PROJECT REPORT

ON

FUNCTION GENERATOR

Submitted by

SHIVAM PRASAD (EC-055)
18ECUOS089

For the term project of

B.TECH

SEM-5

With the guidance of

PROF. VASIM VOHRA

DEPARTMENT OF ELECTRONICS AND COMMUNICATION
FACULTY OF TECHNOLOGY
DHARMSINH DESAI UNIVERSITY

CERTIFICATE

This is to certify that the project on **FUNCTION GENERATOR** and term work carried out in the subject of Term Project is bona fide work of **SHIVAM PRASAD** (Roll no.: **EC 055**) of B. Tech. **Semester V** in the branch of **Electronics & Communication**, during the academic year **2020-21.**

PROF. VASIM VOHRA
PROJECT GUIDE,
E.C. DEPARTMENT

DR. NIKHIL KOTHARI
HEAD OF E.C. DEPARMENT

ABSTRACT

The project that I have taken is "**FUNCTION GENERATOR**". As an EC branch student, I have to connect particular circuit on bread board in laboratory everyday which requires particular input signal to work on. Function generator is used in laboratory to generate typical standard signals. They are quite expensive for individual student and also they are only available in college laboratory so one cannot test his/hers circuit at other places.

So the aim of this project is to build a Function generator which will have limited features but full filing device a learners. Which will provide typical signals at low cost at home.

This project includes use of standard OP AMP ICs, Potentiometer & basic electric components.

INDEX

CHAPTER 1

INTRODUCTION TO FUNCTION GENERATOR

A **'Function Generator'** is usually a piece of electronic test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine wave, square wave, triangular wave and saw tooth shapes.

Figure 1.1 Standard Function Generator

Although function generators cover both audio and RF frequencies, they are usually not suitable for applications that need low distortion or stable frequency signals. When those traits are required, other signal generators would be more appropriate

Function generators are used in the development, test and repair of electronic equipment. For example, they may be used as a signal source to test amplifiers or to introduce an error signal into a control loop. Function generators are primarily used for working with analogue circuits, related pulse generators are primarily used for working with digital circuits.

CHAPTER 2

BLOCK DIAGRAM

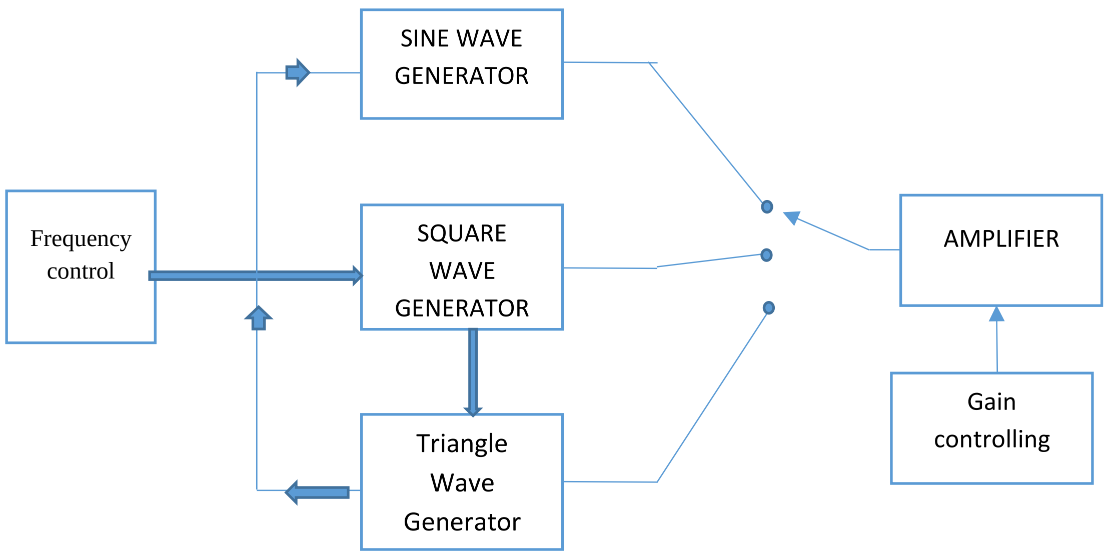


Figure 2.1- BLOCK DIAGRAM

From above (figure 2.1) Block diagram, we can see that it is consist of certain waveform generator circuit and to control their frequency controlling circuit is placed. As to get desired waveform user has to move the knob accordingly. At the end of block diagram Amplifier and Attenuator is placed to get desired Amplitude (voltage) range.

Let’s observe working of each block one by one. From later on we will understand actual circuits.

[1] SINE WAVE GENERATOR

A **sine wave** or **sinusoid** is a mathematical curve that describes a smooth periodic oscillation. A sine wave is a continuous wave. It is named after the function sine. In below from figure we can observe characteristic of sinusoidal wave.

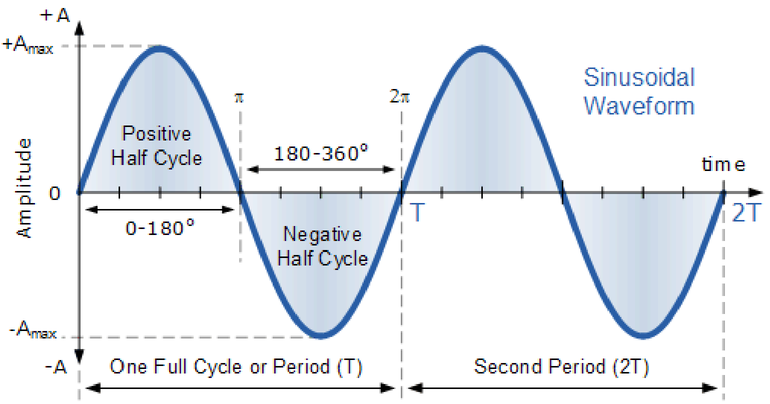


Fig 2.2 Sinusoidal Wave

So, in the block diagram of sine wave generator, in the circuit, there will be one Operational Amplifiers IC. With that, couple of resistor (variable) and capacitor will be placed together to control and to get desired frequency.

This circuit will be generating sinewaves of desired frequency. To get desired amplitude, from the amplifier by varying a knob user can get this.

[2] TRAINGLE WAVE GENERATOR

A **triangular wave** or **triangle wave** is a non-sinusoidal waveform named for its triangular shape.

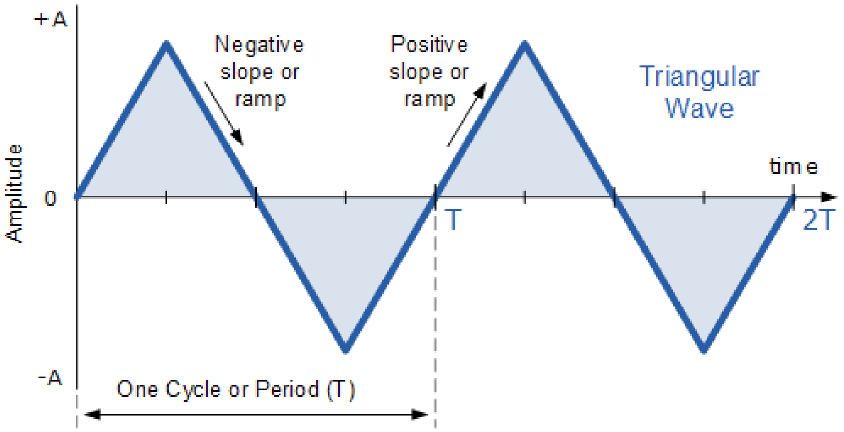


Fig 2.3 Triangle wave

Circuit of Triangle wave is similar to all other wave generator, it is consist of OP-AMP IC with resistors and capacitors. By connecting an Integrator circuit to square wave circuit we can get a triangular response.

[3] SQUARE WAVE GENERATOR

A **square wave** is a non-sinusoidal periodic waveform in which the amplitude alternates at a steady frequency between fixed minimum and maximum values, with the same duration at minimum and maximum. In an ideal square wave, the transitions between minimum and maximum are instantaneous.

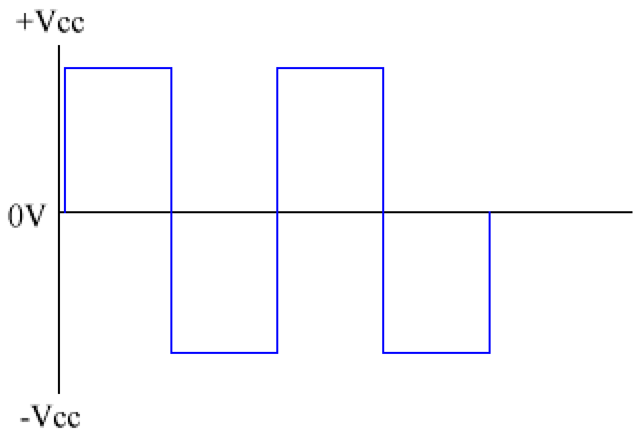


Fig 2.4 Square wave

Again, same components will be used OPAMP, resistors and capacitors with different combination.

