LM4970 Audio Synchronized Color LED Driver



Literature Number: SNVS312C

LM4970 Boomer[®] Audio Power Amplifier Series Audio Synchronized Color LED Driver

General Description

The LM4970 is a LED driver with an audio synchronization mode that virtually eliminates the need for real time software processing for LED lighting effects. The LM4970 includes three individual PWM color LED drivers that provide up to 42mA of current drive for each PWM LED output.

The LM4970 features an audio synchronization mode where the audio input signal that is mixed in from three audio inputs is filtered into three frequency bands, with each frequency band assigned to a specific PWM LED driver.

The PWM LED drivers can also be directly programmed through an I²C compatible interface for applications where user defined LED pattern, color, and intensity programmability is a priority.

The LM4970 also features an audio input gain control which allows the user to increase the gain if the audio input signal does not create a bright enough effect on the LEDs. The LM4970 is a feature rich LED driver that is available in a space saving 14 pin non-pullback LLP package.

Key Specifications

LED Drive Current per channel $V_{DD} = 5V$

Shutdown Current, V_{DD} = 5V

42mA (2X setting)

1.5µA (typ)

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Features

- Audio synchronized color LED driver
- User defined LED pattern, color, and intensity capability
- Programmable: LED Drive current PWM frequency High pass filter frequency select Audio input signal gain
- Eliminates external LED current limiting resistors
- I²C compatible interface
- -Ultra low shutdown current

Applications

- Cell Phones
- Portable MP3, CD, DVD, AAC players
- PDA's





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Connection Diagram



Top View Order Number LM4970SD See NS Package Number SDA14A

Pin Connection

Pin	Name	Pin Description
1	FILT	Low Pass Filter Input
2	V _{DD}	Power Supply Pin
3	M _{IN}	Mono Audio Input
4	GND	Ground
5	L _{IN}	Left Audio Input
6	R _{IN}	Right Audio Input
7	I ² CV _{DD}	I ² C Interface Power Supply
8	SDA	I ² C Data
9	SCL	I ² C Clock
10	ADR	I ² C Address Select
11	LED3	LED output 3
12	LGND	LED ground
13	LED2	LED output 2
14	LED1	LED output 1

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Absolute Maximum Ratings (Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	6.0V
Storage Temperature	-65°C to +150°C
Input Voltage	-0.3V to V _{DD} +0.3V
Power Dissipation (Note 3)	Internally Limited
ESD Susceptibility (Note 4)	2000V
ESD Susceptibility (Note 5)	200V
ESD Susceptibility (Note 12)	100V
Junction Temperature	150°C

Thermal Resistance θ_{JA} (SDA14A) θ_{JC} (SDA14A)

57°C/W 12°C/W

Operating Ratings

Temperature Range

 $T_{MIN} \le T_A \le T_{MAX}$ Supply Voltage $-40^{\circ}C \leq T_A \leq +85^{\circ}C$

 $2.7V \le V_{DD} \le 5.5V$ (Note 13) $2.5V \le I^2 CV_{DD} \le 5.5V$

Control Interface Electrical Characteristics (Notes 1, 2)

The following specifications apply for $3V \le V_{DD} \le 5V$ unless otherwise specified. Limits apply for $T_A = 25^{\circ}C$.

Symbol	Parameter	Conditions	LN	LM4970	
			Typical	Limits	(Limits)
			(Note 6)	(Notes 7, 8)	
t ₁	SCL period			2.5	μs (min)
t ₂	SDA Setup Time			100	ns (min)
t ₃	SDA Stable Time			0	ns (min)
t ₄	Start Condition Time			100	ns (min)
t ₅	Stop Condition Time			100	ns (min)
V _{IH}	Digital Input High Voltage			0.7 x I ² CV _{DD}	V (min)
V _{IL}	Digital Input Low Voltage			0.3 x I ² CV _{DD}	V (max)

Color LED Driver Electrical Characteristics $V_{DD} = 5.0V$ (Notes 1, 2, 9)

The following specifications apply for $V_{DD} = 5.0V$ unless otherwise specified. Limits apply for $T_A = 25^{\circ}C$.

