MOTOR CONTROL- SPEED

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This work is dedicated to

my beloved parents, family and friends.

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ABSTRACT

An induction motor can be controlled by using various methods either it is closed loop or open loop. There are many techniques of controlling the speed either by varying the slip by changing rotor resistance or terminal voltage and varying synchronous speed by changing number of poles or supply frequency. Changing of input frequency is more reliable as it is applicable to all induction motors. The speed of the motor can be controlled by using the pulse width modulation (PWM) method. This paper is mainly about the open-loop speed control method for a single phase induction motor. An open loop controller which is also known as the non-feedback controller is a type of controller that computes its input into a system using only the current state and its model of the system. The control scheme is based on the constant volts per hertz (V/f) method. To verify the functionality of the controller, a full working prototype is built. The prototype consists of an IGBT Full-Bridge Inverter, a motor and an analog controller with PWM. By varying the frequency fed into the PWM unit, the speed of the motor can be controlled. The speed of the motor increased steadily based on the frequency supplied by the control signal until it reached the desired speed and remained constant at the speed.

ABSTRAK

Motor aruhan boleh dikawal dengan menggunakan pelbagai kaedah sama ada ia ditutup gelung atau gelung terbuka. Terdapat berbagai kaedah mengawal kelajuan sama ada dengan mengubah slip dengan menukar rintangan pemutar atau voltan terminal dan pelbagai kelajuan segerak dengan menukar bilangan kutub atau kekerapan bekalan. Berubah-ubah frekuensi input yang lebih dipercayai kerana ia terpakai kepada semua motor induksi. Kelajuan motor boleh dikawal dengan menggunakan modulasi lebar denyut (PWM) kaedah. Kertas kerja ini adalah sebahagian besarnya mengenai kaedah gelung terbuka kawalan kelajuan motor aruhan satu fasa. Pengawal gelung terbuka yang juga dikenali sebagai pengawal bukan maklum balas adalah sejenis pengawal yang mengira input ke dalam sistem menggunakan hanya keadaan semasa dan model sistem. Skim kawalan berdasarkan volt malar setiap hertz (V / f) kaedah. Untuk memastikan keberkesanan fungsi pengawal, prototaip kerja yang penuh dibina. Prototaip terdiri daripada IGBT Penuh Bridge Inverter, motor dan pengawal analog dengan PWM. Dengan mengubah frekuensi yang disuap ke dalam unit PWM, kelajuan motor boleh dikawal. Kelajuan motor terus meningkat berdasarkan kekerapan yang dibekalkan oleh isyarat kawalan sehingga ia mencapai kelajuan yang dikehendaki dan kekal pada kelajuan.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	MEANINGS
PWM	PULSE WIDTH MODULATION
DC	DIRECT CURRENT
AC	ALTERNATING CURRENT
Volts/Hz	VOLTAGE PER HERTZ
Hz	HERTZ
V/f	VOLTAGE PER FREQUENCY
N_S	SYNCHRONOUS SPEED
Aux.	AUXILLARY WINDING
1ϕ	SINGLE PHASE
V	VOLTS
C	CAPACITOR
I_a	AUXILLARY WINDING CURRENT
I_m	MAIN WINDING CURRENT
IGBT	INSULATED GATE BIPOLAR TRANSISTOR
kW	KILOWATT
A	AMPERE
rpm	ROTATION PER MINUTE
PCB	PRINTED CIRCUIT BOARD
f	SUPPLY FREQUENCY

p	**NUMBER OF POLES**
ADC	**ANALOG TO DIGITAL CONVERTER**
PID	**PROPORTIONAL-INTEGRAL-DERIVATIVES**
P	**PROPORTIONAL**
I	**INTEGRAL**
D	**DERIVATIVES**

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CHAPTER 1

INTRODUCTION

1.0 Introduction

The thesis is proposed to control the speed of a single phase induction motor using the Pulse Width Modulation technique which is signaled by the triangle waveform and sinusoidal waveform. The single phase induction motor should be able to produce a system that can control the speed by varying the frequency.

This project is concerned on controlling the speed of a single phase induction motor using the Pulse Width Modulation (PWM) method. It is an open loop system. The signal of the pulse-width modulation (PWM) is generated by the triangle waveform and sinusoidal waveform. The single phase induction motor is supplied by the AC power inverted from a 300V DC voltage. The speed should be increased gradually until it reached its maximum speed which is desired by the voltage apply. The motor will start to rotate slowly to its desired speed when the circuit is ON. When the control signal reached its desired speed, it will remain constant.

1.1 Background

Nowadays, there are many techniques used to control the speed of an induction motor. One of the methods is by altering voltage applied to the stator winding to produce less voltage per turn. By changing the voltage per turns on motor, the voltage per turn as well as the flux will decrease while the slip will increase thus, slower the speed under load. Another method is by changing the number of turns using tapped windings and maintained the voltage applied.

The open loop Volts/Hz control of an induction motor is far the most popular method of speed control because of its simplicity and these types of motors are widely used in industry. Traditionally, induction motors have been used with open loop 60Hz power supplies for constant speed applications.

As for this project, the speed of a single phase induction motor is controlled by using PWM technique via open loop V/f control. The purpose of a motor speed controller is to produce a signal that represents the demanded speed, and to drive the motor at that speed.

1.2 Problem Statement

Motors can be easily damaged without the implementation of control methodology in the system. Normally, the desired performance characteristics of control systems are specified in terms of the transient response which exhibits damped oscillation before reaching steady state. As for motor, having a high overshoot is an undesired condition since the starting current is very high. Thus, control methodology such as Pulse Width Modulation is used to limit the maximum overshoot as well as to reduce the starting current of the motor.

1.3 Objective

This project is set to achieve one main objective which is to design and develop a system that can control the speed by varying the frequency of the sinusoidal waveform fed in the Pulse Width Modulation.

1.4 Scope of Project

This project is developed to control the speed of the single phase AC motor. The DC voltage is used to supply the inverter which changes DC to AC voltage to run the single phase induction motor. The speed of the motor is controlled by varying the frequency fed in the PWM. It is an open loop system.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter is focused on the literature review for each component involved in this project. All the components are described in details based on the finding during the completion of this project.

2.1 Induction Motor

Induction motor which is also known as the AC motor can be grouped into two general groups which are conduction motors and induction motors. Induction motors transferred the power electromagnetically as it is induced in the rotor. Differ from conduction motors that transfer the power by physical connections such as carbon brushes, slip rings or commutators.

Single phase AC motors come in many types such as split phase motor, capacitor start motor, capacitor start-run motor, shaded-pole induction motor and universal motor. The single phase induction motors are classified based on the starting method. An appropriate selection of these motors are depends on the starting and running torque requirements of the load, the duty cycle and the limitations on starting and running current drawn from the supply by these motors.

As for this project, single phase capacitor start and run motor is used to control the speed. Capacitor start and run motor is one of the split phase motor which normally operates at a speed, N close to synchronous speed, Ns. A Small voltage variation close to the rated value is therefore required for the control [1]. Capacitor is used to improve the starting and running performance of the single phase inductions motor. The connection of a single phase capacitor start and run motor is shown in Figure 2.1.1.

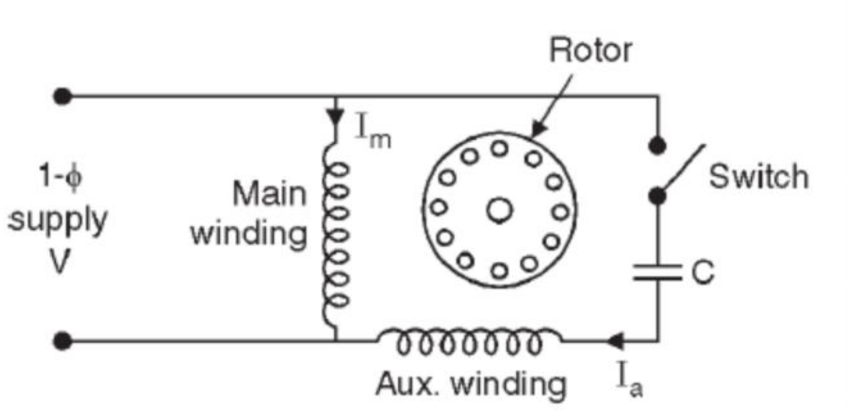

Figure 2.1.1- Connection of capacitor start and run motor

2.2 Pulse-Width Modulation (PWM)

The research on speed control of a motor has been done years ago. As for this project, it will focus more on controlling the speed of the motor by using Pulse Width Modulation (PWM) technique.

The inverter is connected to PWM as been said by Prasad N Enjeti, et.al (1990) in the journal entitled “A new PWM Speed Control System for High Performance AC Motor Drives”, Pulse Width Modulation (PWM) technique is an effective way of controlling the speed of induction motor, and thus allowing the motor to be applied in the area requiring speed control [1]. It is because by using such techniques, the pattern of PWM can be chosen to optimise various objectives functions.

PWM can be used to minimise the voltage harmonics, obtaining minimum losses in the motor as well as reducing the torque pulsation and minimising the generated acoustic noise. In the journal, it has been proven that PWM technique giving an advantage of 50-percent less switching frequency. Smooth operation of the motor control can be obtained when using PWM method as the absence of current transient which provides highly quality of output voltage and current.

There are many techniques to control the speed of induction motor. The methods are varying the slip by changing rotor resistance or terminal voltage and varying synchronous speed by changing number of poles or supply frequency. Another method is by changing rotor resistance requires wound-rotor induction motor and any resistances inserted to the rotor circuit. This technique will reduce the efficiency of the machines. Changing terminal voltage has limited range of speed control while changing the number of poles requires a motor with special stator windings.

M. F. Romlie et.al, (2008) in their research paper of PWM Technique to Control Speed of Induction Motor using Matlab/xPC Target Box proposed that PWM technique is used to control the electrical frequency of the 3-phase voltage supplied to the motor from the Insulated Gate Bipolar Transistors (IGBTs) inverter circuit, hence allowing the speed to be varied with respect to the frequency of the reference signal, input to the PWM signal generator [2]. The rate of rotation of its magnetic fields or the synchronous speed affect the speed of induction motor since it is directly proportional to electrical frequency.

As been said by Stephen J. Chapman (2005), the speed of induction motor depends on the rate of rotation of its magnetic fields or the synchronous speed, which is directly proportional to any change of electrical frequency [4]. In this paper, frequency of the induction motor is varied to produce desired speed of induction motor. The speed will increase gradually until it reached its maximum speed which makes the speed constant depending on the frequency chosen.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this project. It involved the discussion of the project workflow, followed by the system designed and the tools that are applied in this work.

3.2 Project Workflow

The block diagram shown in Figure 3.2.1 is about the open loop system involved in this project.

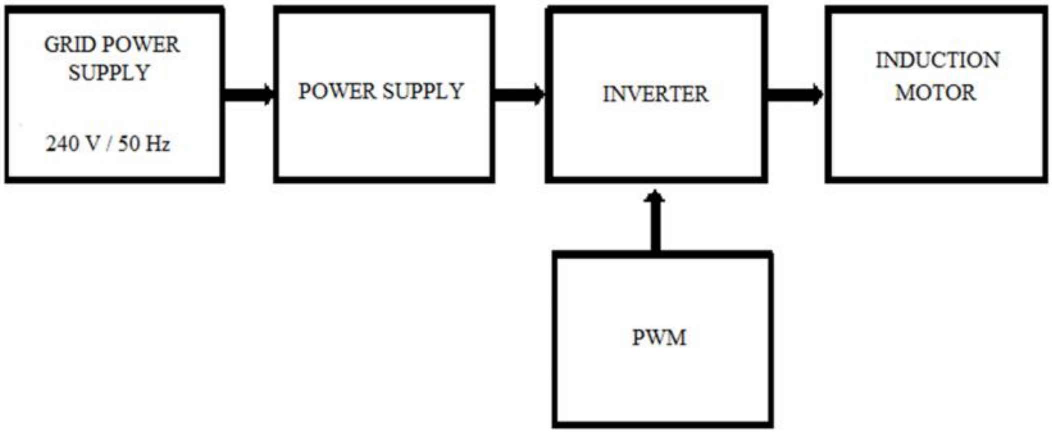

Figure 3.2.1- Open Loop System

The Gantt chart of the project is as in Figure 3.2.2.