[4] Frequency controlling circuit

Frequency controlling circuit is nothing but combination of variable resistive and capacitive networks which will allow operational amplifiers to generate waves at certain frequency. Here we will control the frequency of Square wave generator only. Also this will allow user to get desired frequency waves.

[5] Amplifier Circuit

We are generating waves in desired frequency but not for specific amplitude so at the end of block diagram amplifier will amplify our wave to max amplitude allowed by VCC. Three are two amplifier configuration available Common Emitter (CE) and common base (CB) to amplify our generated wave. Here we will use OP amp as voltage amplifier. Since BJT type amplifier can work if input is in small.

CHAPTER-3

CIRCUIT DIAGRAM AND WORKING

Function Generator

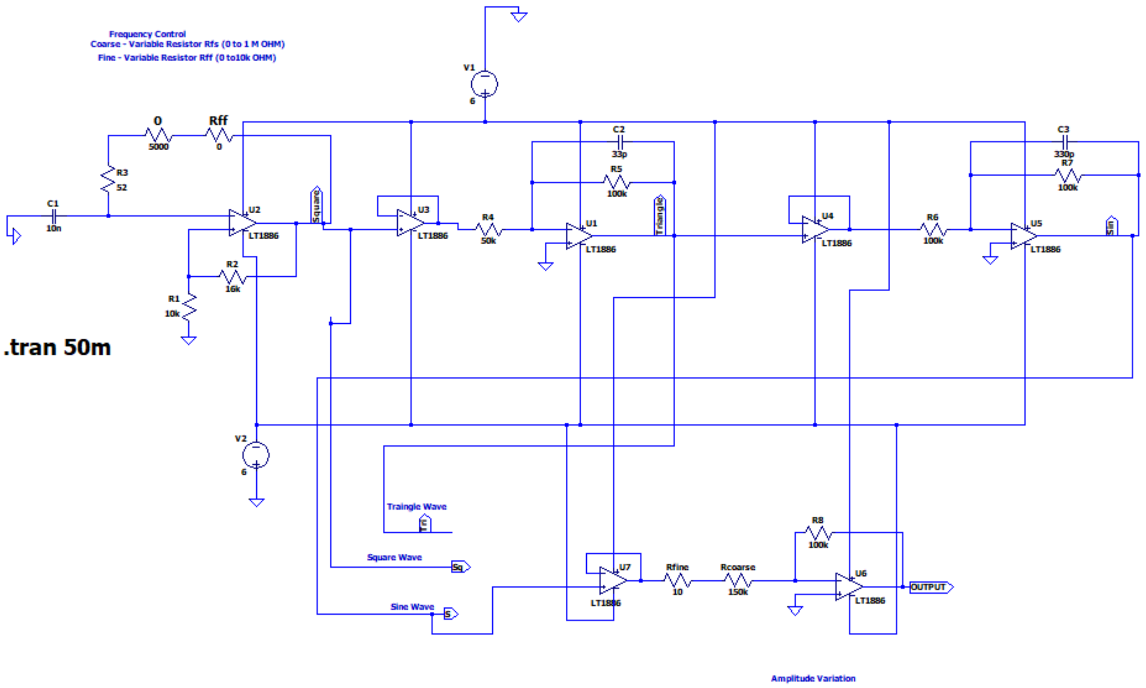


Figure 3.1 Circuit Diagram for Function Generator

- A complete circuit diagram of function generator is shown above. Whole function generator is made of only Operational Amplifiers. This circuit needs two supply for biasing of op-amp. OP amp is used as oscillator. First of all we can achieve square wave with desirable frequency then we use another op amp as integrator to obtain triangle wave from square wave. After wards we integrate triangle wave again so we can obtain sinusoidal wave.
- For above discussion we are concerned about obtaining different signal for different frequency. To achieve desired amplitude, we connect again op amp as Voltage amplifier.
- From circuit diagram one can observe that variable resistor is connected at square wave generator. By varying this resistor we can adjust frequency of signal. Similar way at the amplifier side we have connected another variable resistor to control gain or amplitude the signal.
- Although after each stage of generator '**BUFFER**' is connected. This buffer is also configured from OP AMP. Buffer provides the isolation of two stages of circuit to avoid any "**loading effect**" and also in addition they provide output high impedance to transfer maximum power.

Let's understand working of function generator's each blocks one by one.

(1) Square Wave generator using OP AMP

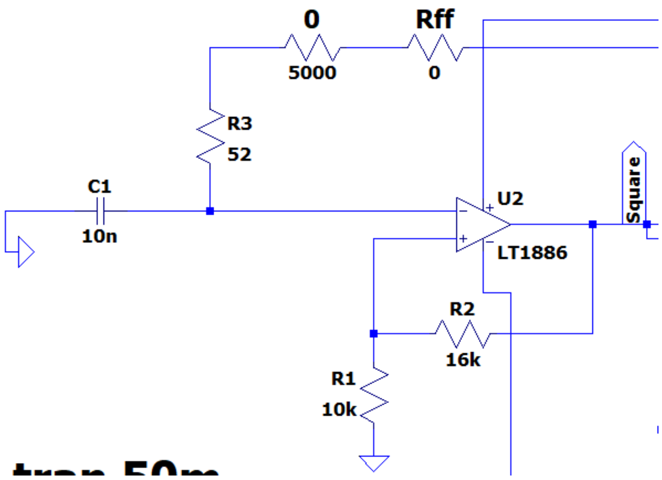


Figure 3.2 Square wave generation

In above figure square wave generator is shown which first block of function generator is. A feedback is provided at inverting pin of op amp. Also a capacitor is connected at inverting terminal or pin. Similar way R1 and R2 are connected with non-inverting pin.

To set time period of output voltage,

$$\mathbf{T = 2*Rff*C1 * \ln((2R2 + R1)/R1)}$$

To make,

$$\ln((2R2 + R1)/R1) = 1$$

$$(2R2 + R6)/R6 = 2.73$$

$$\mathbf{R2 = (1.16)R1}$$

Once this condition satisfies, T = 2RC

So frequency of given square wave generator is given by,

$$\mathbf{f = 1/(2Rff*C1)}$$

By varying Rfc, We can vary frequency of square wave

Here By very varying Rfc we can vary frequency by large amount so it is named knob as ‘COARSE’ and similarly for small variation vary Rff which is known as ‘Fine’ tuning.