Symbol	Parameter	Conditions	LN	Units	
			Typical (Note 6)	Limits (Notes 7, 8)	(Limits)
I _{DDRGB}	Supply Curent		2.5	4	mA (max)
I _{SDRGB}	Shutdown Current	Shutdown Mode	1.5	3.5	μA (max)
	LED Drive Current	.66X current drive setting	14		mA
		1X current drive setting	21		mA
LED		1.33X current drive setting	30		mA
		2X current drive setting	42	23	mA (min)
f _{PWM}	PWM Frequency	PWM_F<1:0> = '01'	60		Hz
	Input Signal Lovel Cain Control	Maximum setting	12		dB
		Minimum setting	-11		dB

Color LED Driver Electrical Characteristics $V_{DD} = 3.0V$ (Notes 1, 2, 9)

The following specifications apply for $V_{DD} = 3.0V$ unless otherwise specified. Limits apply for $T_A = 25^{\circ}C$.

Symbol	Parameter	Conditions	LN	14970	Units
			Typical	Limits	(Limits)
			(Note 6)	(Notes 7, 8)	
I _{DDRGB}	Supply Curent		2.2	3	mA (max)
I _{SDRGB}	Shutdown Current	Shutdown Mode	0.5	2	μA (max)
	LED Drive Current	.66X current drive setting	12		mA
		1X current drive setting	18		mA
LED		1.33X current drive setting	27		mA
		2X current drive setting	35	21	mA (min)

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Symbol	bol Parameter	Parameter Conditions		M4970	Units
			Typical (Note 6)	Limits (Notes 7, 8)	(Limits)
f _{PWM}	PWM Frequency	PWM_F<1:0> = '01'	60		Hz
	Input Signal Level Gain Control	Maximum setting	12		dB
		Minimum setting	-11		dB
Note 1: Note 2: functiona which gu where no	All voltages are measured with respect to Absolute Maximum Ratings indicate limits al but do not guarantee specific performar juarantee specific performance limits. This o limit is given. however, the tvoical value	the GND pin unless otherwise specified. beyond which damage to the device may occur. Op ice limits. Electrical Characteristics state DC and AC assumes that the device is within the Operating Rat is a good indication of device performance.	perating Ratings indi Celectrical specifica tings. Specifications	cate conditions for w tions under particular are not guaranteed f	nich the device is test conditions or parameters

Note 3: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX} , θ_{JA} , and the ambient temperature, T_A . The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower.

Note 4: Human body model, 100pF discharged through a $1.5k\Omega$ resistor.

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Note 5: Machine Model, 200pF–220pF discharged through all pins, except pins 13 and 14.

Note 6: Typicals are measured at +25°C and represent the parametric norm.

Note 7: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Note 9: Shutdown current and supply current are measured in a normal room environment. All digital input pins are connected to I2CVDD.

Note 10: The given θ_{JA} is for an LM4970SD mounted on a PCB with a 2in² area of 1oz printed circuit board copper ground plane.

Note 11: Audio input level set at $1V_{RMS}$. The input summing amplifier gain is set to 12dB.

Note 12: Machine Model, 200pF–220pF discharge through pins 13 and 14 (LED1 and LED2).

Note 13: V_{DD} may be used to power the LEDs. It may be necessary to drive the LEDs from a boost ($V_{DDBOOST}$) found within the system.

External Components Description

Com	ponents	Functional Description
1.	C _i	This is the input coupling capacitor. It blocks the DC voltage and couples the input signal to the amplifier's input
		terminals. C_{IN} also creates a highpass filter with an internal 20k Ω resistor at $f_c = 1/(2\pi .20000.C_i)$.
2.	Cs	This is the supply bypass capacitor. It filters the supply voltage applied to the V _{DD} pin and helps reduce the noise
		at the V _{DD} pin.
3.	C _{filt}	This capacitor creates a low pass filter with an internal $4k\Omega$ resistor at $f_c = 1/(2\pi 4000 C_{filt})$. This pole set at f_c
		determines the high cutoff frequency for the low band PWM color LED driver output, LED1.

Typical Performance Characteristics (Note 11)

Audio Sync LED Frequency Response (Left - lowband, Mid - midband, Right - highband) (Cfilt = 0.047µF, HPF = 3.5kHz setting)





























Audio Sync LED Frequency Response (Left - lowband, Mid - midband, Right - highband)

(Cfilt = 2.2µF, HPF = 3.5kHz setting)

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Low Pass Filter Frequency Responsevs Cfilt (From Left to Right: Cfilt (μ F) = 2.2, 1.0, 0.68, 0.47, 0.22, 0.1, 0.068, 0.047, No Cfilt)





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TABLE 1.	Color LE	D Driver	Chip	Address