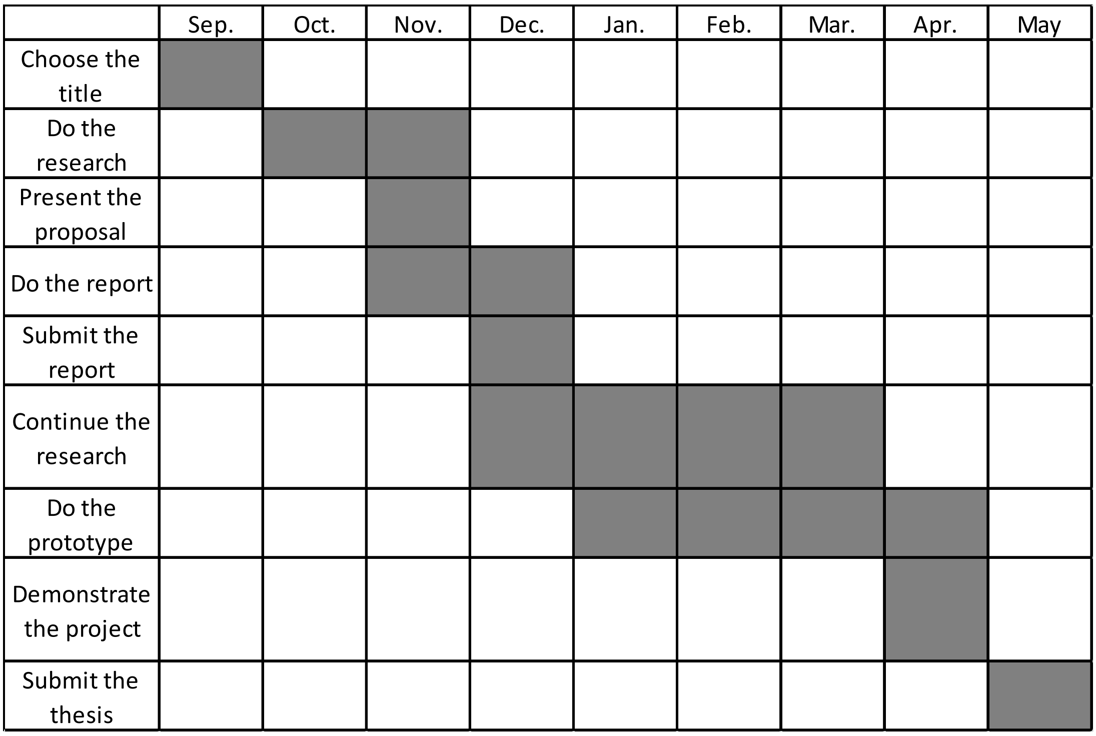

Figure 3.3.2- Gantt Chart

3.3 System Designed

In order to control the speed of the single phase induction motor, the method of controlling the voltage applied to the stator of the motor. A DC supply of 300V is connected to the full bridge inverter which is then produced AC power to run the single phase AC motor.

The inverter of Insulated Gate Bipolar Transistors (IGBT) is connected to the motor. The type of single phase AC motor used in this project is single phase capacitor start and run motor. The inverter is controlled by Pulse Width Modulation (PWM) technique. The PWM is fed with the triangle waveform and sinusoidal waveform generated from the function generator.

The output produced by the PWM is signaled into the voltage translator to switch ON and OFF the inverter. The circuit diagram of the overall project of Motor Control-Speed is shown in Figure 3.3.1 as below:

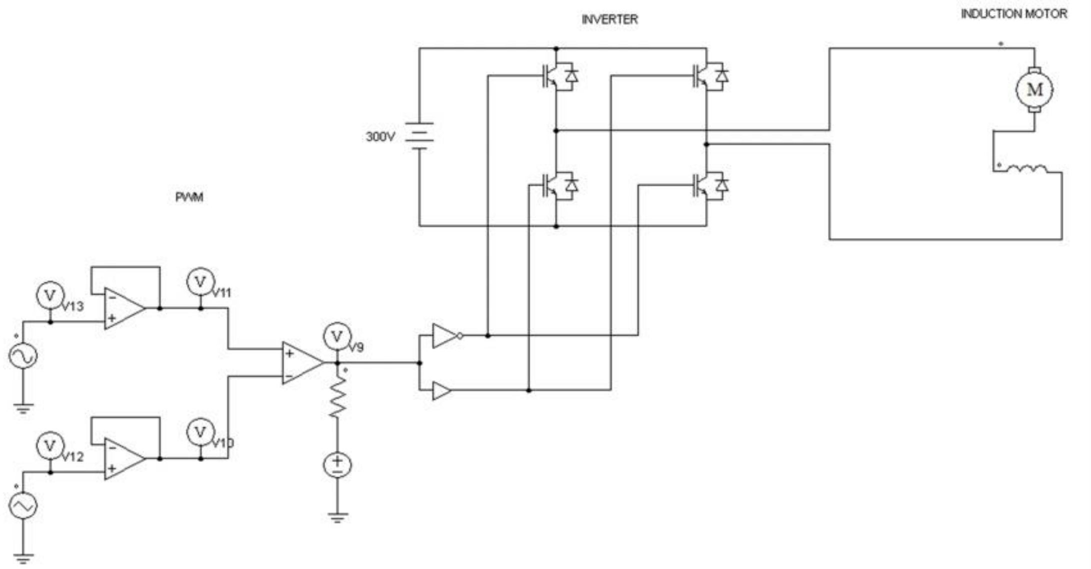

Figure 3.3.1- Overall Project Diagram

The pulse width modulation (PWM) is used to switch ON and OFF the inverter. The input of the PWM comes from the waveforms produced by the function generator. The sinusoidal and triangle waveforms are generated by using the function generator. The frequency of the sinusoidal waveform is set to 500Hz while the frequency of the triangle waveform is set to 50 kHz. The triangle waveform is fixed and only the sinusoidal waveform is varied in 100 Hz step to produce the desired speed of the induction motor. Figure 3.3.2 shows the PWM circuit used in this project.

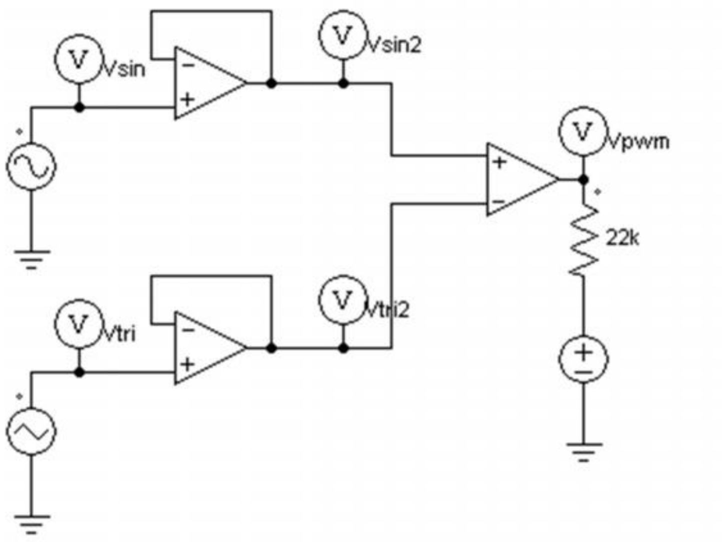

Figure 3.3.2- PWM circuit

3.3 Instruments Used

The block diagram of overall project is shown in Figure 3.3.1.

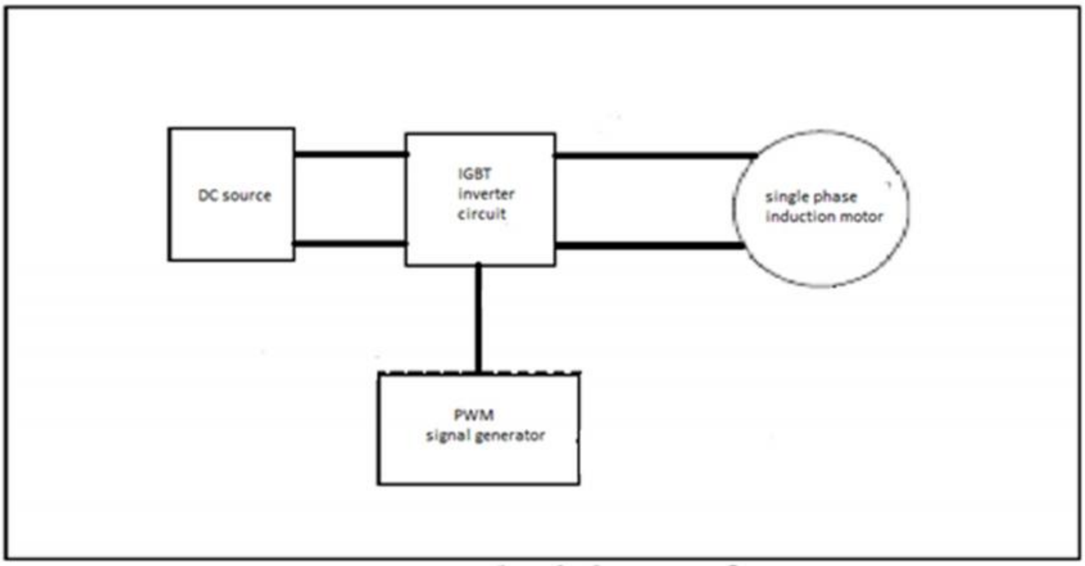

Figure 3.3.1- Overall Project Block Diagram

This project requires the hardware as shown in Figure 3.3.1. The hardware that used in this project is DC power supply, inverter and a single phase induction motor. The motor ratings are shown in Table 3.3.1. The software used in this project is PSim. It is used to prove the signal produced by the function generators in terms of Pulse Width Modulation (PWM) waveform.

Motor Ratings
Power: 0.75kW Voltage: 240V Current: 4.79 A Frequency: 50Hz Speed: 1400 rpm

Table 3.3.1- Motor ratings

The load resistor is used to test the functionality of the open loop system as it replaced the induction motor at the beginning. Basically, the hardware used in this project involved:

i. DC power supply
ii. Single phase capacitor start and run motor
iii. Semikron single phase inverter SKS 15F B2CI 03 V12
iv. Function generator
v. Oscilloscope
vi. PWM
vii. Load resistor

Figures below show the hardware and components used in this project.

Figure 3.3.2- 300 V DC power supply

Figure 3.3.3- Semikron single phase inverter SKS 15F B2CI 03 V12

Figure 3.3.4- Single phase induction motor

Figure 3.3.5- DC power supply

Figure 3.3.6- Function Generator- Triangle waveform

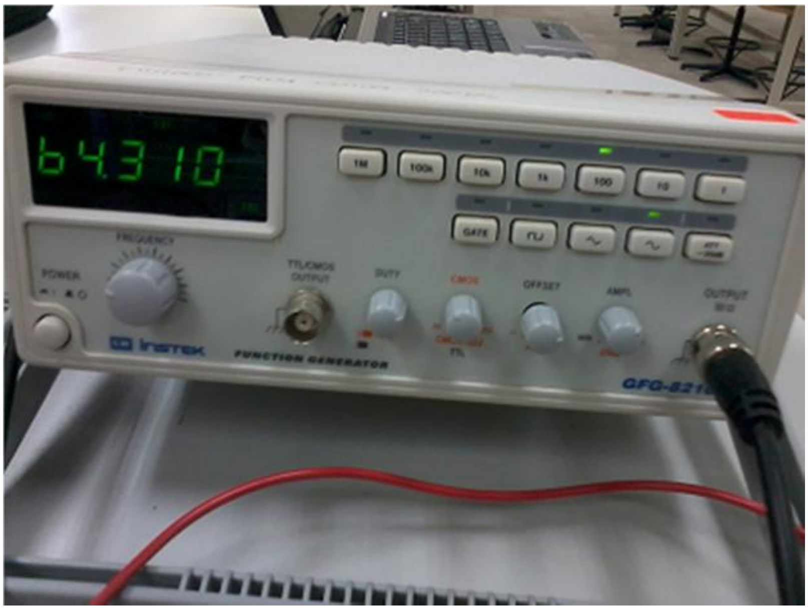

Figure 3.3.7- Function Generator- Sinusoidal Waveform

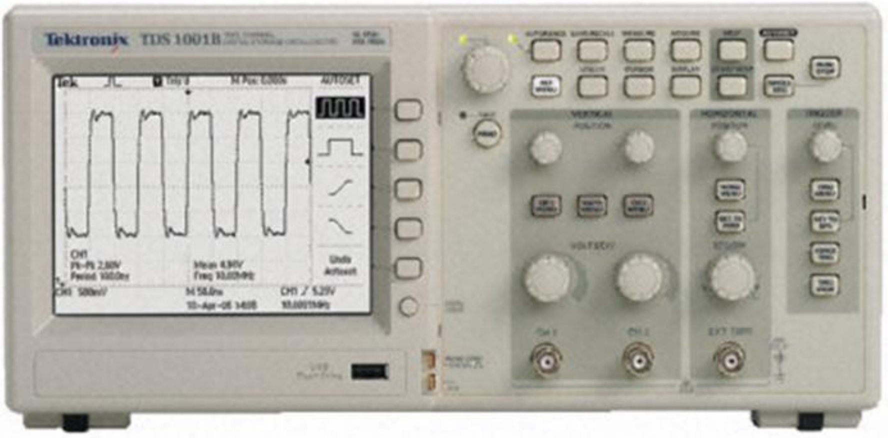

Figure 3.3.8- Oscilloscope

Figure 3.3.9- Load Resistor

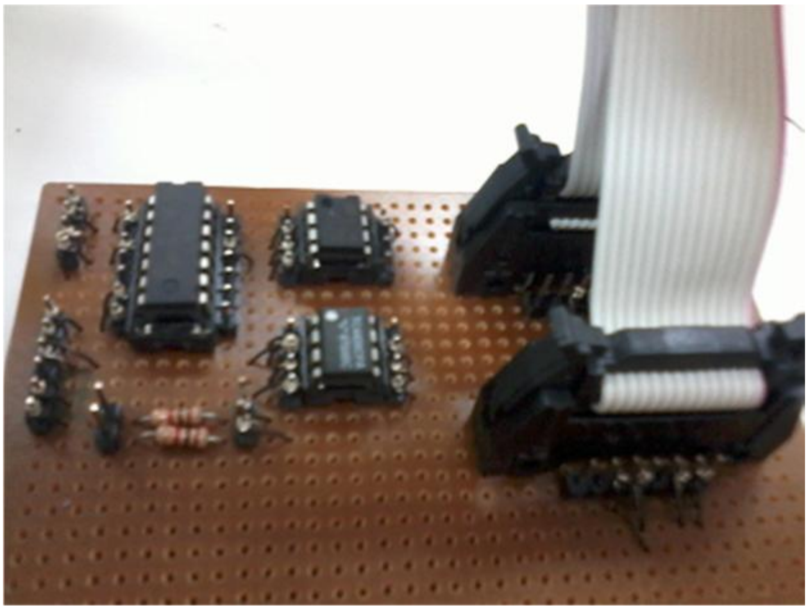

Figure 3.3.10- Project PCB board

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

This chapter is mainly about the result obtained throughout the project and discussion based on the analysis of the result.