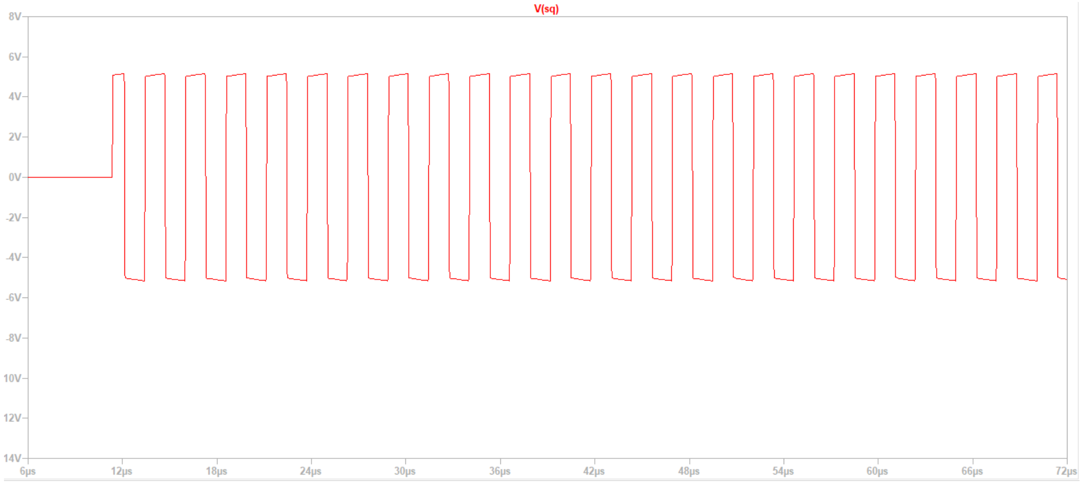


Figure 3.3: 388Khz frequency of square wave

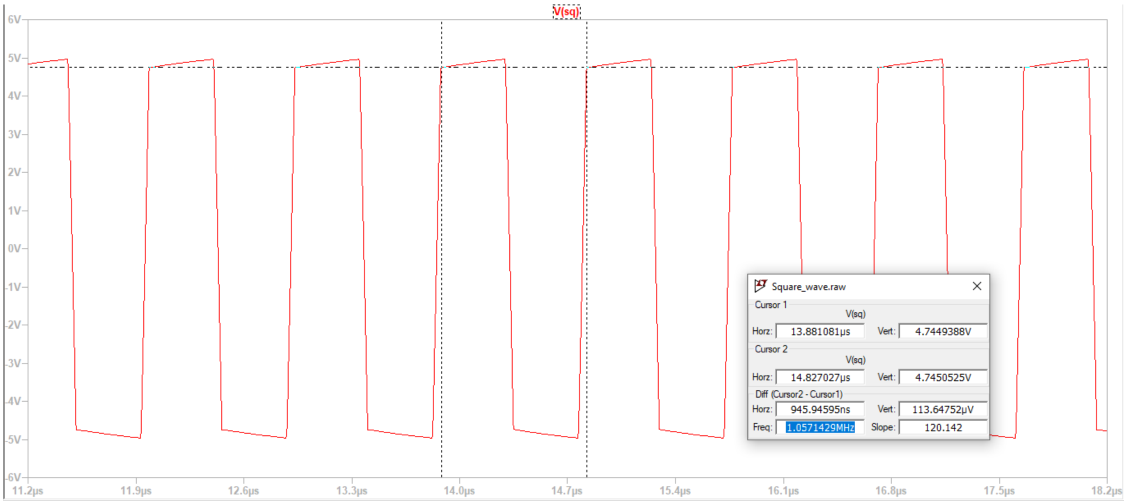


Figure 3.4 : Square wave of 1MHz

[2] Triangle Wave generator using OP AMP as Integrator

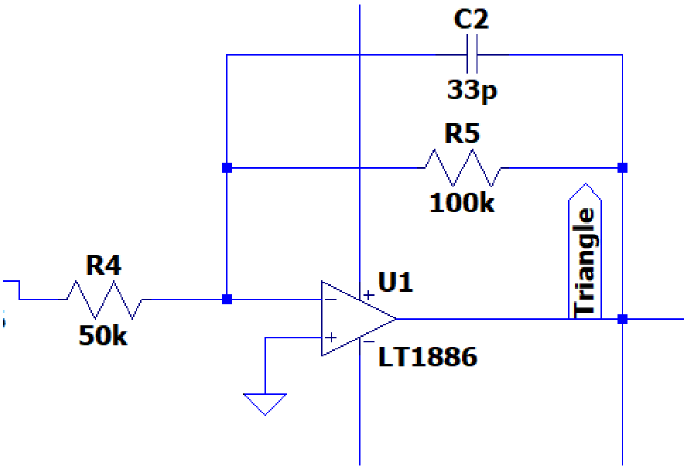


Figure 3.5 Triangle wave generator

Op Amp can be useful to solve arithmetic operation. In earlier days where computers were not designed, OP amps were used to solve arithmetic equations.

We know that if you integrate square wave it will become Triangle wave. Triangle wave have equal rise time and fall time. Output voltage is given as,

$$Vout = \frac{-1}{R1Cf}\int Vin(t)$$

So we can see out depends on value R1 and Cf as well as on frequency of input.

Frequency increases, Vout decreases. This is our first limitation of circuit

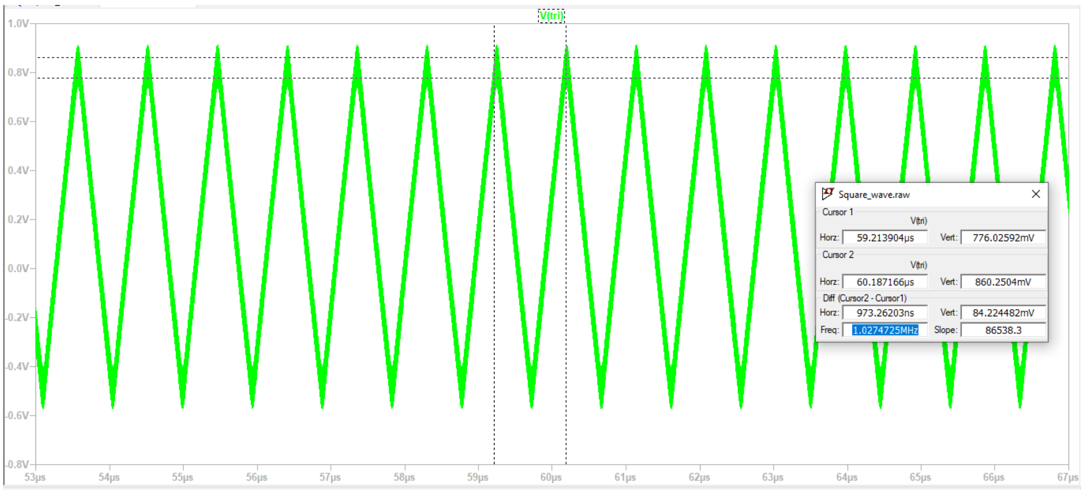


Figure 3.6 Triangle wave of 1 MHZ

[3] Sine Wave generator using OP AMP as Integrator

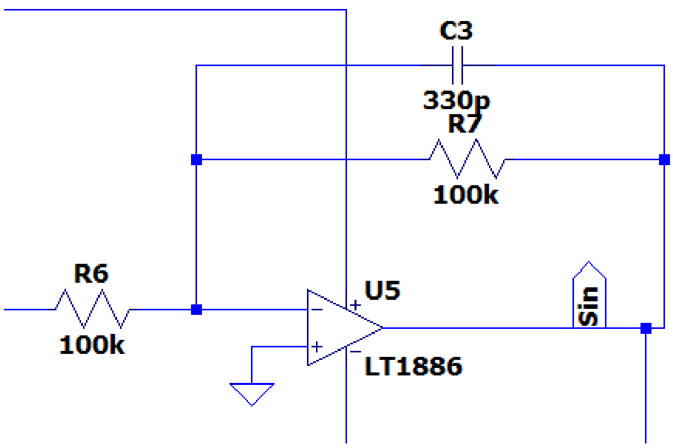


Figure 1.10 Sinewave Generator

Now we apply triangle wave to integrator, so it becomes sinusoidal wave. Again formula is same again output voltage depends RC constant and input frequency.

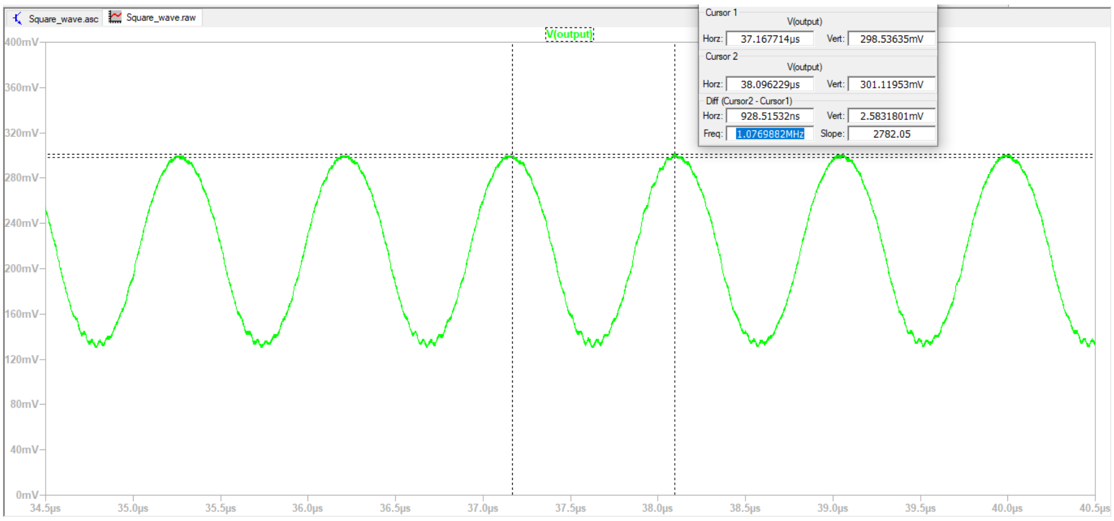


Figure 1.11 Sine wave of 1 MHz

Sinusoidal wave's peak voltage decreases the as frequency increases (when more than 500KHz). For lower frequency It we can get proper sine wave.

4] OP amp as amplifier

Operational Amplifier can be also used as voltage gain amplifier.