	A7	A6	A5	A4	A3	A2	A1	A0
Chip Address	1	1	1	1	0	1	EC	0
ADR = 0	1	1	1	1	0	1	0	0
ADR = 1	1	1	1	1	0	1	1	0

EC - externally configured by ADR pin

TABLE 2. Col	or LED Driver	Control Registers
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Register Name	D7	D6	D5	D4	D3	D2	D1	D0
Mode Select	0	0	0	MS4	MS3	MS2	MS1	MS0
Frequency Select	0	1	0	FS4	FS3	FS2	FS1	FS0
Pattern Select	0	1	1	PS4	PS3	PS2	PS1	PS0
Current Select	1	0	CS5	CS4	CS3	CS2	CS1	CS0
Gain Select	1	1	GS5	GS4	GS3	GS2	GS1	GS0

TABLE 3. Mode Select Register

Data Bit	Bit Name	Default Value	Condition	Function
MSO		-	0	Enables device power up mode
10130		I	1	Enables device shutdown mode
MOI		0	0	Enables device normal operation
10131	1-0_031	0	1	Enables device RESET, excluding the I ² C register settings
MED	RAND	-	0	Disables the audio synchronization randomizer
10152		NAND	1	1
MED	MS3 RSVD	0	0	
10155		0	1	RESERVED
		0	0	PESEDVED
10154	n3VD	0	1	NEGERVED

TABLE 4. Frequency Select Register

Data Bit	Bit Name	Default Value	Condition	Function		
FSO PWM_FO		0	0	Programs the oscillation frequency of the PWM. PWM oscillation frequency is set as follows:		
			1	Fund Programs the oscillation frequency is a frequency is a program to one of the second of the	PWM Frequency	
	PWM_F1	0	0	00	15kHz	
E01				01	60Hz	
FS1			1	10	7Hz	
				11	4Hz	
F00	FS2 RSVD	0	0	DECEDVED		
F32			1	RESE	=SERVED	
	0	0	Programs the internal high pass fil	ter cutoff frequency. High pass filter		
F 33		0	1	cutoff frequency	off frequency is set as follows:	
FS4	HPF_F1	F_F1 1		0	HPF_F<1:0>	High Pass Filter Cutoff Frequency
			1	00	3.5kHz	
				01	6.3kHz	
				10	6.3kHz	
				11	8.9kHz	

TABLE 5. Pattern Select Register Data Bit Default Value Bit Name Condition Function 0 Enables LED drivers to be controlled by audio PSO I2C_SEL 0 synchronization 1 Enables LED drivers to be controlled through I²C 0 Disables the LED1 driver, if I²C_SEL is set I²C_LED1 PS1 0 Enables the LED1 driver, if I2C_SEL is set 1 0 Disables the LED2 driver, if I2C_SEL is set PS2 I²C_LED2 0 1 Enables the LED2 driver, if I2C_SEL is set 0 Disables the LED3 driver, if I²C_SEL is set PS3 I²C_LED3 0 1 Enables the LED3 driver, if I²C_SEL is set 0 RESERVED PS4 RSVD 0 1 RESERVED

TABLE 6. Current Select Register

Data Bit	Bit Name	Default Value	Condition	Function			
cso	ILED1_0	0	0	Programs the current drive of the LED1 driver. Current drive for LED1 set as follows:			
			1	ILED1<1:0>	Current Drive Setting		
				00	0.66X		
0.01		4	0	01	1X		
CS1			-	10	1.33X		
			1	11	2X		
		0			0	Programs the current drive of the LED2 driver. Current drive for LED2 is	
CS2	ILED2_0		0	set as follows:			
			1	ILED2<1:0>	Current Drive Setting		
			0	00	0.66X		
		1	0	01	1X		
		I	-1	$\begin{array}{c c} 0 \\ \hline \\ Programs the current drive of the LE set as 1 \\ \hline 1 \\ 1 \\ \hline \\ 0 \\ \hline \\ 0 \\ \hline \\ 0 \\ \hline \\ 1 \\ 1 \\ \hline \\ 1 \\ 0 \\ \hline \\ 1 \\ 1 \\ \hline \\ 1 \\ 1 \\ \hline \\ 1 \\ 1 \\ \hline \\ 1 \\ 1$	1.33X		
			1	11	2X		
		0	0	Programs the current drive of the LED3 driver. Current drive for LED3 is			
CS4	ILED3_0			set as follows:			
			1	ILED3<1:0>	Current Drive Setting		
CS5	ILED3_1	1	0	00	0.66X		
				01	1X		
			1	10	1.33X		
				11	2X		