4.1 Results

Here are the results obtained throughout this project. Figure 4.2.1 and Figure 4.2.2 show the output of Pulse Width Modulation (PWM) when the frequencies of the sinusoidal waveforms are set to 750 Hz and 950 Hz, respectively.

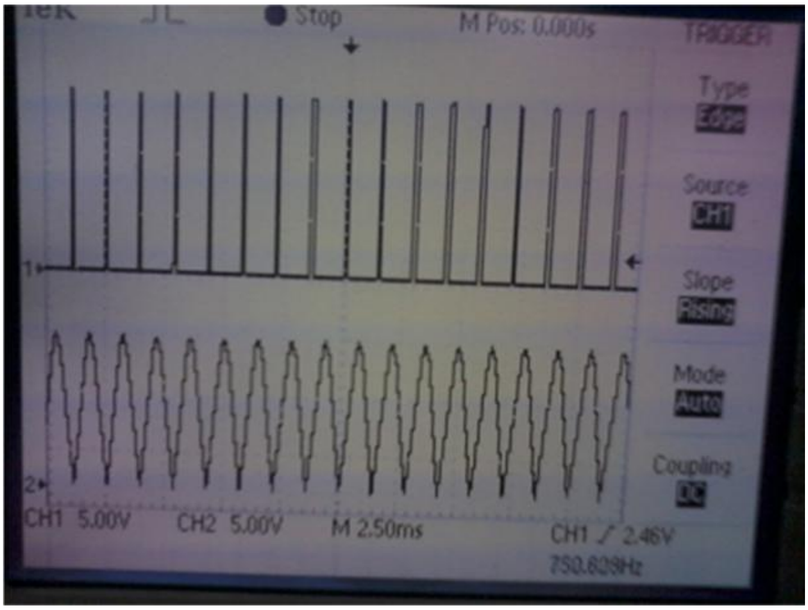

Figure 4.2.1- PWM output when the frequency is set to 750 Hz

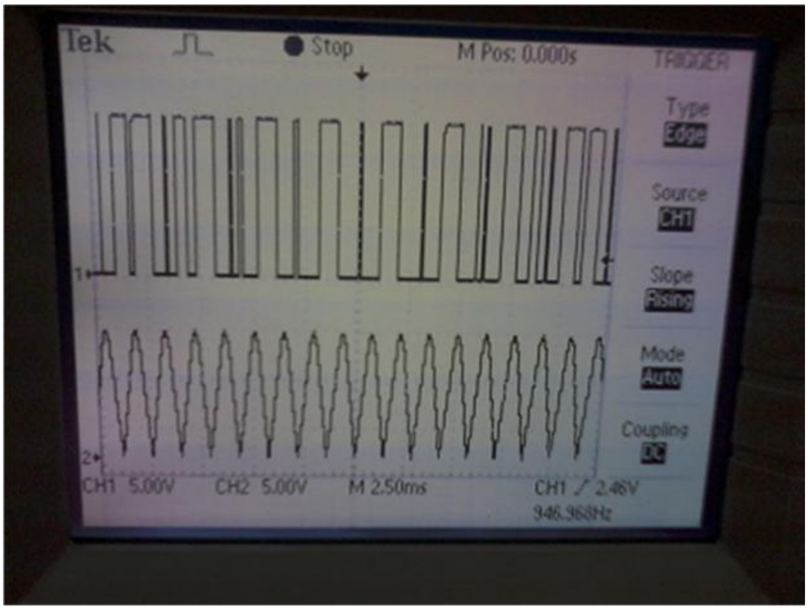

Figure 4.2.2- PWM output when the frequency is set to 950 Hz

Table 4.2.1 shows the speed in rpm with the proportional frequency of sinusoidal waveform.

Frequency (f/Hz)	Speed (n_s/rpm)
500	15 000
550	16 500
600	18 000
650	19 500
700	21 000
750	22 500
800	24 000
850	25 500
900	27 000
950	28 500

Table 4.2.1- Speed produced by the motor

Next figures show the PWM signal simulated by using the PSim where triangle and sinusoidal waveforms are generated to produce the PWM signal.

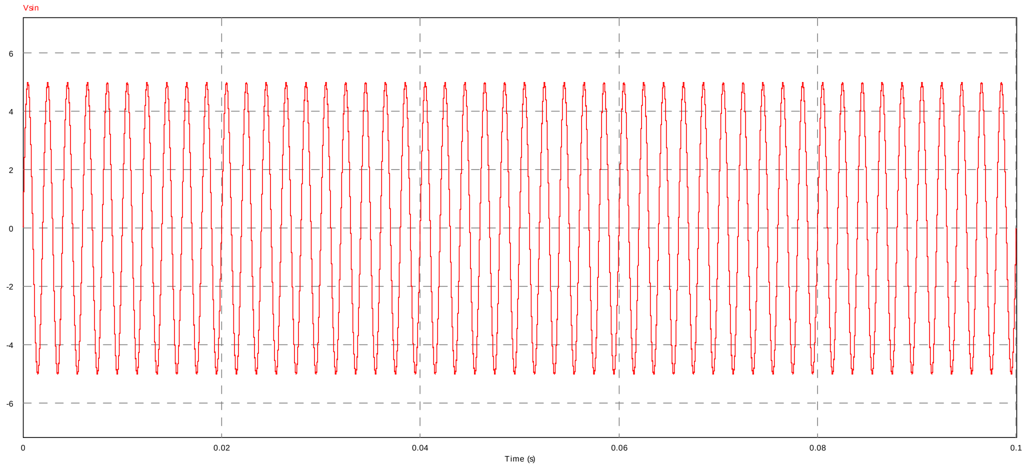

Figure 4.2.3- Triangle wave from function generator

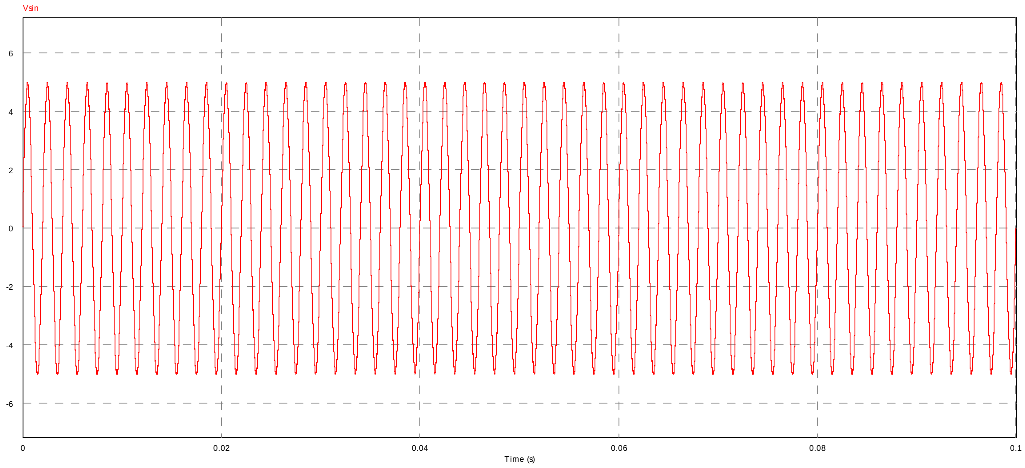

Figure 4.2.4- Sinusoidal waveform

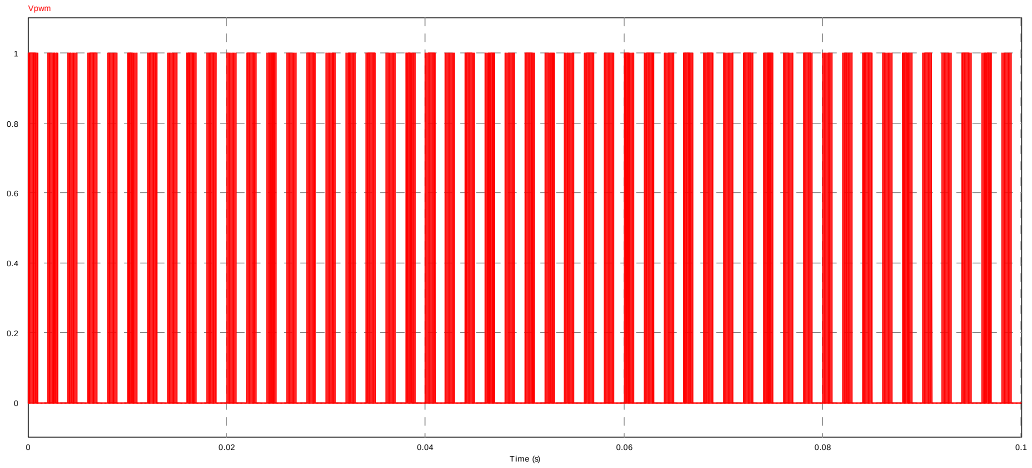

Figure 4.2.5- PWM signal waveform

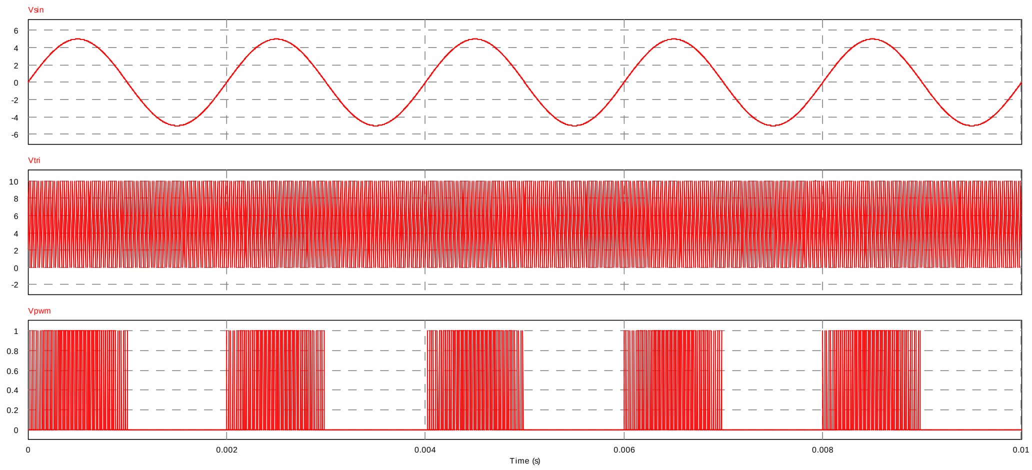

Figure 4.2.6- Overall PWM circuit waveforms

4.2 Discussion

Based on the overall project, the speed of the single phase induction motor is controlled by using the PWM technique. The PWM gives the signal to the inverter to switch on and off the IGBTs in order to run the inverter. The inverter is used to convert the DC to AC as it is the induction motor. The speed of the motor measured is as shown in Table 4.2.1. It shows that the speed produced is increased when the frequency of the sinusoidal waveform is increased. There are 3 types of speed control of a single phase induction motor which are varying the rotor resistance, varying the supply voltage and varying the supply voltage and supply frequency. As for this project, it chose to control the speed of the induction motor by varying the supply voltage and frequency.

The purpose of a motor speed controller is to take a signal representing the demanded speed and to drive a motor at that speed. Pulse width modulation (PWM) is a very efficient way to provide an intermediate amount of electrical power between fully on and fully off. Based on the result obtained, the PWM produced a duty cycle which depends on the triangle waveform and the sinusoidal waveform. The triangle waveform should have greater frequency than the sinusoidal waveform in order to produce the PWM signal waveform or also known as the duty cycle which is in the form of square waveform. As the sinusoidal waveform is changed, the duty cycle is also changed.

In an open loop control system the controlling parameters are fixed or set by an operator and the system finds its own equilibrium state. In the case of a motor the desired operating equilibrium may be the motor speed or its angular position. The controlling parameters such as the supply voltage or the load on the motor may or may not be under the control of the operator. If any of the parameters such as the load or the supply voltage are changed then the motor will find a new equilibrium state, in this case it will settle at a different speed. The actual equilibrium state can be changed by forcing a change in the parameters over which the operator has control.

The speed of AC motors generally depends on the frequency of the supply voltage and the number of magnetic poles per phase in the stator. The Volts/Hertz control is needed for speed control of induction motors. In an open loop system the control system converts the desired speed to a frequency reference input to a variable frequency, variable voltage inverter. At the same time it multiplies the frequency reference by the Volts/Hertz characteristic ratio of the motor to provide the corresponding voltage reference to the inverter. Changing the speed reference will then cause the voltage and frequency outputs from the inverter to change in unison.