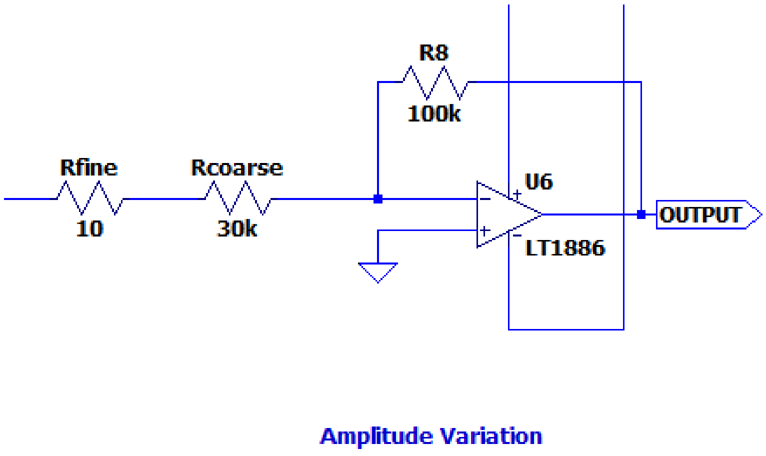


Figure 1.12 OP AMP as amplifier

Output voltage is given by,

Vout = (-R8/Rcoarse) *Vin

By adjusting **Rcoarse** we can vary gain of amplifier. So output can be achieved upto 10v peak to peak. Also we can **Rfine** is used for small variation in gain.

CHAPTER 4

COMPONENTS AND ITS DESCRIPTION

Components are used in this project are listed below:

- Operational amplifiers (IC – LT1886)
- Resistors
- Capacitors
- Potentiometer (Variable resistor)
- Push Buttons

Description:

1. **Operation Amplifier:**

An **Operational Amplifier**, or op-amp for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. These feedback components determine the resulting function or "operation" of the amplifier and by virtue of the different feedback configurations whether resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of "Operational Amplifier".

An Operational Amplifier is basically a three-terminal device which consists of two high impedance inputs. One of the inputs is called the **Inverting Input**, marked with a negative or "minus" sign, (–). The other input is called the **Non-inverting Input**, marked with a positive or "plus" sign (+).

A third terminal represents the operational amplifiers output port which can both sink and source either a voltage or a current. In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain (A) multiplied by the value of the input signal and depending on the nature of these input and output signals, there can be four different classifications of operational amplifier gain.

- Voltage – Voltage "in" and Voltage "out"
- Current – Current "in" and Current "out"
- Transconductance – Voltage "in" and Current "out"
- Transresistance – Current "in" and Voltage "out"

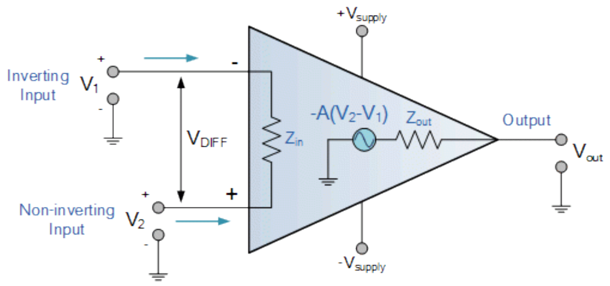


Figure 4.1 Resistive model of an OP AMP

Since most of the circuits dealing with operational amplifiers are voltage amplifiers, we will limit the tutorials in this section to voltage amplifiers only, (Vin and Vout).

The output voltage signal from an Operational Amplifier is the difference between the signals being applied to its two individual inputs. In other words, an op-amps output signal is the difference between the two input signals as the input stage of an Operational Amplifier.

Op-amp Parameter and Idealised Characteristic

- **Open Loop Gain, (Avo)**
  - **Infinite** – The main function of an operational amplifier is to amplify the input signal and the more open loop gain it has the better. Open-loop gain is the gain of the op-amp without positive or negative feedback and for such an amplifier the gain will be infinite but typical real values range from about 20,000 to 200,000.

- **Input impedance, (Z_{IN})**
  - **Infinite** – Input impedance is the ratio of input voltage to input current and is assumed to be infinite to prevent any current flowing from the source supply into the amplifiers input circuitry ($I_{IN} = 0$). Real op-amps have input leakage currents from a few pico-amps to a few milli-amps.

- **Output impedance, (Z_{OUT})**
    - **Zero** – The output impedance of the ideal operational amplifier is assumed to be zero acting as a perfect internal voltage source with no internal resistance so that it can supply as much current as necessary to the load. This internal resistance is effectively in series with the load thereby reducing the output voltage available to the load. Real op-amps have output impedances in the 100-20kΩ range.

- **Bandwidth, (BW)**
    - **Infinite** – An ideal operational amplifier has an infinite frequency response and can amplify any frequency signal from DC to the highest AC frequencies so it is therefore assumed to have an infinite bandwidth. With real op-amps, the bandwidth is limited by the Gain-Bandwidth product (GB), which is equal to the frequency where the amplifiers gain becomes unity.

- **Offset Voltage, (V_{IO})**
    - **Zero** – The amplifiers output will be zero when the voltage difference between the inverting and the non-inverting inputs is zero, the same or when both inputs are grounded. Real op-amps have some amount of output offset voltage.

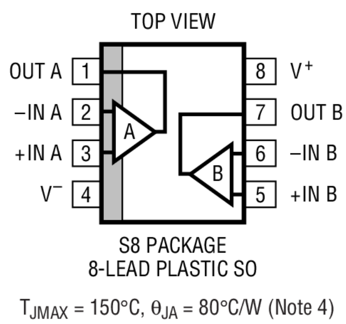


Figure 4.2 Pin diagram of dual package LT1886

There are lots of variants of this ICs are available in market. Each IC may have designed for particular parameter. One of them is **LT1886** (please refer **datasheet** at the end of this report)
This is mainly focused on it frequency response like it can work upto 700 MHz frequency and 2500 V/us slew rate.

2. **Resistors:** A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element.

Figure 4.3 Resistors

Mainly resistors are used to control the flow of current and voltage.

3. **Capacitors:**

A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit.

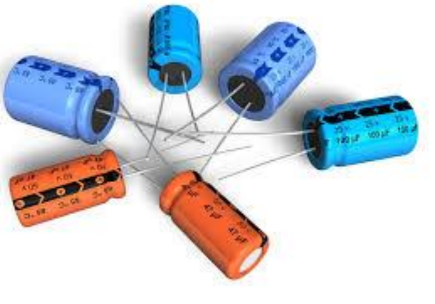


Figure 4.4 Capacitors

4. **Potentiometer:**

Figure 4.5 Potentiometer

A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat. The measuring instrument called a potentiometer is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle, hence its name. Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment. Potentiometers operated by a mechanism can be used as position transducers, for example, in a joystick. Potentiometers are rarely used to directly control significant power (more than a watt), since the power dissipated in the potentiometer would be comparable to the power in the controlled load.

5. **Push Buttons:**

Figure 4.6 Pushbuttons

Push-button or simply button is a simple switch mechanism to control some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, although many un-biased buttons (due to their physical nature) still require a spring to return to their un-pushed state. Terms for the "pushing" of a button include pressing.

CHAPTER 5
TROUBLESHOOTING

- In this project, simply I had to connect all three generates in series. And output of each of generates are connected to amplifier in parallel manner. All OP AMP has their own impedance and also all the integrator circuits depends on their inverting terminal impedance. Op amp has its own input impedance, so these two impedance forms parallel connection and reduces the overall impedance which causes the distortion.
- So to solve that, op amp can be used as isolation circuit or buffers. By connecting output terminal to the inverting terminal, we can make buffers which will have unity gain. So now just to connect to generators we have to put buffers in between them. Only disadvantages is that circuit becomes costly and bulky.
- Since all the op amps are highly rated and each individual generators consumes power. Now one can observe that when user requires only square wave at time only square wave generator is required to fulfil the purpose but at same time other generator are also generating signals. So one can say that it is wastages of power.
- To avoid such situation we can use pushbuttons at output of each generator which will make sure that other circuit don’t get inputs and one can fulfil his requirement.
- As discussed in chapter 4, op amps has certain parameters which limits the op amp for working. Slew Rate and maximum frequency to work, are the important parameters.

  Slew Rate:
  The slew rate of an op amp or any amplifier circuit is the rate of change in the output voltage caused by a step change on the input. It is measured as a voltage change in a given time - typically V/µs or V/ms.

- So slew rate determines the maximum frequency that can be operate and also shape of output. I have selected LT1886 IC for this project it has better frequency response (See the DATASHEET). Because normal general purpose op-amp has very low slew rate (0.5v/us) which cannot be used at higher frequency.