TABLE 7. Gain Select Register

Data Bit	Bit Name	Default Value	Condition	Function		
			0	Programs the gain response of the midband audio synchronized filter		
GSO	MGAIN0	0	1	which drives the LED2 PWM color LED driver for the midband au frequencies. Gain is set as follows:		
		1	0	MCAIN 20-0	Midband Filter Gain	
GST	MGAINT		1	MGAIN<2:0>		
		0	0	000	minimum	
	MGAIN2		1	001	low	
GS2				010	medium	
				011	high	
				100	maximum	
GS3	SGAIN0	0	0	Programs the audio gain of the inputer following the audio gain of the inputer following following for the state of the st	he audio gain of the input summing amplifier. Gain is set as follows:	
			1	Programs the gain response of the which drives the LED2 PWM colo frequencies. Gain MGAIN<2:0> 000 001 010 011 100 Programs the audio gain of the inp follo SGAIN<2:0> 000 001 100 Programs the audio gain of the inp follo 010 011 100 011 101 101 101 101 101 110	Input Signal Gain	
GS4 SGAIN1		4	0	000	-11dB	
	I	1	001	-6.5dB		
GS5	SGAIN2	SGAIN2 0	0	010	0dB	
				011	3.5dB	
			1	100	6dB	
				101	10dB	
				110	12dB	

I²C COMPATIBLE INTERFACE

The LM4970 uses a serial bus which conforms to the l²C protocol to control the chip's functions with two wires: clock (SCL) and data (SDA). The clock line is uni-directional. The data line is bi-directional (open-collector) with a pullup resistor (typically 10k Ω). The maximum clock frequency specified by the l²C standard is 400kHz. In this discussion, the master is the controlling microcontroller and the slave is the LM4970.

The I²C address for the LM4970 is determined using the ADR pin. The LM4970's two possible I²C chip addresses are of the form 111101X₁0 (binary), where X₁ = 0, if ADR is logic low; and X₁ = 1, if ADR is logic high. If the I²C interface is used to address a number of chips in a system, the LM4970's chip address can be changed to avoid any possible address conflicts.

The bus format for the I²C interface is shown in Figure 3. The data is latched in on the rising edge of the clock. The bus format diagram is broken up into six major sections:

The "start" signal is generated by lowering the data signal while the clock signal is high. The start signal will alert all devices attached to the I²C bus to check the incoming address against their own address.

The 8-bit chip address is sent next, most significant bit first. Each address bit must be stable while the clock level is high.

After the last bit of the address bit is sent, the master checks for the LM4970's acknowledge. The master releases the data line high (through a pullup resistor). Then the master sends a clock pulse. If the LM4970 has received the address correctly, then it holds the data line low during the clock pulse. If the data line is not low, then the master should send a "stop" signal (discussed later) and abort the transfer.

The 8 bits of data are sent next, most significant bit first. Each data bit should be valid while the clock level is stable high.

After the data byte is sent, the master must check for another acknowledge to see if the LM4970 received the data.

If the master has more data bytes to send to the LM4970, then the master can repeat the previous two steps until all data bytes have been sent.

The "stop" signal ends the transfer. To signal "stop", the data signal goes high while the clock signal is high. The data line should be held high when not in use.

AUDIO SYNCHRONIZATION MODE

The LM4970 features an audio synchronization mode where each PWM color LED driver output is dependent on the audio input signal. The audio synchronization mode allows each LED output to react to the amplitude of the audio input signal, according to the LED output's assigned frequency band. Audio synchronization mode is activated by clearing the I2C_SEL bit in the Pattern Select Register.

The audio synchronization filter separates the mixed audio signal into three frequency bands: lowband, midband, and highband. Each frequency band is assigned to a particular PWM LED output, with lowband controlling the duty cycle of the LED1 output, midband controlling the duty cycle of the LED2 output, and highband controlling the duty cycle of the LED3 output. This occurs whenever the audio synchronization randomizer is explained in the **Audio Synchronization Randomizer** section. The duty cycle of any given LED output is dependent upon the amplitude of the audio signal for its particular frequency band. An increase in the amplitude of the audio signal will increase the duty cycle of the PWM LED driver. LEDs driven with a higher duty cycle results in a brighter lighting effect.