When the stator winding is connected to a voltage supply, the current will flow in the windings, which also will induce the flux in the stator. The flux will rotate at a speed called a Synchronous Speed, n_s. The flux is called as rotating magnetic field. The speed is defined by the formula stated next page:

$$n_s = \frac{120\,f}{p} \tag{4.1}$$

Where; p = is the number of poles, and

f = frequency of supply

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter is involved of the conclusion of the overall project and the recommendations for the project.

5.1 Conclusion

Speed control of the single phase induction motor can be controlled by using the Pulse Width Modulation (PWM) technique which is signaled by the sinusoidal waveform and triangle waveform generated from the function generator. The single phase induction motor is able to produce a system that can control the speed at desired frequency and voltage. The open loop system is act like the variable frequency drive in order to control the speed of the motor.

5.3 Recommendations

In order to control the speed of the motor, there is a need to have the close loop feedback system instead of the open loop system as it allows the user to set a desired speed and the control system will automatically move the system to the desired speed and maintain it at that point thereafter. The open loop system is only required in a simple low cost and low power machines. In the closed loop system a speed feedback signal provided from a tacho-generator on the motor output shaft is used in the control loop to derive a speed error signal to drive a speed of an induction motor via Volts/Hertz control technique.

Nowadays, most of the equipment is used in digital form instead of the analog. Though it is not easy to handle as there is much work to be done, the digital form is produced more accurate result as it is designed with more decimal points. There is a need to have the analog to digital converter (ADC) to convert the analog signal produced by the speed sensor in order to measure the speed of the motor. The speed of a single phase induction motor controlled by using PWM technique can be improved by adding the PID controller.

The purpose of a motor speed controller is to produce a signal that represents the demanded speed, and to drive the motor at that speed. The theory show that the control with Proportional-Integral-Derivative (PID) Controller can improve in terms of percentage overshoot and steady state error. Proportional (P) is a form of anticipatory action which slows the speed to increase when approaching set-point. The variations are more smoothly corrected but an offset will occur between set and achieved speed. By adding an integral (I) term and derivative term to proportional (D) control can provide automatic and continuous elimination of any offset as the integral action operates in the steady state condition by shifting the proportional band upscale or downscale until the speed and set-point are synchronized.

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[6] M.Syed Jarnil, Asghar (1999) *Smooth Speed Control of Single-phase Induction Motors by Integral-Cycle Switching*. IEEE Transactions on Energy Conversion.

Available at: http://ieeexplore.ieee.org

[7] H., Hui Chin (2006) *All Digital Design and Implementation of Proportional-Integral-Derivative (PID) Controller*. Master Thesis. Paper 272.

Available at: http://uknowledge.uky.edu/gradschooltheses/272

APPENDICES

MOTOROLA

LM358, LM258, LM2904, LM2904V

Dual Low Power Operational Amplifiers

Utilizing the circuit designs perfected for recently introduced Quad Operational Amplifiers, these dual operational amplifiers feature 1) low power drain, 2) a common mode input voltage range extending to ground/V_{EE}, 3) single supply or split supply operation and 4) pinouts compatible with the popular MC1558 dual operational amplifier. The LM158 series is equivalent to one–half of an LM124.

These amplifiers have several distinct advantages over standard operational amplifier types in single supply applications. They can operate at supply voltages as low as 3.0 V or as high as 32 V, with quiescent currents about one–fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

- Short Circuit Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Single and Split Supply Operation
- Similar Performance to the Popular MC1558
- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation

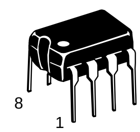
MAXIMUM RATINGS (T_A = +25°C, unless otherwise noted.)

Rating	Symbol	LM258 LM358	LM2904 LM2904V	Unit
Power Supply Voltages				Vdc
Single Supply	V_{CC}	32	26	
Split Supplies	V_{CC}, V_{EE}	±16	±13	
Input Differential Voltage Range (Note 1)	V_{IDR}	±32	±26	Vdc
Input Common Mode Voltage Range (Note 2)	V_{ICR}	–0.3 to 32	–0.3 to 26	Vdc
Output Short Circuit Duration	t_{SC}	Continuous		
Junction Temperature	T_J	150		°C
Storage Temperature Range	T_{stg}	–55 to +125		°C
Operating Ambient Temperature Range	T_A			°C
LM258		–25 to +85	–	
LM358		0 to +70	–	
LM2904		–	–40 to +105	
LM2904V		–	–40 to +125	

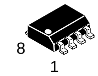
NOTES: 1. Split Power Supplies.
2. For Supply Voltages less than 32 V for the LM258/358 and 26 V for the LM2904, the absolute maximum input voltage is equal to the supply voltage.

DUAL DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

SEMICONDUCTOR TECHNICAL DATA

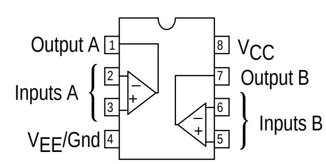


N SUFFIX
PLASTIC PACKAGE
CASE 626



D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

Device	Operating Temperature Range	Package
LM2904D	T_A = –40° to +105°C	SO–8
LM2904N		Plastic DIP
LM2904VD	T_A = –40° to +125°C	SO–8
LM2904VN		Plastic DIP
LM258D	T_A = –25° to +85°C	SO–8
LM258N		Plastic DIP
LM358D	T_A = 0° to +70°C	SO–8
LM358N		Plastic DIP

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 V, V_{EE} = Gnd, T_A = 25°C, unless otherwise noted.)

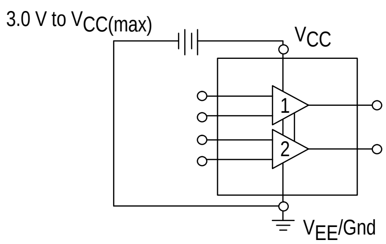
Characteristic	Symbol	LM258			LM358			LM2904			LM2904V			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage V_{CC} = 5.0 V to 30 V (26 V for LM2904, V), V_{IC} = 0 V to V_{CC} –1.7 V, $V_O \simeq$ 1.4 V, R_S = 0 Ω	V_{IO}													mV
T_A = 25°C		–	2.0	5.0	–	2.0	7.0	–	2.0	7.0	–	–	–	
$T_A = T_{high}$ (Note 1)		–	–	7.0	–	–	9.0	–	–	10	–	–	13	
$T_A = T_{low}$ (Note 1)		–	–	2.0	–	–	9.0	–	–	10	–	–	10	
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{high}$ to T_{low} (Note 1)	$\Delta V_{IO}/\Delta T$	–	7.0	–	–	7.0	–	–	7.0	–	–	7.0	–	µV/°C
Input Offset Current	I_{IO}	–	3.0	30	–	5.0	50	–	5.0	50	–	5.0	50	nA
$T_A = T_{high}$ to T_{low} (Note 1)		–	–	100	–	–	150	–	45	200	–	45	200	
Input Bias Current	I_{IB}	–	–45	–150	–	–45	–250	–	–45	–250	–	–45	–250	
$T_A = T_{high}$ to T_{low} (Note 1)		–	–50	–300	–	–50	–500	–	–50	–500	–	–50	–500	
Average Temperature Coefficient of Input Offset Current $T_A = T_{high}$ to T_{low} (Note 1)	$\Delta I_{IO}/\Delta T$	–	10	–	–	10	–	–	10	–	–	10	–	pA/°C
Input Common Mode Voltage Range (Note 2), V_{CC} = 30 V (26 V for LM2904, V)	V_{ICR}	0	–	28.3	0	–	28.3	0	–	24.3	0	–	24.3	V
V_{CC} = 30 V (26 V for LM2904, V), $T_A = T_{high}$ to T_{low}		0	–	28	0	–	28	0	–	24	0	–	24	
Differential Input Voltage Range	V_{IDR}	–	–	V_{CC}	–	–	V_{CC}	–	–	V_{CC}	–	–	V_{CC}	V
Large Signal Open Loop Voltage Gain R_L = 2.0 kΩ, V_{CC} = 15 V, For Large V_O Swing,	A_{VOL}	50	100	–	25	100	–	25	100	–	25	100	–	V/mV
$T_A = T_{high}$ to T_{low} (Note 1)		25	–	–	15	–	–	15	–	–	15	–	–	
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	–120	–	–	–120	–	–	–120	–	–	–120	–	dB
Common Mode Rejection R_S ≤ 10 kΩ	CMR	70	85	–	65	70	–	50	70	–	50	70	–	dB
Power Supply Rejection	PSR	65	100	–	65	100	–	50	100	–	50	100	–	dB
Output Voltage–High Limit ($T_A = T_{high}$ to T_{low}) (Note 1)	V_{OH}													V
V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C		3.3	3.5	–	3.3	3.5	–	3.3	3.5	–	3.3	3.5	–	
V_{CC} = 30 V (26 V for LM2904, V), R_L = 2.0 kΩ		26	–	–	26	–	–	22	–	–	22	–	–	
V_{CC} = 30 V (26 V for LM2904, V), R_L = 10 kΩ		27	28	–	27	28	–	23	24	–	23	24	–	
Output Voltage–Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, $T_A = T_{high}$ to T_{low} (Note 1)	V_{OL}	–	5.0	20	–	5.0	20	–	5.0	20	–	5.0	20	mV
Output Source Current V_{ID} = +1.0 V, V_{CC} = 15 V	$I_{O\,+}$	20	40	–	20	40	–	20	40	–	20	40	–	mA
Output Sink Current	$I_{O\,-}$													
V_{ID} = –1.0 V, V_{CC} = 15 V		10	20	–	10	20	–	10	20	–	10	20	–	mA
V_{ID} = –1.0 V, V_O = 200 mV		12	50	–	12	50	–	–	–	–	–	–	–	µA
Output Short Circuit to Ground (Note 3)	I_{SC}	–	40	60	–	40	60	–	40	60	–	40	60	mA
Power Supply Current ($T_A = T_{high}$ to T_{low}) (Note 1)	I_{CC}													mA
V_{CC} = 30 V (26 V for LM2904, V), V_O = 0 V, R_L = ∞		–	1.5	3.0	–	1.5	3.0	–	1.5	3.0	–	1.5	3.0	
V_{CC} = 5 V, V_O = 0 V, R_L = ∞		–	0.7	1.2	–	0.7	1.2	–	0.7	1.2	–	0.7	1.2	

NOTES: 1. T_{low} = –40°C for LM2904; = –40°C for LM2904V; = –25°C for LM258; = 0°C for LM358
T_{high} = +105°C for LM2904; = +125°C for LM2904V; = +85°C for LM258; = +70°C for LM358

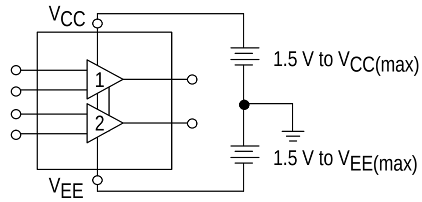
2. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is V_{CC} –1.7 V.

3. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Single Supply

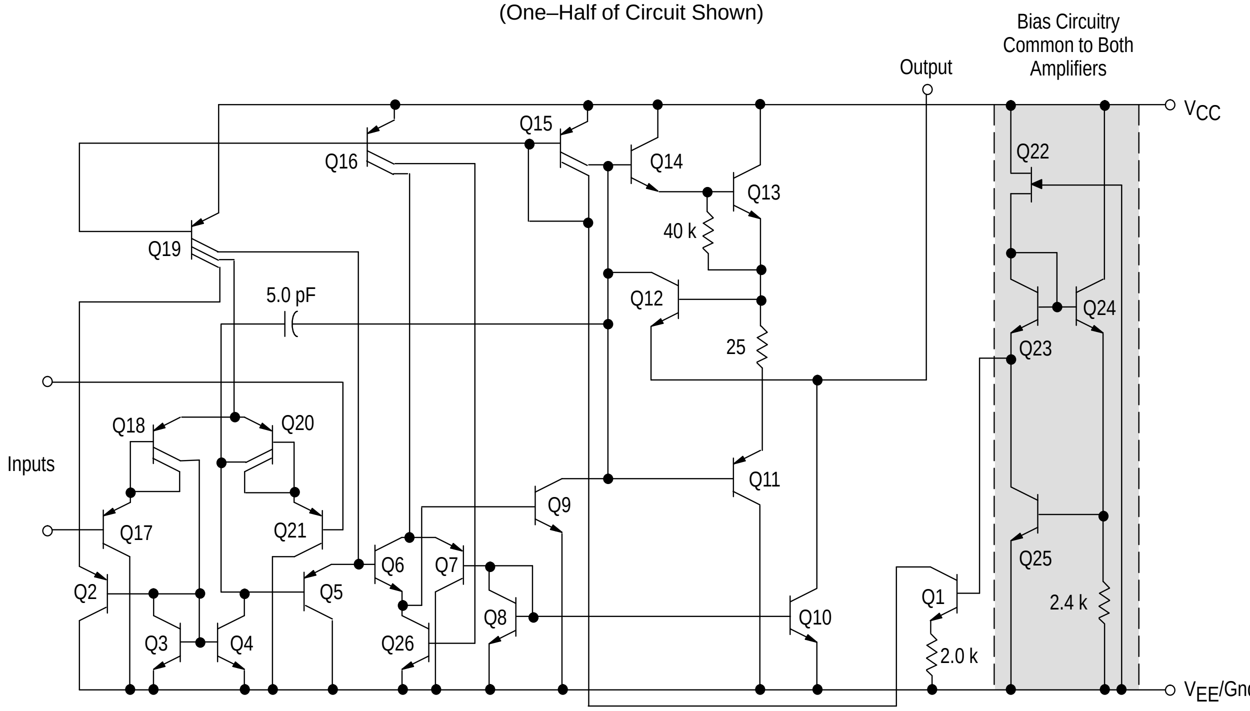


Split Supplies



Representative Schematic Diagram

(One–Half of Circuit Shown)



CIRCUIT DESCRIPTION

The LM258 series is made using two internally compensated, two–stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single–ended converter. The second stage consists of a standard current source load amplifier stage.