CHAPTER 6
LIMITATION OF CIRCUIT

1. Circuit is operating on 6 volts so it may happen that numbers of battery is required. Circuit temperature may rise so Heat sinks are required. Which leads to make circuit bulkier.
2. Due to tolerance of component and variation in temperature, there may be a slight variation in frequency and amplitude will be there.
3. In figure 1.4, overcurrent flow may occur – limiting resistors are required. Which will increase the cost of circuit
4. If one of components burns out whole circuit will not work.
5. IC LM1886 used in FG which is highly costly.(but much lesser than standard FG)
6. At lower frequency multiple harmonics may be there.(reason unknown)
7. **Reliability:** Since we are not using any standard components, noise generated by components itself would be added in output signals, so this function generator should be used only in small projects for testing purposes.

CHAPTER 7

CONCLUSION

In this project, we designed general purpose Function Generator using Operation Amplifiers. I successfully implemented circuit on LTspice simulator and also verified output signals for maximum and minimum frequency. At lower frequency there may be some harmonic distortion but can be tolerable at the cost. Also I realised how op amps are useful to generate all signals and can be implemented as amplifier. Also I learned that if I am using an op amp at desired frequency, so I have to select such operational amplifier that matches to certain parameters of it. Also trouble shooting is most time consuming work because it is difficult to judge which parameter is affecting my circuit response.

CHAPTER 8
REFERENCES

Textbooks

- Op-amps and Linear Integrated Circuits by Ramakant Gayakward
- Linear integrated circuits by Millman
- Electronics and principle by Albert Malvino

Websites

- http://www.learningaboutelectronics.com/Articles/Function-generator-circuit.php
- https://www.electronicsforu.com/technology-trends/learn-electronics/operational-amplifier-basics

DATASHEETS

LT1886

Dual 700MHz, 200mA Operational Amplifier

FEATURES

- **700MHz Gain Bandwidth**
- **±200mA Minimum I_{OUT}**
- **Low Distortion: –72dBc at 1MHz, $4V_{P-P}$, 25Ω, $A_V = 2$**
- Stable in $A_V \geq 10$, Simple Compensation for $A_V < 10$
- ±4.3V Minimum Output Swing, $V_S = \pm 6V$, $R_L = 25\Omega$
- 7mA Supply Current per Amplifier
- 200V/µs Slew Rate
- Stable with 1000pF Load
- 6nV/√Hz Input Noise Voltage
- 2pA/√Hz Input Noise Current
- 4mV Maximum Input Offset Voltage
- 4µA Maximum Input Bias Current
- 400nA Maximum Input Offset Current
- ±4.5V Minimum Input CMR, $V_S = \pm 6V$
- Specified at ±6V, ±2.5V

APPLICATIONS

- DSL Modems
- xDSL PCI Cards
- USB Modems
- Line Drivers

DESCRIPTION

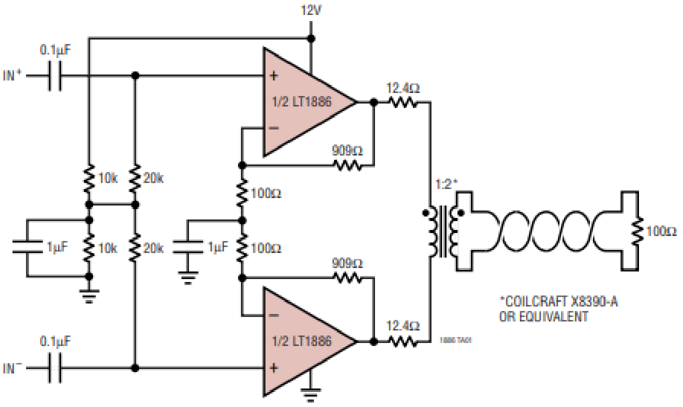
The LT®1886 is a 200mA minimum output current dual op amp with outstanding distortion performance. The amplifiers are gain-of-ten stable, but can be easily compensated for lower gains. The LT1886 features balanced, high impedance inputs with 4µA maximum input bias current, and 4mV maximum input offset voltage. Single supply applications are easy to implement and have lower total noise than current feedback amplifier implementations.

The output drives a 25Ω load to ±4.3V with ±6V supplies. On ±2.5V supplies the output swings ±1.5V with a 100Ω load. The amplifier is stable with a 1000pF capacitive load which makes it useful in buffer and cable driver applications.

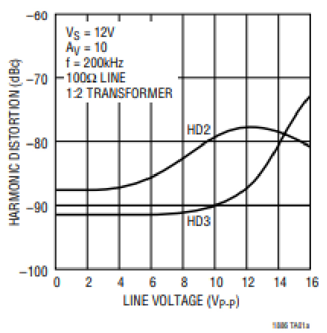
The LT1886 is manufactured on Linear Technology's advanced low voltage complementary bipolar process and is available in a thermally enhanced SO-8 package.

TYPICAL APPLICATION

Single 12V Supply ADSL Modem Line Driver



ADSL Modem Line Driver Distortion



LT1886

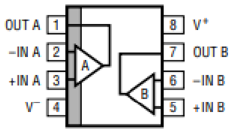
ABSOLUTE MAXIMUM RATINGS

(Note 1)

Total Supply Voltage (V^+ to V^-) 13.2V
Input Current (Note 2) .... ±10mA
Input Voltage (Note 2) .... $\pm V_S$
Maximum Continuous Output Current (Note 3)
DC .... ±100mA
AC .... ±300mA
Operating Temperature Range (Note 10) −40°C to 85°C
Specified Temperature Range (Note 9) .. −40°C to 85°C
Maximum Junction Temperature .... 150°C
Storage Temperature Range .... −65°C to 150°C
Lead Temperature (Soldering, 10 sec)................ 300°C

PACKAGE/ORDER INFORMATION

TOP VIEW



S8 PACKAGE
8-LEAD PLASTIC SO
T_{JMAX} = 150°C, θ_{JA} = 80°C/W (Note 4)

ORDER PART NUMBER
LT1886CS8
S8 PART MARKING
1886

Consult factory for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = ±6V, V_{CM} = 0V, pulse power tested unless otherwise noted. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 5)	 ●		1	4 5	mV mV
	Input Offset Voltage Drift	(Note 8)	●		3	17	µV/°C
I_{OS}	Input Offset Current		 ●		150	400 600	nA nA
I_B	Input Bias Current		 ●		1.5	4 6	µA µA
e_n	Input Noise Voltage	f = 10kHz			6		nV/√Hz
i_n	Input Noise Current	f = 10kHz			2		pA/√Hz
R_{IN}	Input Resistance	V_{CM} = ±4.5V Differential		5	10 35		MΩ kΩ
C_{IN}	Input Capacitance				2		pF
	Input Voltage Range (Positive) Input Voltage Range (Negative)		● ●	4.5	5.9 −5.2	 −4.5	V V
CMRR	Common Mode Rejection Ratio	V_{CM} = ±4.5V	●	77	98		dB
	Minimum Supply Voltage	Guaranteed by PSRR	●			±2	V
PSRR	Power Supply Rejection Ratio	V_S = ±2V to ±6.5V	 ●	80 78	86		dB dB
A_{VOL}	Large-Signal Voltage Gain	V_{OUT} = ±4V, R_L = 100Ω	 ●	5.0 4.5	12		V/mV V/mV
		V_{OUT} = ±4V, R_L = 25Ω	 ●	4.5 4.0	12		V/mV V/mV
V_{OUT}	Output Swing	R_L = 100Ω, 10mV Overdrive	 ●	4.85 4.70	5		±V ±V
		R_L = 25Ω, 10mV Overdrive	 ●	4.30 4.10	4.6		±V ±V
		I_{OUT} = 200mA, 10mV Overdrive	 ●	4.30 4.10	4.5		±V ±V
I_{SC}	Short-Circuit Current (Sourcing) Short-Circuit Current (Sinking)	(Note 3)			800 500		mA mA

LT1886

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25°C$. $V_S = \pm6V$, $V_{CM} = 0V$, pulse power tested unless otherwise noted. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
SR	Slew Rate	$A_V = -10$ (Note 6)		133	200		V/µs
			●	110			V/µs
	Full Power Bandwidth	4V Peak (Note 7)			8		MHz
GBW	Gain Bandwidth	f = 1MHz			700		MHz
t_r, t_f	Rise Time, Fall Time	$A_V = 10$, 10% to 90% of 0.1V, $R_L = 100\Omega$			4		ns
	Overshoot	$A_V = 10$, 0.1V, $R_L = 100\Omega$			1		%
	Propagation Delay	$A_V = 10$, 50% V_{IN} to 50% V_{OUT}, 0.1V, $R_L = 100\Omega$			2.5		ns
t_S	Settling Time	6V Step, 0.1%			50		ns
	Harmonic Distortion	HD2, $A_V = 10$, $2V_{P\text{-}P}$, f = 1MHz, $R_L = 100\Omega/25\Omega$			−75/−63		dBc
		HD3, $A_V = 10$, $2V_{P\text{-}P}$, f = 1MHz, $R_L = 100\Omega/25\Omega$			−85/−71		dBc
IMD	Intermodulation Distortion	$A_V = 10$, f = 0.9MHz, 1MHz, 14dBm, $R_L = 100\Omega/25\Omega$			−81/−80		dBc
R_{OUT}	Output Resistance	$A_V = 10$, f = 1MHz			0.1		Ω
	Channel Separation	$V_{OUT} = \pm4V$, $R_L = 25\Omega$		82	92		dB
			●	80			dB
I_S	Supply Current	Per Amplifier			7	8.25	mA
			●			8.50	mA