The LM4970 has three single-ended analog audio inputs designated M_{IN} , L_{IN} , and R_{IN} , where mono voice data is routed to M_{IN} and stereo MP3 or stereo FM radio data is routed to L_{IN} and R_{IN} . Audio signals coupled in from M_{IN} , L_{IN} , and R_{IN} are mixed together by an audio input summing amplifier. The gain of the audio input summing amplifier is programmed by the SGAIN<2:0> bits of the Gain Select Register. Increasing the gain of the audio input summing amplifier will increase the intensity of the LEDs in audio synchronization mode.

The pole of the low pass filter band is set by the filter cap, Cfilt, and an internal $4k\Omega$ resistor. The pole of the high pass filter band is internally set by programming the HPF_F<1:0> bits of the Frequency Select Register. The midband frequency band is a function of the lowband and highband poles. The gain response of the midband frequency band can be set by programming the MGAIN<2:0> bits of the Gain Select Register.

To minimize LED leakage between audio bands, care should be taken when selecting input gain, midband gain, Cfilt, and LED current drive. There is a trade off between LED brightness and LED leakage in other audio bands. Leakage can be minimized by reducing LED current drive and input gain. Please refer to the frequency response graphs found in the **Typical Performance Characteristics** section as a guideline to minimize LED leakage.

AUDIO SYNCHRONIZATION RANDOMIZER

The LM4970 features a randomizer block that randomizes the frequency band assigned to each PWM LED driver during audio synchronization operation. The randomizer is activated by setting the RAND bit in the Mode Select Register. Clearing the RAND bit will disable the randomizer. The randomizer can only be activated when the LM4970 is programmed to audio synchronization mode. The interval at which randomizer assigns a new frequency band is set to occur once every 3.2 seconds. The randomizer ensures that all the colored LEDs will light up over a long duration even if the audio input has a fixed frequency.

I²C PATTERN MODE

The LM4970 features an I²C pattern mode for applications where direct control of the LED outputs is required. I²C pattern mode is activated by setting the I2C_SEL bit in the Pattern Select Register. The LED1 output duty cycle can be programmed to 100% by setting the I2C_LED1 bit in the Pattern Select Register. Clearing the I2C_LED1 bit sets the LED1 output duty cycle to 0%. The LED2 output duty cycle can be programmed to 100% by setting the I2C_LED2 bit in the Pattern Select Register. Clearing the I2C_LED2 bit sets the LED1 output duty cycle to 0%. The LED3 output duty cycle can be programmed to 100% by setting the I2C_LED2 bit sets the LED2 output duty cycle to 0%. The LED3 output duty cycle can be programmed to 100% by setting the I2C_LED3 bit in the Pattern Select Register. Clearing the I2C_LED3 bit in the Pattern Select Register. Clearing the I2C_LED3 bit sets the LED3 output duty cycle to 0%. Color LEDs driven at 100% duty cycle are fully on, and driven at 0% duty cycle are fully off.

PWM FREQUENCY

The PWM frequency of the color LED drivers is programmed through the PWM_F<1:0> bits of the Frequency Select Register. The LM4970 features four different PWM frequency settings: 15kHz, 60Hz, 7Hz, and 4Hz. PWM frequency is analogous to the sampling rate of the audio input signal. A higher PWM frequency setting will result in a more accurate LED representation of the audio input signal in the audio synchronization mode. However, a PWM frequency that is set too high will decrease the ON time of the LED which will result in reduced LED intensity. A PWM frequency setting of 60Hz results in an optimal balance between LED accuracy and intensity.

DRIVING RGB LED MODULES

The LM4970's PWM LED outputs can be used to drive individual color LEDs or RGB LED modules. When driving RGB

LED modules in audio synchronization mode, the color and intensity of the RGB LED module will be dependent on the audio input signal. In I²C pattern mode, the RGB LED module can be set to any of seven distinct colors, based on the status of the I²C_LED1, I²C_LED2, and I²C_LED3 bit settings.







Revision History

Rev	Date	Description
1.1	5/26/06	On Table 2 (pg 8), col D7 for Pattern Select, changed the '1' into '0'.
1.2	04/01/08	Added the last paragraph under the AUDIO SYNCHRONIZATION MODE.



Notes

Pr	oducts	Design Support		
Amplifiers	www.national.com/amplifiers	WEBENCH	www.national.com/webench	
Audio	www.national.com/audio	Analog University	www.national.com/AU	
Clock Conditioners	www.national.com/timing	App Notes	www.national.com/appnotes	
Data Converters	www.national.com/adc	Distributors	www.national.com/contacts	
Displays	www.national.com/displays	Green Compliance	www.national.com/quality/green	
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