Each amplifier is biased from an internal–voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.

Large Signal Voltage Follower Response

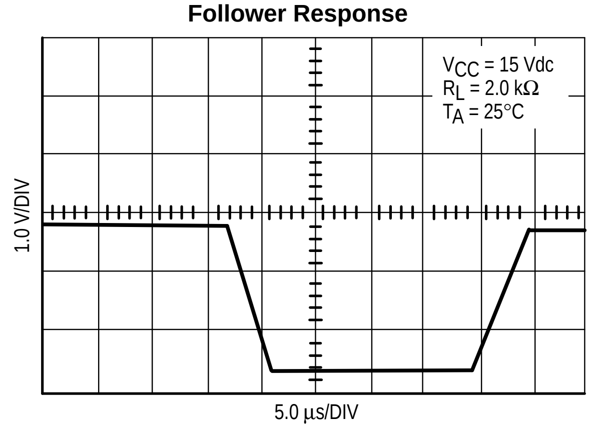


Figure 1. Input Voltage Range

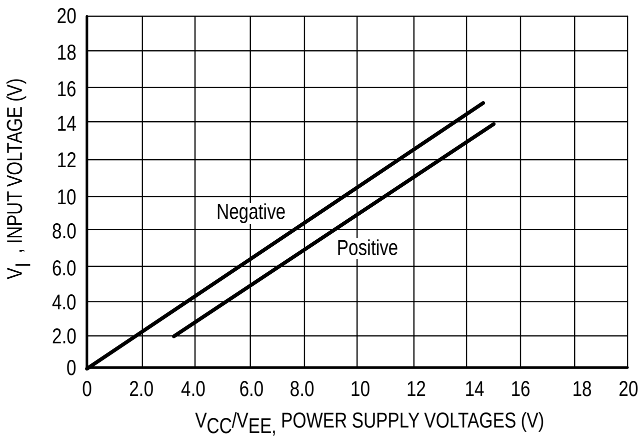


Figure 2. Large–Signal Open Loop Voltage Gain

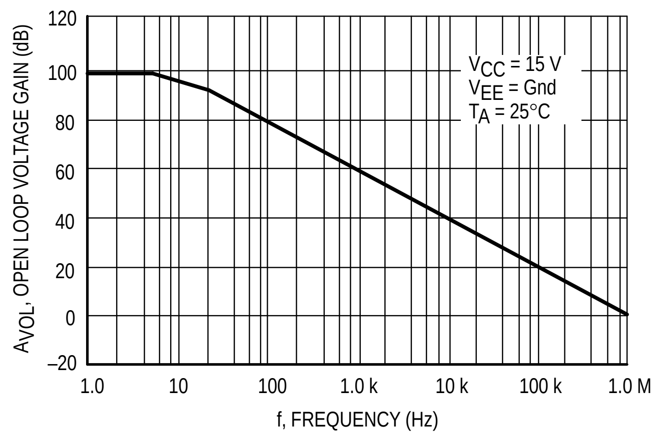


Figure 3. Large–Signal Frequency Response

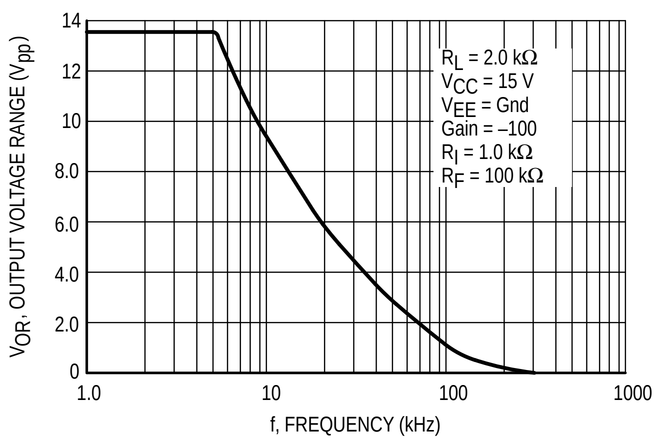


Figure 4. Small Signal Voltage Follower Pulse Response (Noninverting)

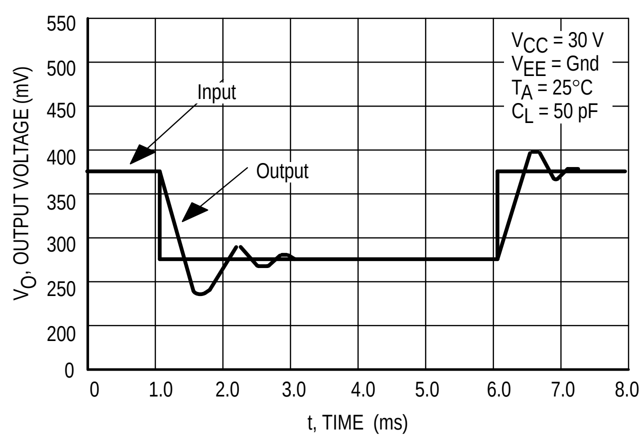


Figure 5. Power Supply Current versus Power Supply Voltage

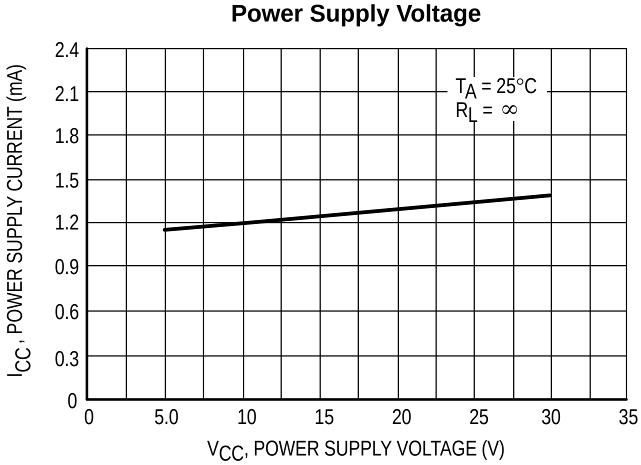


Figure 6. Input Bias Current versus Supply Voltage

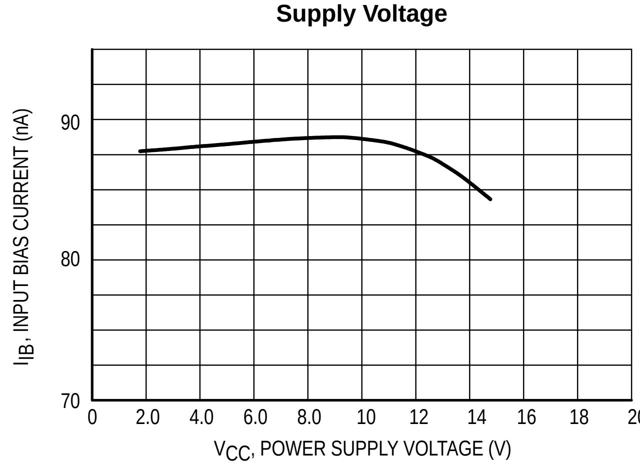
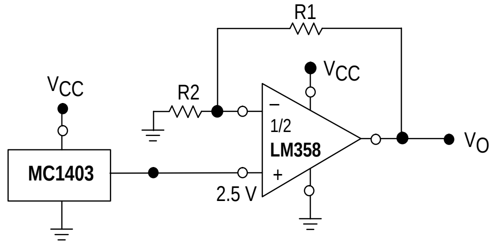


Figure 7. Voltage Reference



$$V_O = 2.5\ V\left(1 + \frac{R1}{R2}\right)$$

Figure 8. Wien Bridge Oscillator

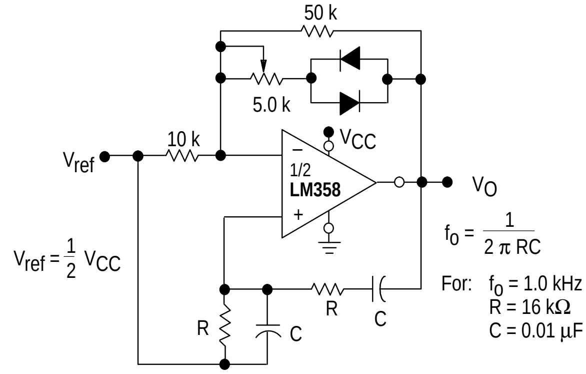
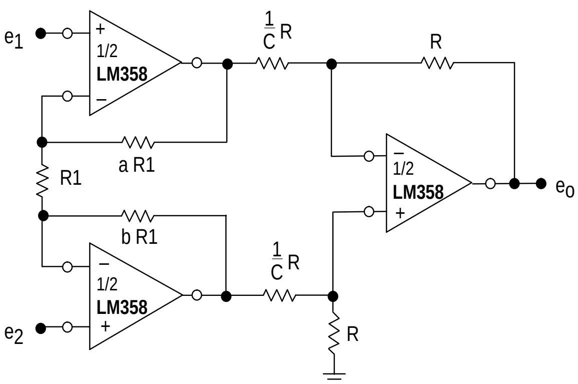
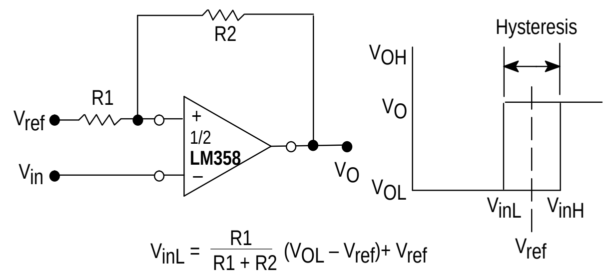


Figure 9. High Impedance Differential Amplifier



$$e_O = C\,(1 + a + b)\,(e_2 - e_1)$$

Figure 10. Comparator with Hysteresis



$$V_{inL} = \frac{R1}{R1 + R2}\,(V_{OL} - V_{ref}) + V_{ref}$$

$$V_{inH} = \frac{R1}{R1 + R2}\,(V_{OH} - V_{ref}) + V_{ref}$$

$$H = \frac{R1}{R1 + R2}\,(V_{OH} - V_{OL})$$

Figure 11. Bi–Quad Filter

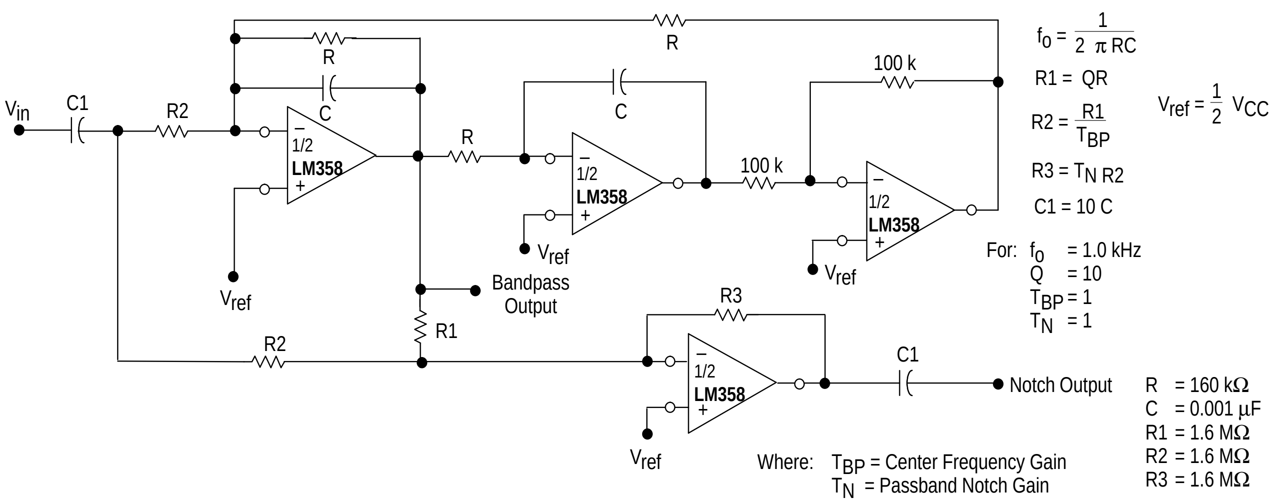
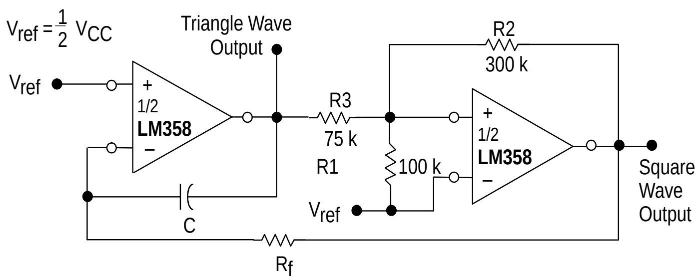
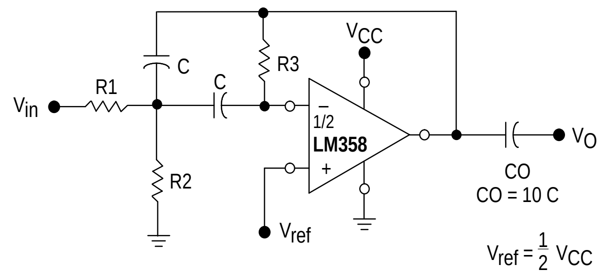