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25°C$. $V_S = \pm2.5V$, $V_{CM} = 0V$, pulse power tested unless otherwise noted. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	(Note 5)			1.5	5	mV
			●			6	mV
	Input Offset Voltage Drift	(Note 8)	●		5	17	µV/°C
I_{OS}	Input Offset Current				100	350	nA
			●			550	nA
I_B	Input Bias Current				1.2	3.5	µA
			●			5.5	µA
e_n	Input Noise Voltage	f = 10kHz			6		$nV/\sqrt{Hz}$
i_n	Input Noise Current	f = 10kHz			2		$pA/\sqrt{Hz}$
R_{IN}	Input Resistance	$V_{CM} = \pm1V$		10	20		MΩ
		Differential			50		kΩ
C_{IN}	Input Capacitance				2		pF
	Input Voltage Range (Positive)		●	1	2.4		V
	Input Voltage Range (Negative)		●		−1.7	−1	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = \pm1V$	●	75	91		dB
A_{VOL}	Large-Signal Voltage Gain	$V_{OUT} = \pm1V$, $R_L = 100\Omega$		5.0	10		V/mV
			●	4.5			V/mV
		$V_{OUT} = \pm1V$, $R_L = 25\Omega$		4.5	10		V/mV
			●	4.0			V/mV
V_{OUT}	Output Swing	$R_L = 100\Omega$, 10mV Overdrive		1.50	1.65		±V
			●	1.40			±V
		$R_L = 25\Omega$, 10mV Overdrive		1.35	1.50		±V
			●	1.25			±V
		$I_{OUT} = 200mA$, 10mV Overdrive		0.87	1		±V
			●	0.80			±V

LT1886

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25°C$. $V_S = \pm 2.5V$, $V_{CM} = 0V$, pulse power tested unless otherwise noted. (Note 9)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
I_{SC}	Short-Circuit Current (Sourcing) Short-Circuit Current (Sinking)	(Note 3)			600 400		mA mA
SR	Slew Rate	$A_V = -10$ (Note 6)	 ●	66 60	100		V/µs V/µs
	Full Power Bandwidth	1V Peak (Note 7)			16		MHz
GBW	Gain Bandwidth	f = 1MHz			530		MHz
t_r, t_f	Rise Time, Fall Time	$A_V = 10$, 10% to 90% of 0.1V, $R_L = 100\Omega$			7		ns
	Overshoot	$A_V = 10$, 0.1V, $R_L = 100\Omega$			5		%
	Propagation Delay	$A_V = 10$, 50% V_{IN} to 50% V_{OUT}, 0.1V, $R_L = 100\Omega$			5		ns
	Harmonic Distortion	HD2, $A_V = 10$, $2V_{P-P}$, f = 1MHz, $R_L = 100\Omega/25\Omega$ HD3, $A_V = 10$, $2V_{P-P}$, f = 1MHz, $R_L = 100\Omega/25\Omega$			–75/–64 –80/–66		dBc dBc
IMD	Intermodulation Distortion	$A_V = 10$, f = 0.9MHz, 1MHz, 5dBm, $R_L = 100\Omega/25\Omega$			–77/–85		dBc
R_{OUT}	Output Resistance	$A_V = 10$, f = 1MHz			0.2		Ω
	Channel Separation	$V_{OUT} = \pm 1V$, $R_L = 25\Omega$	 ●	82 80	92		dB dB
I_S	Supply Current	Per Amplifier	 ●		5	5.75 6.25	mA mA

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: The inputs are protected by back-to-back diodes. If the differential input voltage exceeds 0.7V, the input current should be limited to less than 10mA.

Note 3: A heat sink may be required to keep the junction temperature below absolute maximum.

Note 4: Thermal resistance varies depending upon the amount of PC board metal attached to the device. θ_{JA} is specified for a 2500mm^2 test board covered with 2 oz copper on both sides.

Note 5: Input offset voltage is exclusive of warm-up drift.

Note 6: Slew rate is measured between ±2V on a ±4V output with ±6V supplies, and between ±1V on a ±1.5V output with ±2.5V supplies.

Note 7: Full power bandwidth is calculated from the slew rate: $FPBW = SR/2\pi V_P$.

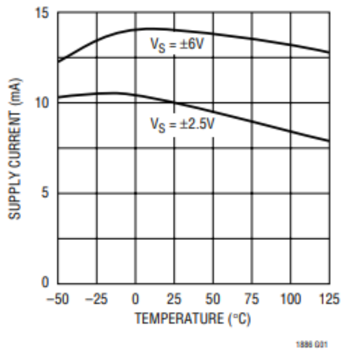
Note 8: This parameter is not 100% tested.

Note 9: The LT1886C is guaranteed to meet specified performance from 0°C to 70°C. The LT1886C is designed, characterized and expected to meet specified performance from –40°C to 85°C but is not tested or QA sampled at these temperatures. For guaranteed I-grade parts, consult the factory.

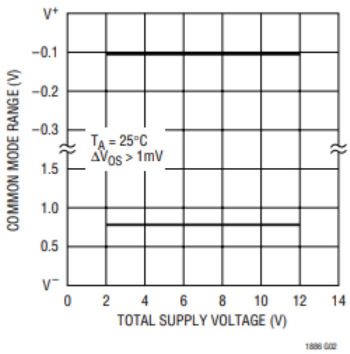
Note 10: The LT1886C is guaranteed functional over the operating temperature range of –40°C to 85°C.

TYPICAL PERFORMANCE CHARACTERISTICS

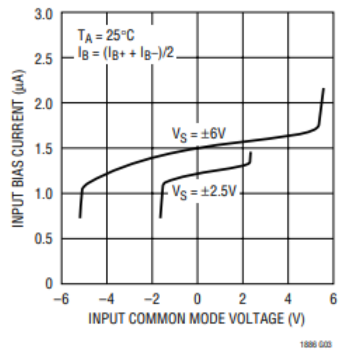
Supply Current vs Temperature



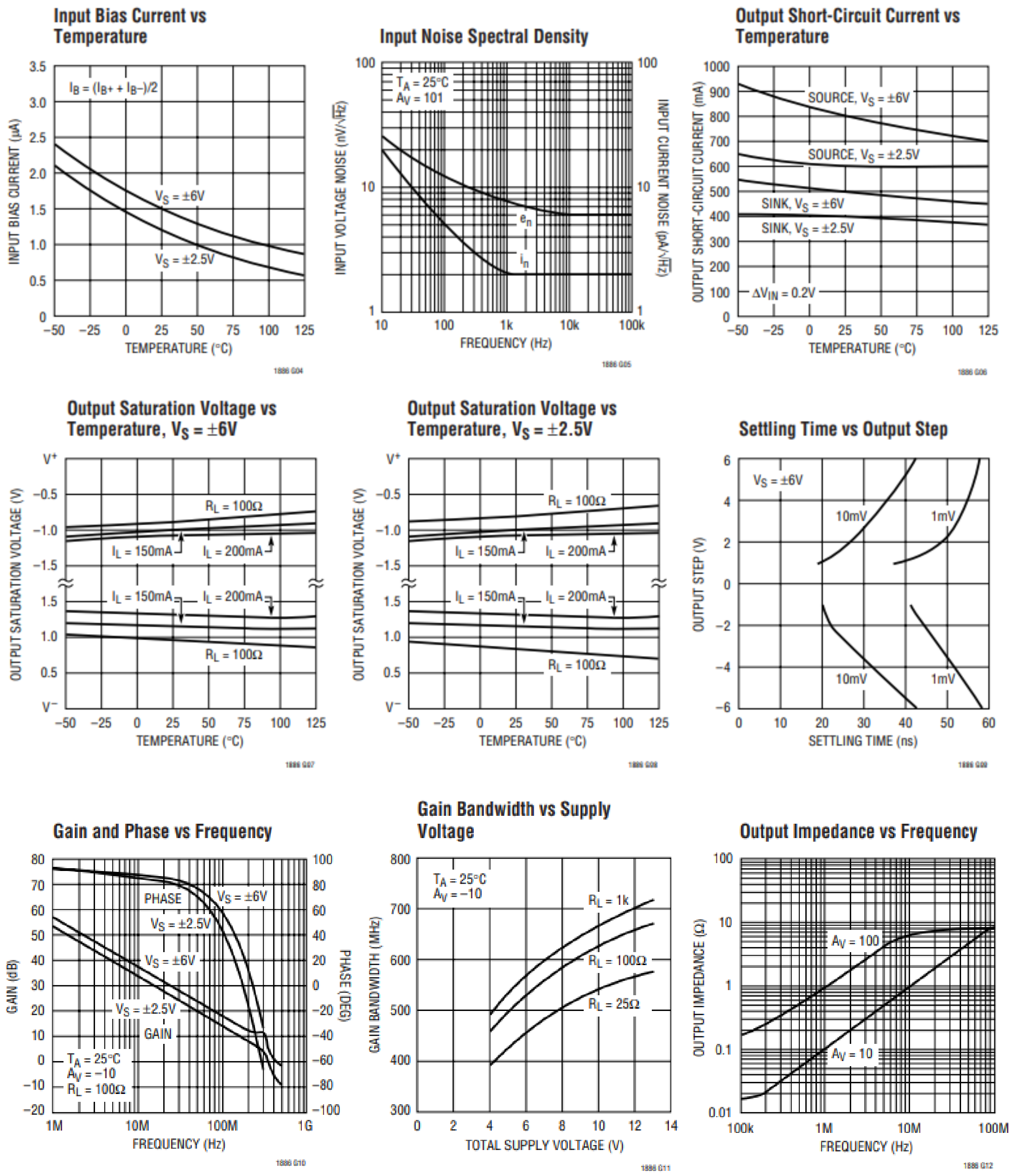
Input Common Mode Range vs Supply Voltage



