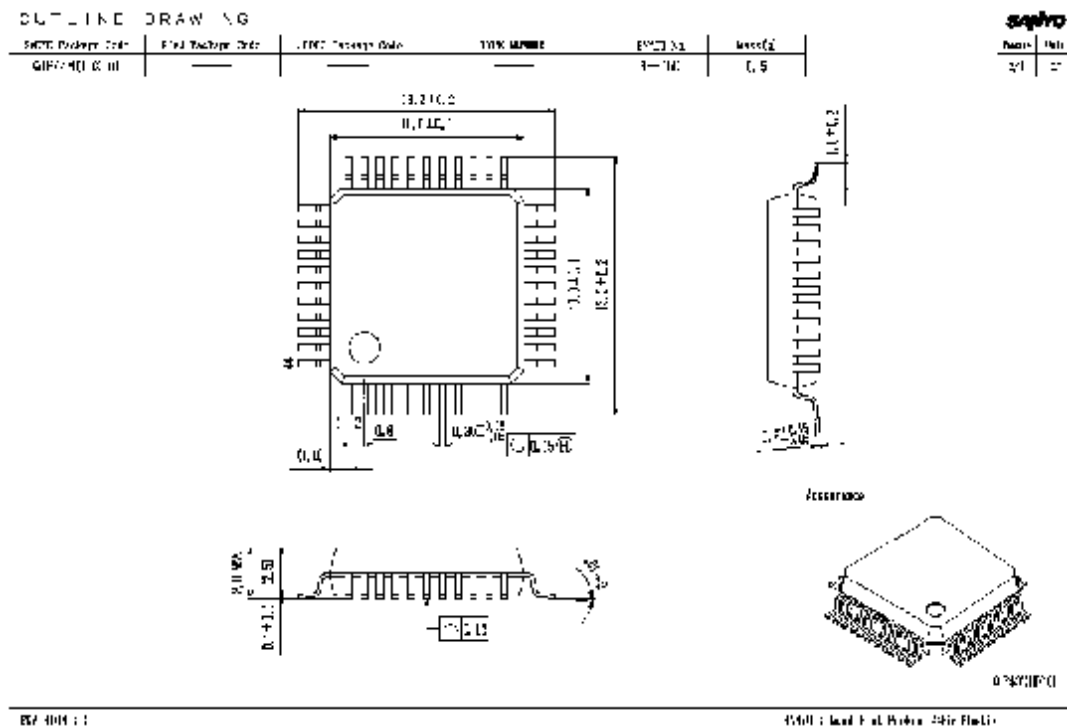


Figure 17: Outline Drawing, LA4930

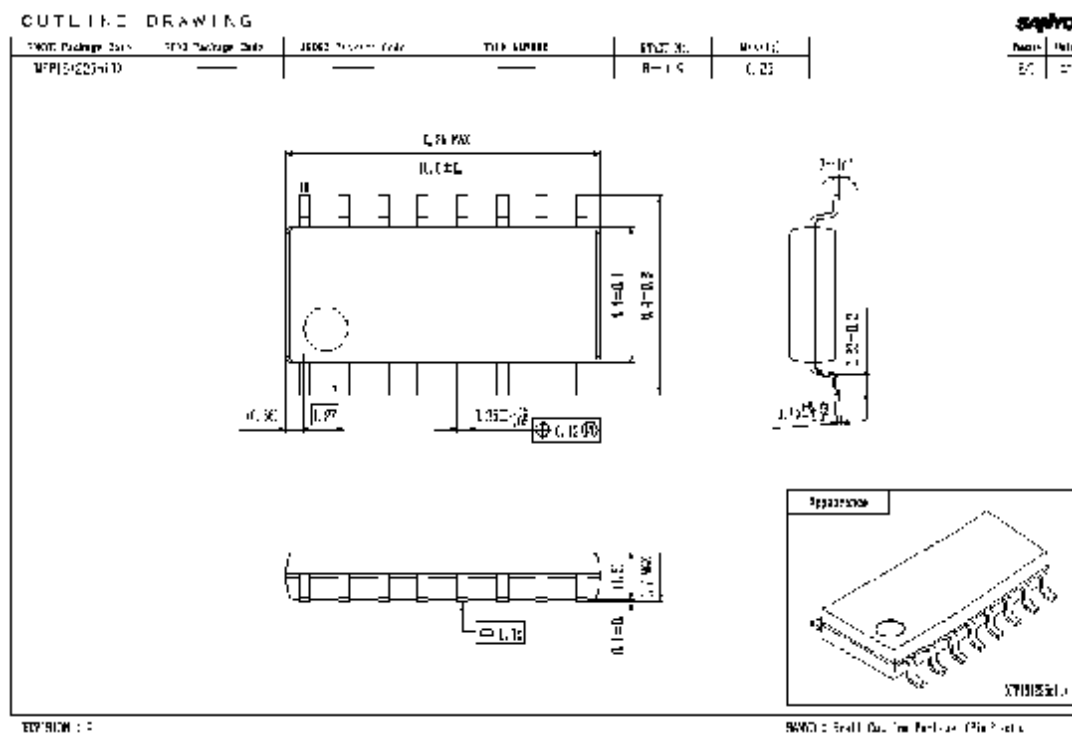


Figure 18 Outline Drawing, LV4970