Figure 12. Function Generator



$$f = \frac{R1 + R_C}{4\,CR_f\,R1} \qquad \text{if, } R3 = \frac{R2\,R1}{R2 + R1}$$

Figure 13. Multiple Feedback Bandpass Filter



Given: f_o = center frequency

$A(f_o)$ = gain at center frequency

Choose value f_o, C

Then: $R3 = \frac{Q}{\pi f_o C}$

$R1 = \frac{R3}{2\,A(f_o)}$

$R2 = \frac{R1\,R3}{4Q^2\,R1 - R3}$

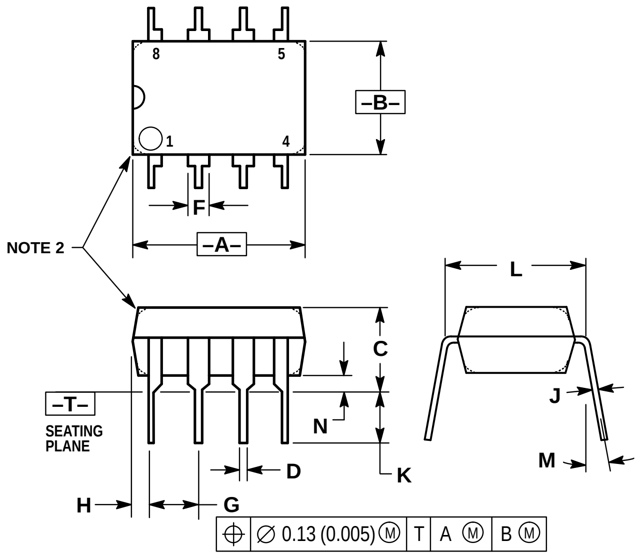
For less than 10% error from operational amplifier. $\frac{Q_o f_o}{BW} < 0.1$

Where f_o and BW are expressed in Hz.

If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

OUTLINE DIMENSIONS

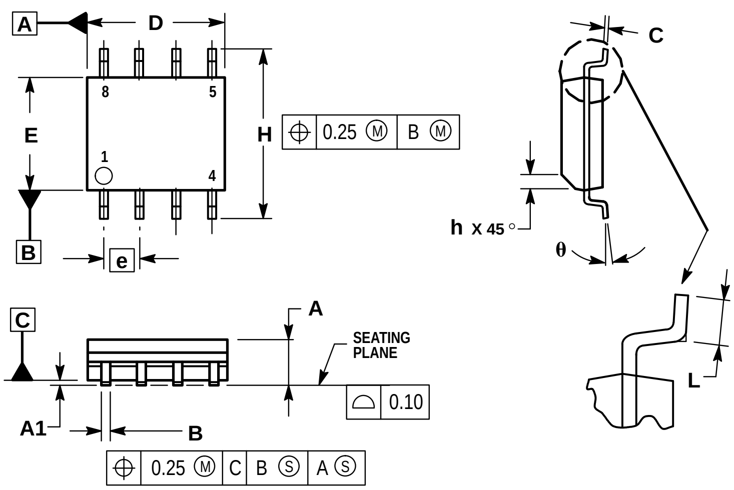
N SUFFIX
PLASTIC PACKAGE
CASE 626–05
ISSUE K



NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	—	10°	—	10°
N	0.76	1.01	0.030	0.040

D SUFFIX
PLASTIC PACKAGE
CASE 751–05
(SO–8)
ISSUE R



NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. DIMENSIONS ARE IN MILLIMETERS.
3. DIMENSION D AND E DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

	MILLIMETERS	
DIM	MIN	MAX
A	1.35	1.75
A1	0.10	0.25
B	0.35	0.49
C	0.18	0.25
D	4.80	5.00
E	3.80	4.00
e	1.27 BSC	
H	5.80	6.20
h	0.25	0.50
L	0.40	1.25
θ	0°	7°

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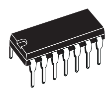
JAPAN: Nippon Motorola Ltd.; Tatsumi–SPD–JLDC, 6F Seibu–Butsuryu–Center, 3–14–2 Tatsumi Koto–Ku, Tokyo 135, Japan. 03–81–3521–8315

ASIA / PACIFIC: Motorola Semiconductors H.K. Ltd.; 8B Tai Ping Industrial Park, 51 Ting Kok Road, Tai Po, N.T., Hong Kong. 852–26629298

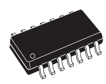
LM139,A
LM239,A - LM339,A

LOW POWER QUAD VOLTAGE COMPARATORS

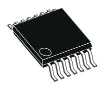
- WIDE SINGLE SUPPLY VOLTAGE RANGE OR DUAL SUPPLIES FOR ALL DEVICES : +2V TO +36V OR ±1V TO ±18V
- VERY LOW SUPPLY CURRENT (1.1mA) INDEPENDENT OF SUPPLY VOLTAGE (1.4mW/comparator at +5V)
- LOW INPUT BIAS CURRENT : 25nA TYP
- LOW INPUT OFFSET CURRENT : ±5nA TYP
- LOW INPUT OFFSET VOLTAGE : ±1mV TYP
- INPUT COMMON-MODE VOLTAGE RANGE INCLUDES GROUND
- LOW OUTPUT SATURATION VOLTAGE : 250mV TYP; (Io = 4mA)
- DIFFERENTIAL INPUT VOLTAGE RANGE EQUAL TO THE SUPPLY VOLTAGE
- TTL, DTL, ECL, MOS, CMOS COMPATIBLE OUTPUTS



N
DIP14
(Plastic Package)



D
SO14
(Plastic Micropackage)



P
TSSOP14
(Thin Shrink Small Outline Package)

DESCRIPTION

These devices consist of four independent precision voltage comparators with an offset voltage specifications as low as 2mV max for LM339A, LM239A and LM139A. All these comparators were designed specifically to operate from a single power supply aver a wide range of voltages. Operation from split power supplies is also possible.

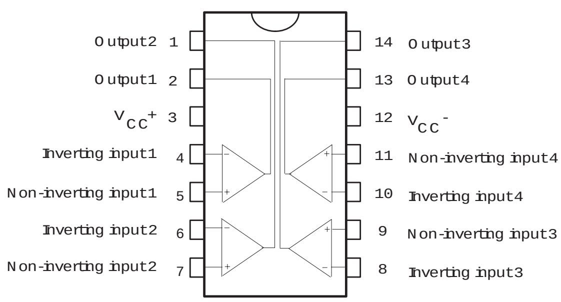
These comparators also have a unique characteristic in that the input common-mode voltage range includes ground even though operated from a single power supply voltage.

ORDER CODE

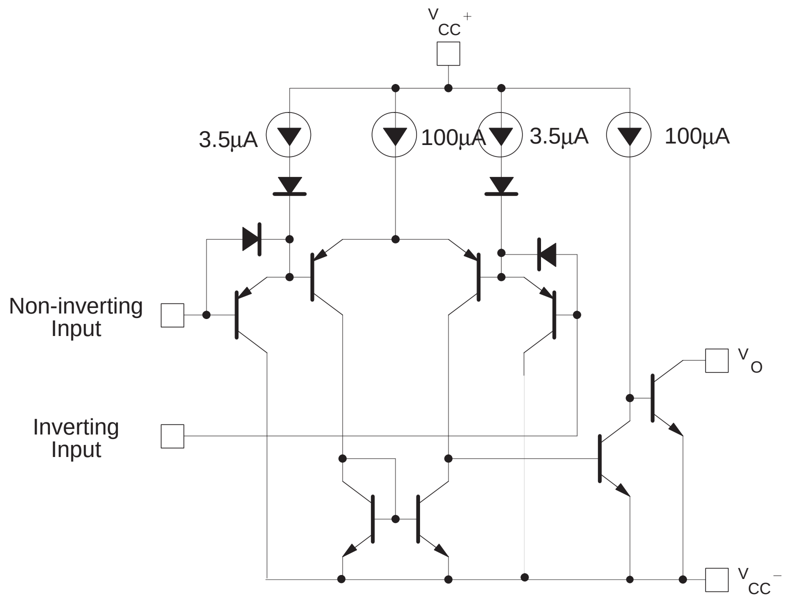
Part Number	Temperature Range	Package		
		N	D	P
LM139,A	-55°C, +125°C	•	•	•
LM239,A	-40°C, +105°C	•	•	•
LM339,A	0°C, +70°C	•	•	•
Example : LM139AN				

N = Dual in Line Package (DIP)
D = Small Outline Package (SO) - also available in Tape & Reel (DT)
P = Thin Shrink Small Outline Package (TSSOP) - only available in Tape &Reel (PT)

PIN CONNECTIONS (top view)



SCHEMATIC DIAGRAM (1/4 LM139)



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	±18 or 36	V
V_{id}	Differential Input Voltage	±36	V
V_i	Input Voltage	-0.3 to +36	V
	Output Short-circuit to Ground - note 1)	Infinite	
p_d	Power Dissipation 2) DIP14 SO14 TSSOP14	1500 830 710	mW
T_{stg}	Storage Temperature Range	-65 to +150	°C
T_j	Junction Temperature	+150	°C

1. Short-circuits from the output to V_{CC}^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 20mA independent of the magnitude of V_{CC}^+.
2. Pd is calculated with T_{amb} = +25°C, T_j = +150°C and R_{thja} = 80°C/W for DIP14 package
= 150°C/W for SO14 package
= 175°C/W for TSSOP14 package

OPERATING CONDITIONS (T_{amb} = 25°C)

Symbol	Parameter	Value	Unit
V_{CC}	Supply Voltage	2 to 32 ±1 to ±16	V
Vicm	Common Mode Input Voltage Range	0 to (V_{CC}^+ - 1.5)	V
T_{oper}	Operating Free-air Temperature Range LM139, LM139A LM239, LM239A LM339, LM339A	-55, +125 -40, +105 0, +70	°C

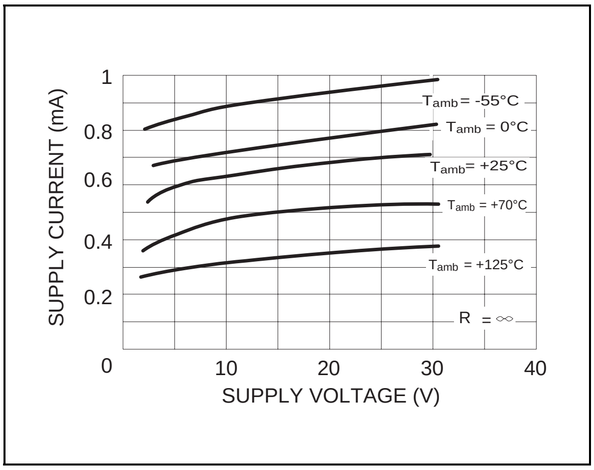
ELECTRICAL CHARACTERISTICS

$V_{CC}^+ = +5V$, $V_{CC}^- =$ GND, $T_{amb} = +25°C$ (unless otherwise specified)

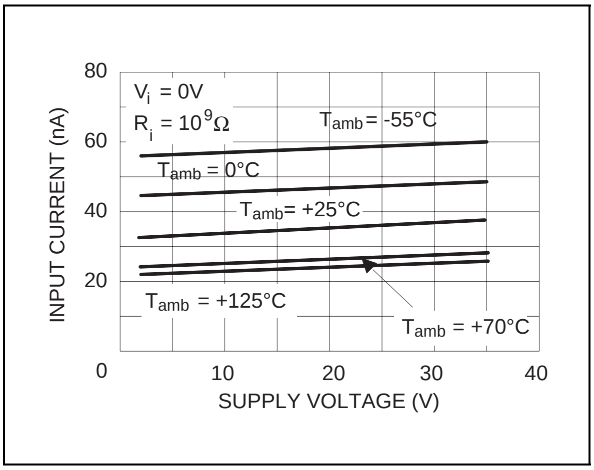
Symbol	Parameter	LM139A - LM239A LM339A			LM139- LM239 LM339			Unit
		Min.	Typ.	Max.	Min	Typ.	Max.	
V_{io}	Input Offset Voltage - note 1) $T_{amb} = +25°C$ $T_{min} \le T_{amb} \le T_{max}$		1	2 4		1	5 9	mV
I_{io}	Input Offset Current $T_{amb} = +25°C$ $T_{min} \le T_{amb} \le T_{max}$		3	25 100		5	50 150	nA
I_{ib}	Input Bias Current (I^+ or I^-) - note 2) $T_{amb} = +25°C$ $T_{min} \le T_{amb} \le T_{max}$		25	100 300		25	250 400	nA
A_{vd}	Large Signal Voltage Gain $V_{CC} = 15V$, $R_L = 15k\Omega$, $V_o = 1V$ to $11V$	50	200		50	200		V/mV
I_{CC}	Supply Current (all comparators) $V_{CC} = +5V$, no load $V_{CC} = +30V$, no load		1.1 1.3	2 2.5		1.1 1.3	2 2.5	mA
V_{icm}	Input Common Mode Voltage Range - note 3) $V_{CC} = 30V$ $T_{amb} = +25°C$ $T_{min} \le T_{amb} \le T_{max}$	0 0		$V_{CC}^+ -1.5$ $V_{CC}^+ -2$	0 0		$V_{CC}^+ -1.5$ $V_{CC}^+ -2$	V
V_{id}	Differential Input Voltage -note 4)			V_{CC}^+			V_{CC}^+	V
V_{OL}	Low Level Output Voltage $V_{id} = -1V$, $I_{sink} = 4mA$ $T_{amb} = +25°C$ $T_{min} \le T_{amb} \le T_{max}$		250	400 700		250	400 700	mV
I_{OH}	High Level Output Current ($V_{id} = 1V$) $V_{CC} = V_o = 30V$ $T_{amb} = +25°C$ $T_{min} \le T_{amb} \le T_{max}$		0.1	1		0.1	1	nA µA
Isink	Output Sink Currrent $V_{id}= 1V$, $V_o = 1.5V$	6	16		6	16		mA
tre	Response Time - note 5) $R_L= 5.1k\Omega$ connected to V_{CC}^+		1.3			1.3		µs
trel	Large Signal Response Time $R_L= 5.1k\Omega$ connected to V_{CC}^+, e_I = TTL, $V_{(ref)} = +1.4v$		300			300		ns