Input Bias Current vs Input Common Mode Voltage



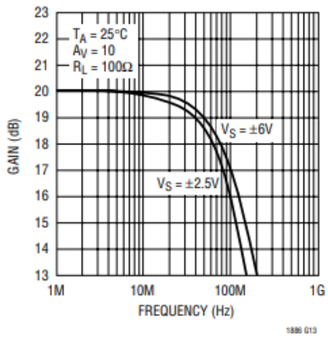
TYPICAL PERFORMANCE CHARACTERISTICS



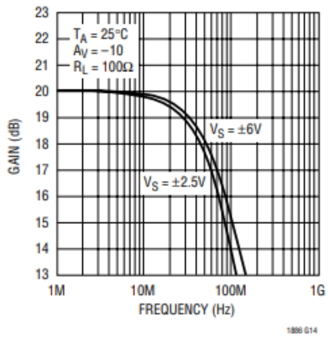
LT1886

TYPICAL PERFORMANCE CHARACTERISTICS

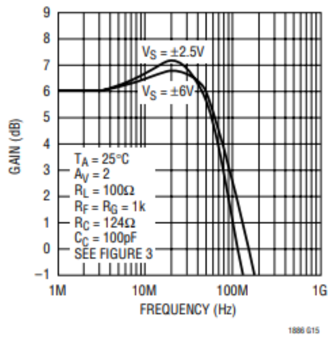
Frequency Response vs Supply Voltage, A_V = 10



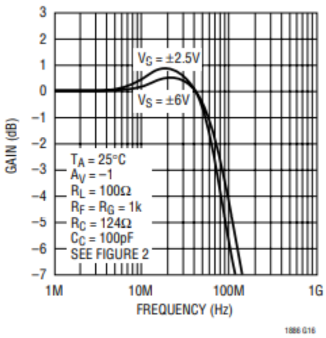
Frequency Response vs Supply Voltage, A_V = –10



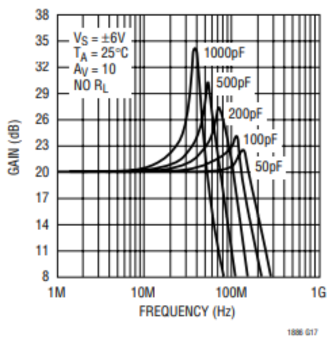
Frequency Response vs Supply Voltage, A_V = 2



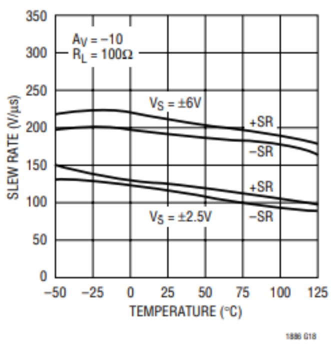
Frequency Response vs Supply Voltage, A_V = –1



Frequency Response vs Capacitive Load



Slew Rate vs Temperature

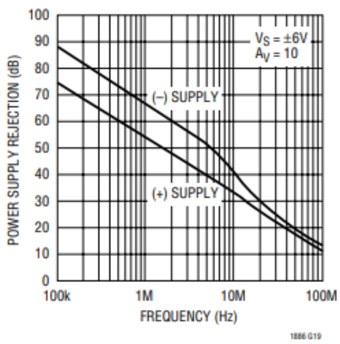


1886 G16

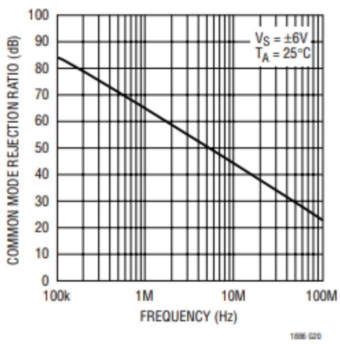
1886 G17

1886 G18

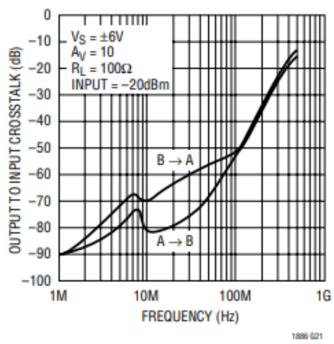
Power Supply Rejection vs Frequency



Common Mode Rejection Ratio vs Frequency



Amplifier Crosstalk vs Frequency



APPLICATIONS INFORMATION

Input Considerations

The inputs of the LT1886 are an NPN differential pair protected by back-to-back diodes (see the Simplified Schematic). There are no series protection resistors onboard which would degrade the input voltage noise. If the inputs can have a voltage difference of more than 0.7V, the input current should be limited to less than 10mA with external resistance (usually the feedback resistor or source resistor). Each input also has two ESD clamp diodes—one to each supply. If an input drive exceeds the supply, limit the current with an external resistor to less than 10mA.

The LT1886 design is a true operational amplifier with high impedance inputs and low input bias currents. The input offset current is a factor of ten lower than the input bias current. To minimize offsets due to input bias currents, match the equivalent DC resistance seen by both inputs. The low input noise current can significantly reduce total noise compared to a current feedback amplifier, especially for higher source resistances.

Layout and Passive Components

With a gain bandwidth product of 700MHz the LT1886 requires attention to detail in order to extract maximum performance. Use a ground plane, short lead lengths and a combination of RF-quality supply bypass capacitors (i.e., 470pF and 0.1µF). As the primary applications have high drive current, use low ESR supply bypass capacitors (1µF to 10µF). For best distortion performance with high drive current a capacitor with the shortest possible trace lengths should be placed between Pins 4 and 8. The optimum location for this capacitor is on the back side of the PC board. The DSL driver demo board (DC304) for this part uses a Taiyo Yuden 10µF ceramic (TMK432BJ106MM).

The parallel combination of the feedback resistor and gain setting resistor on the inverting input can combine with the input capacitance to form a pole which can cause frequency peaking. In general, use feedback resistors of 1kΩ or less.

Thermal Issues

The LT1886 enhanced θ_{JA} SO-8 package has the V^- pin fused to the lead frame. This thermal connection increases the efficiency of the PC board as a heat sink. The PCB material can be very effective at transmitting heat between the pad area attached to the V^- pin and a ground or power plane layer. Copper board stiffeners and plated through-holes can also be used to spread the heat generated by the device. Table 1 lists the thermal resistance for several different board sizes and copper areas. All measurements were taken in still air on 3/32" FR-4 board with 2oz copper. This data can be used as a rough guideline in estimating thermal resistance. The thermal resistance for each application will be affected by thermal interactions with other components as well as board size and shape.