1. At output switch point, $V_o \approx 1.4V$, $R_s = 0$ with V_{CC}^+ from 5V to 30V, and over the full common-mode range (0V to V_{CC}^+ -1.5V).
2. The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output, so no loading charge exists on the reference of input lines.
3. The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is V_{CC}^+ -1.5V, but either or both inputs can go to +30V without damage
4. The response time specified is for a 100mV input step with 5mV overdrive. For larger overdrive signals 300ns can be obtained
5. Posistive excursions of input voltage may exceed the power supply level. As long as the other voltage remains within the common-mode range, the comparator will provide a proper output state. The low input voltage state must not be less than -0.3V (or 0.3V bellow the negative power supply, if used).

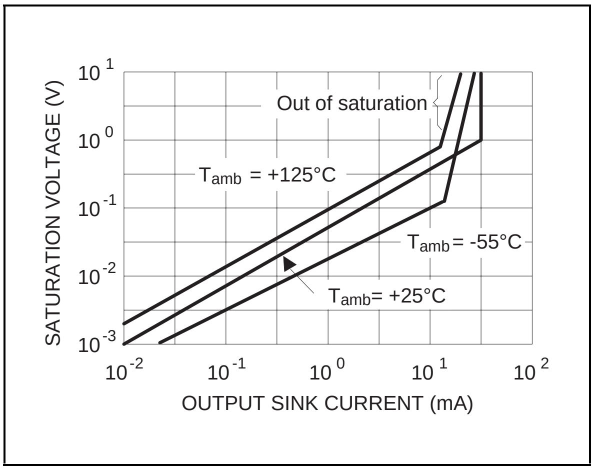
SUPPLY CURRENT versus SUPPLY VOLTAGE



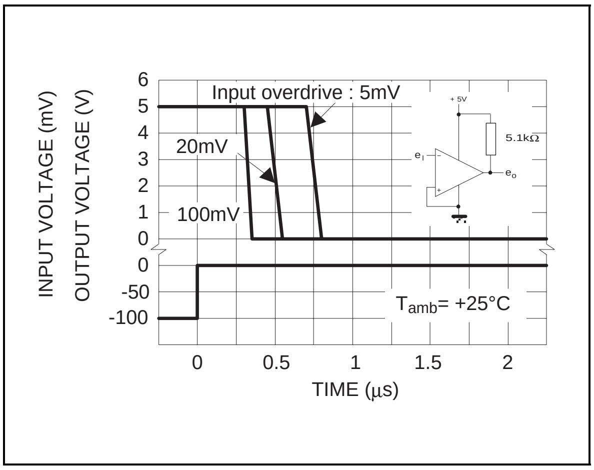
INPUT CURRENT versus SUPPLY VOLTAGE



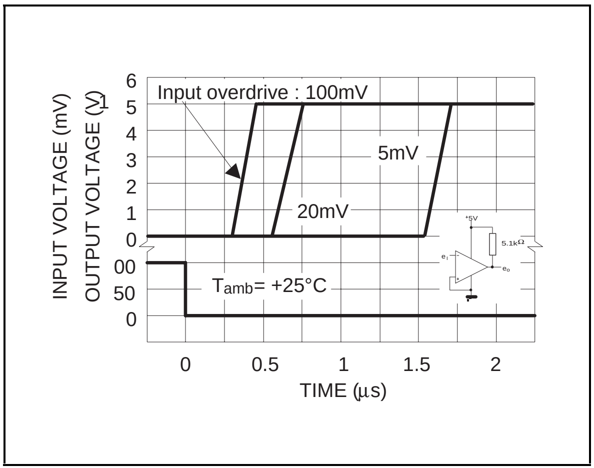
OUTPUT SATURATION VOLTAGE versus OUTPUT CURRENT