Table 1. Fused 8-Lead SO Package

COPPER AREA (2oz) TOPSIDE	BACKSIDE	TOTAL COPPER AREA	θJA
2500 sq. mm	2500 sq. mm	5000 sq. mm	80°C/W
1000 sq. mm	2500 sq. mm	3500 sq. mm	92°C/W
600 sq. mm	2500 sq. mm	3100 sq. mm	96°C/W
180 sq. mm	2500 sq. mm	2680 sq. mm	98°C/W
180 sq. mm	1000 sq. mm	1180 sq. mm	112°C/W
180 sq. mm	600 sq. mm	780 sq. mm	116°C/W
180 sq. mm	300 sq. mm	480 sq. mm	118°C/W
180 sq. mm	100 sq. mm	280 sq. mm	120°C/W
180 sq. mm	0 sq. mm	180 sq. mm	122°C/W

Calculating Junction Temperature

The junction temperature can be calculated from the equation:

$T_J = (P_D)(\theta_{JA}) + T_A$

T_J = Junction Temperature

T_A = Ambient Temperature

P_D = Device Dissipation

θ_{JA} = Thermal Resistance (Junction-to-Ambient)

As an example, calculate the junction temperature for the circuit in Figure 1 assuming an 85°C ambient temperature.

The device dissipation can be found by measuring the supply currents, calculating the total dissipation and then subtracting the dissipation in the load.

APPLICATIONS INFORMATION

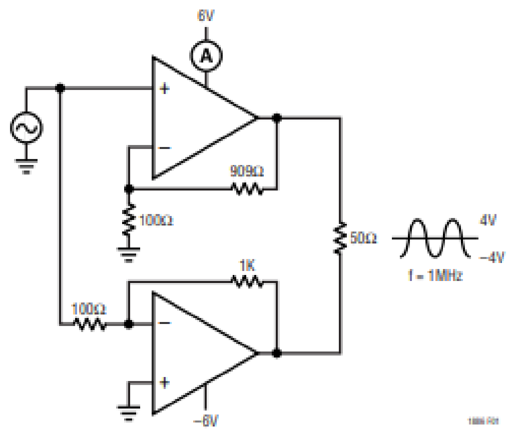


Figure 1. Thermal Calculation Example

The dissipation for the amplifiers is:

$P_D = (63.5mA)(12V) – (4V/\sqrt{2})^2/(50) = 0.6W$

The total package power dissipation is 0.6W. When a 2500 sq. mm PC board with 2oz copper on top and bottom is used, the thermal resistance is 80°C/W. The junction temperature T_J is:

$T_J = (0.6W)(80°C/W) + 85°C = 133°C$

The maximum junction temperature for the LT1886 is 150°C so the heat sinking capability of the board is adequate for the application.

If the copper area on the PC board is reduced to 180 sq. mm the thermal resistance increases to 122°C/W and the junction temperature becomes:

$T_J = (0.6W)(122°C/W) + 85°C = 158°C$

which is above the maximum junction temperature indicating that the heat sinking capability of the board is inadequate and should be increased.

Capacitive Loading

The LT1886 is stable with a 1000pF capacitive load. The photo of the small-signal response with 1000pF load in a gain of 10 shows 50% overshoot. The photo of the large-signal response with a 1000pF load shows that the output slew rate is not limited by the short-circuit current. The Typical Performance Curve of Frequency Response vs Capacitive Load shows the peaking for various capacitive loads.

This stability is useful in the case of directly driving a coaxial cable or twisted pair that is inadvertently unterminated. For best pulse fidelity, however, a termination resistor of value equal to the characteristic impedance of the cable or twisted pair (i.e., 50Ω/75Ω/100Ω/135Ω) should be placed in series with the output. The other end of the cable or twisted pair should be terminated with the same value resistor to ground.

Compensation

The LT1886 is stable in a gain 10 or higher for any supply and resistive load. It is easily compensated for lower gains with a single resistor or a resistor plus a capacitor. Figure 2 shows that for inverting gains, a resistor from the inverting node to AC ground guarantees stability if the parallel combination of R_C and R_G is less than or equal to $R_F/9$. For lowest distortion and DC output offset, a series capacitor, C_C, can be used to reduce the noise gain at lower frequencies. The break frequency produced by R_C and C_C should be less than 15MHz to minimize peaking. The Typical Curve of Frequency Response vs Supply Voltage, $A_V = –1$ shows less than 1dB of peaking for a break frequency of 12.8MHz.

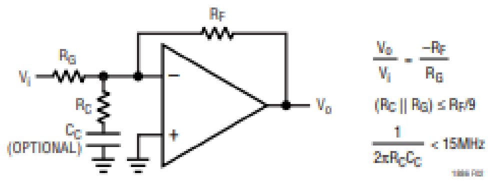


Figure 2. Compensation for Inverting Gains

Figure 3 shows compensation in the noninverting configuration. The R_C, C_C network acts similarly to the inverting case. The input impedance is not reduced because the network is bootstrapped. This network can also be placed between the inverting input and an AC ground.

Another compensation scheme for noninverting circuits is shown in Figure 4. The circuit is unity gain at low frequency and a gain of $1 + R_F/R_G$ at high frequency. The DC output offset is reduced by a factor of ten. The techniques of

APPLICATIONS INFORMATION

Figures 3 and 4 can be combined as shown in Figure 5. The gain is unity at low frequencies, $1 + R_F/R_G$ at mid-band and for stability, a gain of 10 or greater at high frequencies.

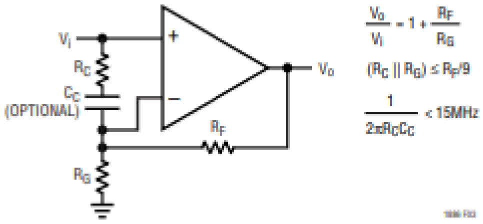


Figure 3. Compensation for Noninverting Gains

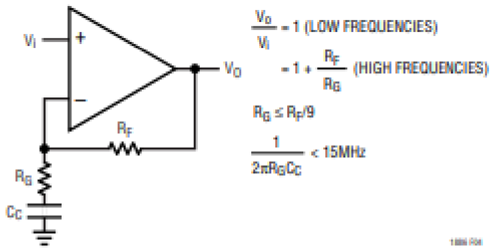


Figure 4. Alternate Noninverting Compensation

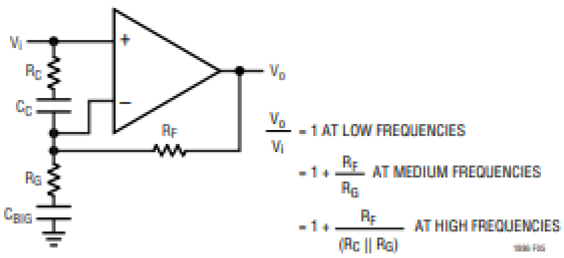


Figure 5. Combination Compensation

Output Loading

The LT1886 output stage is very wide bandwidth and able to source and sink large currents. Reactive loading, even isolated with a back-termination resistor, can cause ringing at frequencies of hundreds of MHz. For this reason, any design should be evaluated over a wide range of output conditions. To reduce the effects of reactive loading, an optional snubber network consisting of a series RC across the load can provide a resistive load at high frequency. Another option is to filter the drive to the load. If a back-termination resistor is used, a capacitor to ground at the load can eliminate ringing.

Line Driving Back-Termination

The standard method of cable or line back-termination is shown in Figure 6. The cable/line is terminated in its characteristic impedance (50Ω, 75Ω, 100Ω, 135Ω, etc.). A back-termination resistor also equal to to the chararacteristic impedance should be used for maximum pulse fidelity of outgoing signals, and to terminate the line for incoming signals in a full-duplex application. There are three main drawbacks to this approach. First, the power dissipated in the load and back-termination resistors is equal so half of the power delivered by the amplifier is wasted in the termination resistor. Second, the signal is halved so the gain of the amplifer must be doubled to have the same overall gain to the load. The increase in gain increases noise and decreases bandwidth (which can also increase distortion). Third, the output swing of the amplifier is doubled which can limit the power it can deliver to the load for a given power supply voltage.

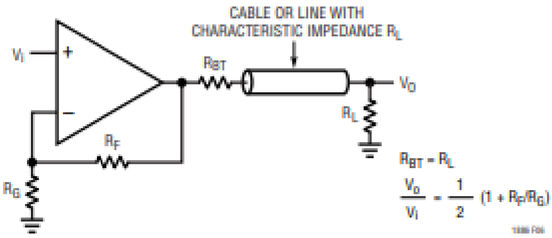


Figure 6. Standard Cable/Line Back-Termination

An alternate method of back-termination is shown in Figure 7. Positive feedback increases the effective back-termination resistance so R_{BT} can be reduced by a factor of n. To analyze this circuit, first ground the input. As $R_{BT} = R_L/n$, and assuming $R_{P2} >> R_L$ we require that:

$V_a = V_o (1 - 1/n)$ to increase the effective value of R_{BT} by n.

$V_p = V_o (1 - 1/n)/(1 + R_F/R_G)$

$V_o = V_p (1 + R_{P2}/R_{P1})$

Eliminating Vp, we get the following:

$(1 + R_{P2}/R_{P1}) = (1 + R_F/R_G)/(1 - 1/n)$