RESPONSE TIME FOR VAROIOUS INPUT OVERDRIVES - NEGATIVE TRANSITION

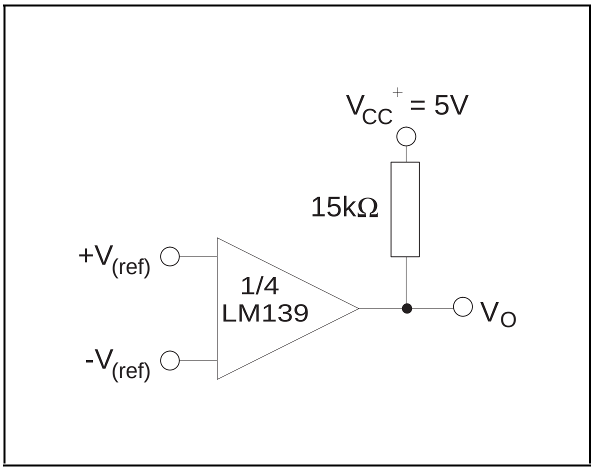


RESPONSE TIME FOR VARIOUS INPUT OVERDRIVES - POSITIVE TRANSITION

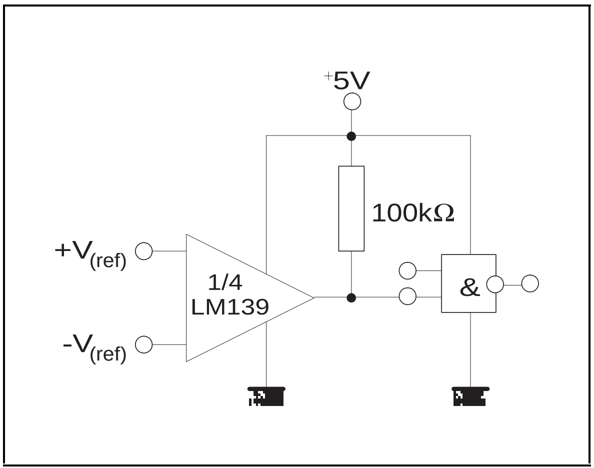


TYPICAL APPICATIONS

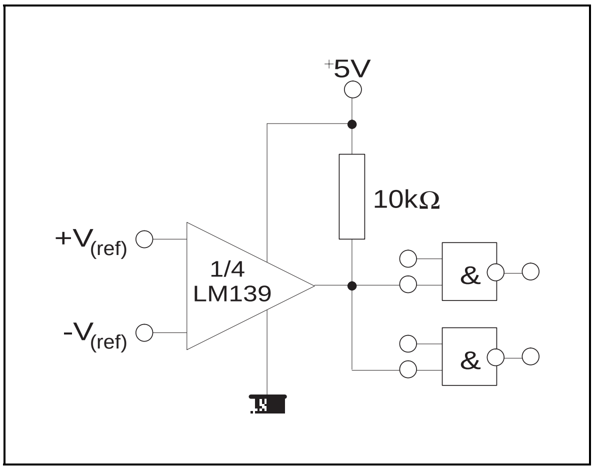
BASIC COMPARATOR



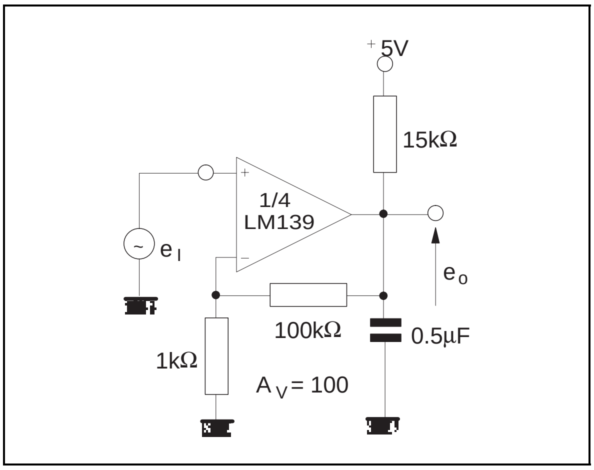
DRIVING CMOS



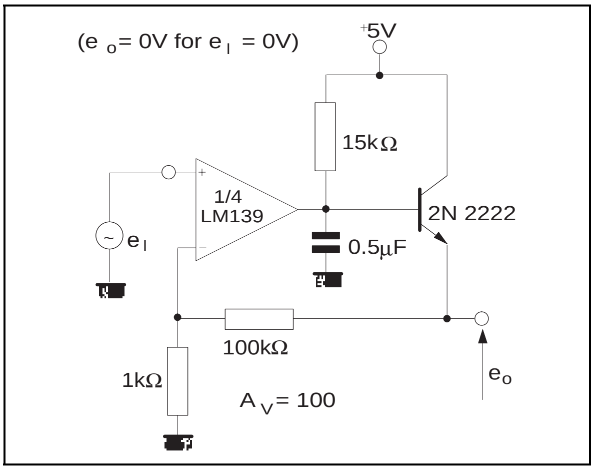
DRIVING TTL



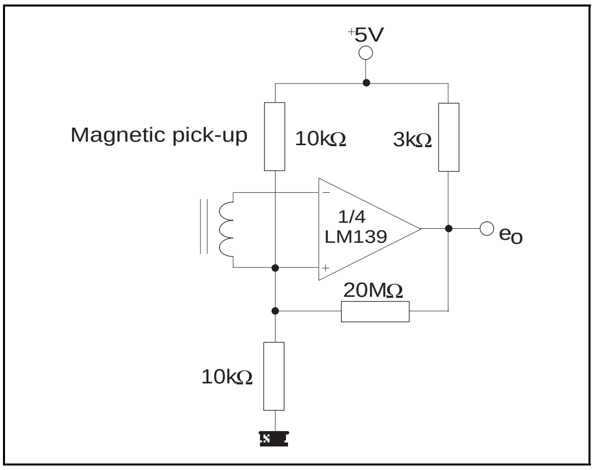
LOW FREQUENCY OP AMP



LOW FREQUENCY OP AMP

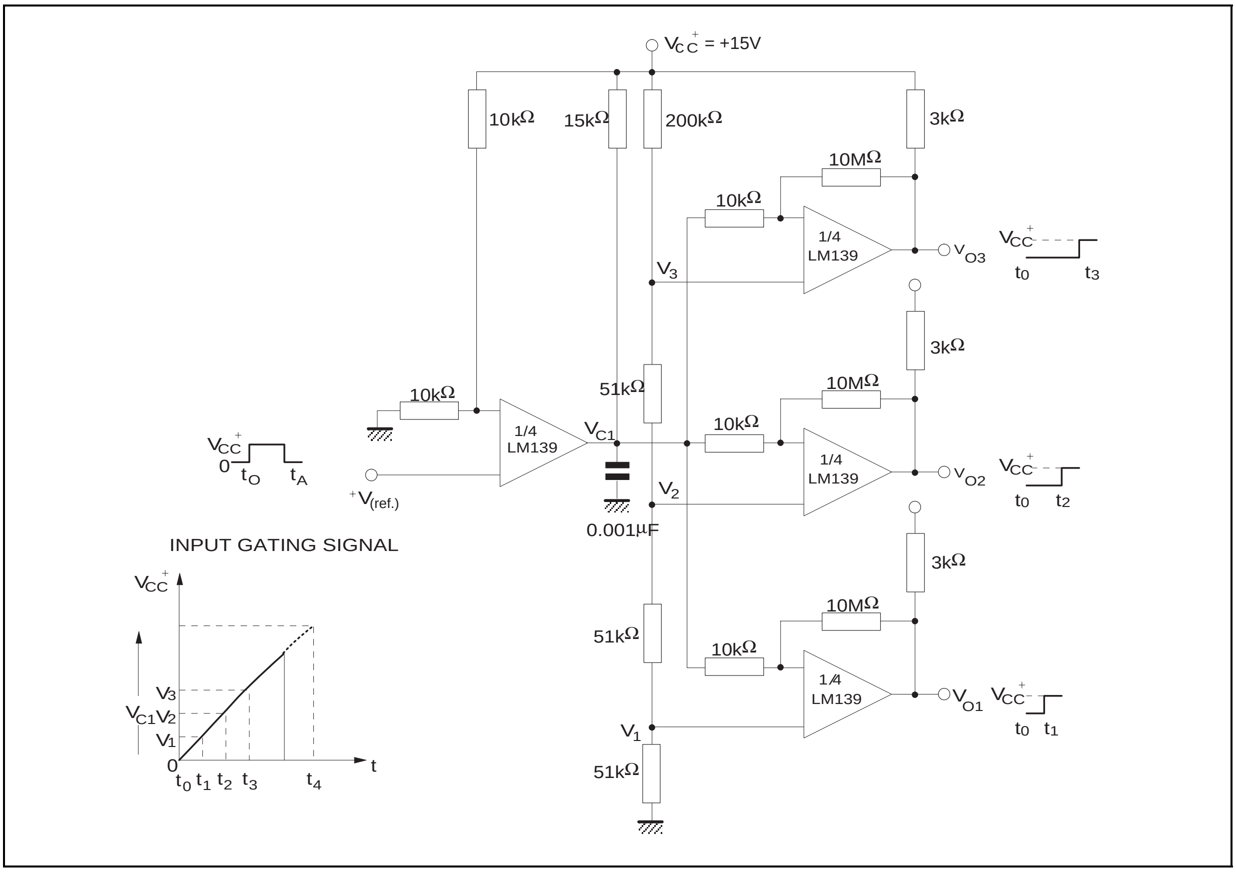


TRANSDUCER AMPLIFIER

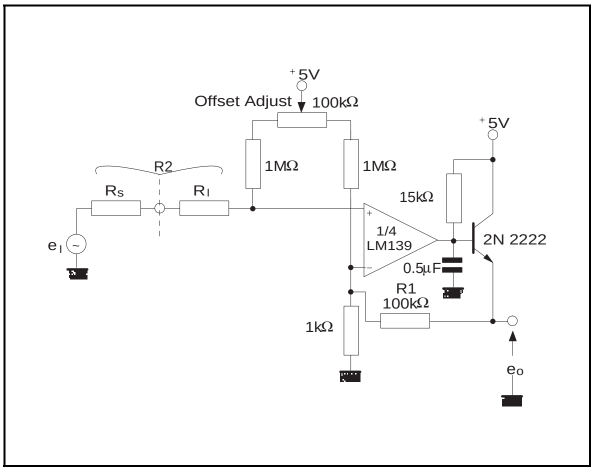


TYPICAL SINGLE (continued)

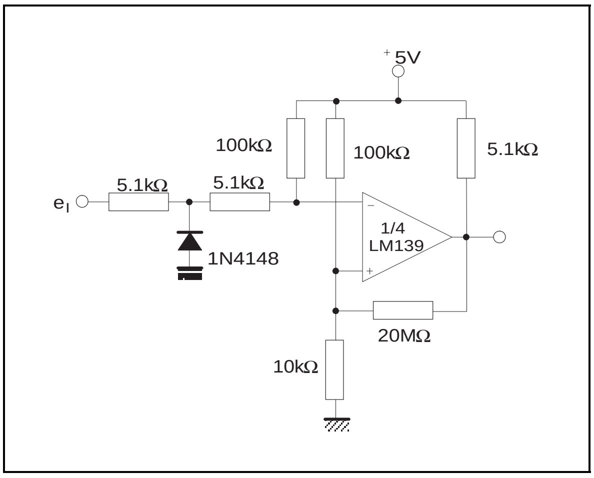
TIME DEALY GENERATOR



LOW FREQUANCY OP AMP WITH OFFSET ADJUST

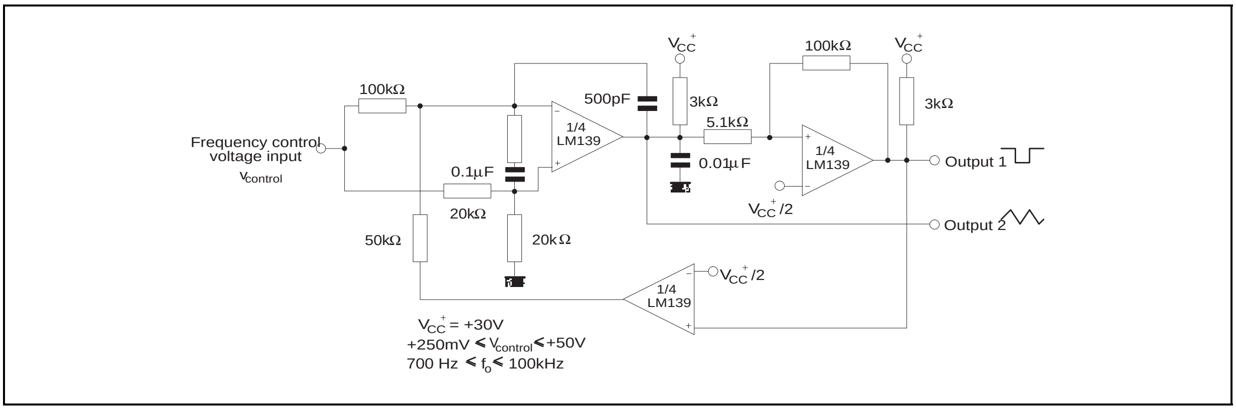


ZERO CROSSING DETECTOR (single power supply)

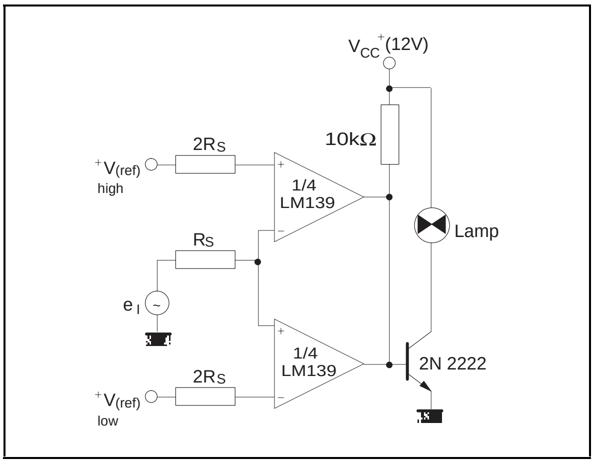


TYPICAL SINGLE (continued)

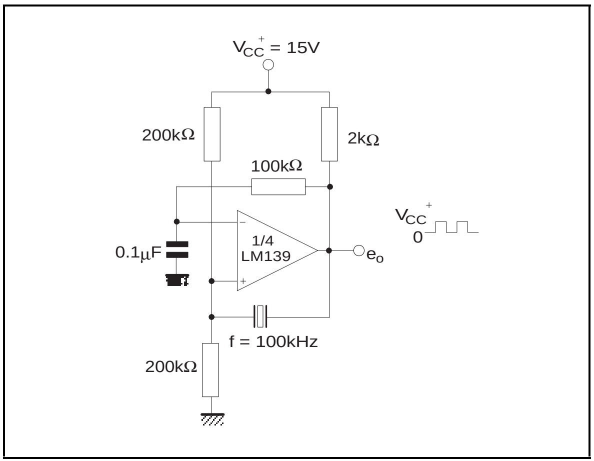
TWO-DECADE HIGH-FREQUENCY VCO



LIMIT COMPARATOR

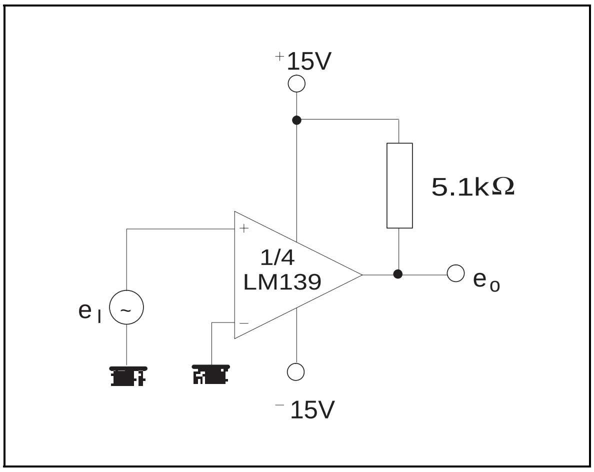


CRYSTAL CONTROLLED OSCILLATOR

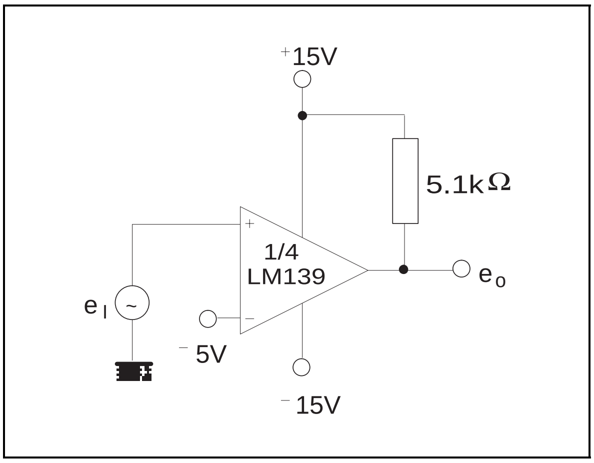


SPLIT-SUPPLY APPLICATIONS

ZERO CROSSING DETECTOR

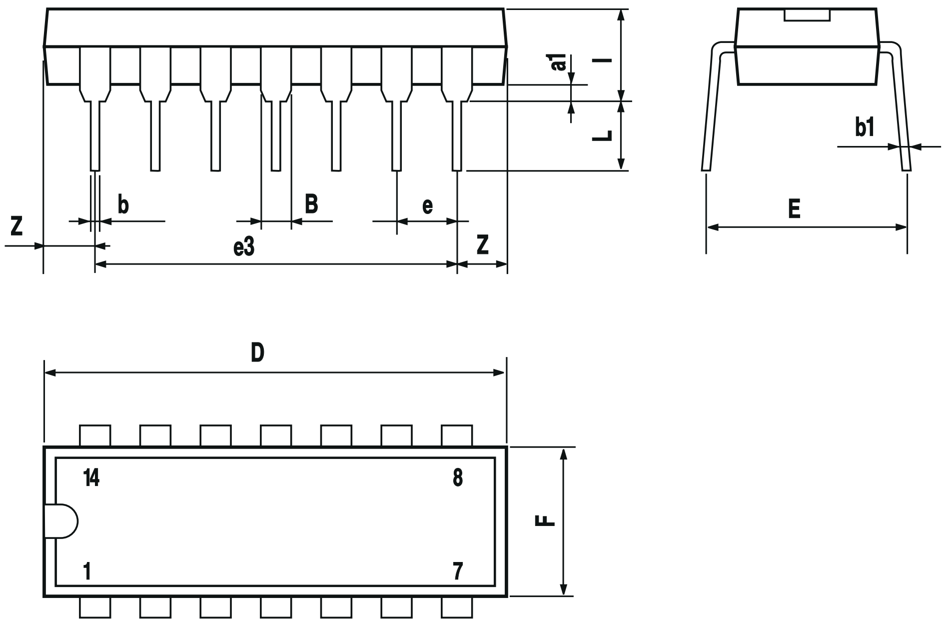


COMPARATOR WITH A NEGATIVE REFERENCE



PACKAGE MECHANICAL DATA

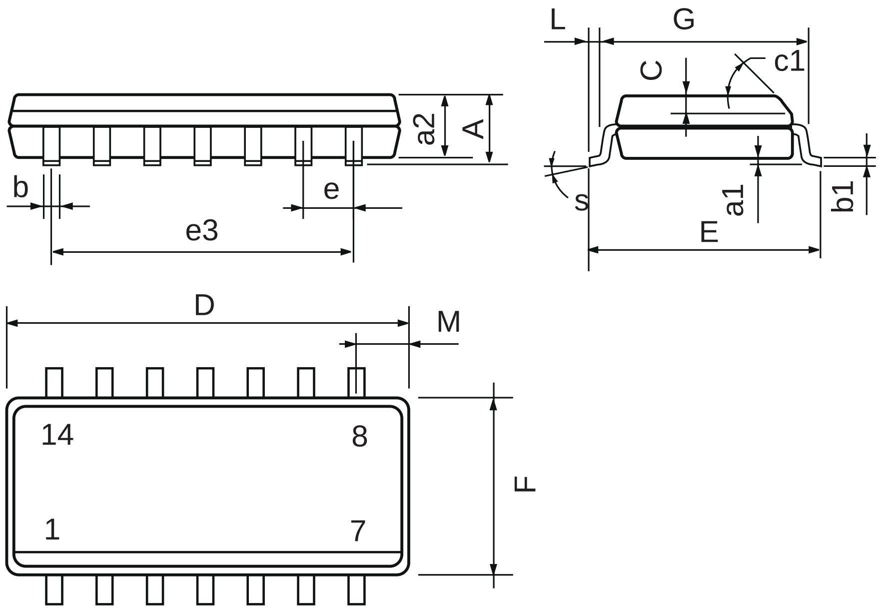
14 PINS - PLASTIC DIP



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
a1	0.51			0.020		
B	1.39		1.65	0.055		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		15.24			0.600	
F			7.1			0.280
i			5.1			0.201
L		3.3			0.130	
Z	1.27		2.54	0.050		0.100

PACKAGE MECHANICAL DATA

14 PINS - PLASTIC MICROPACKAGE (SO)

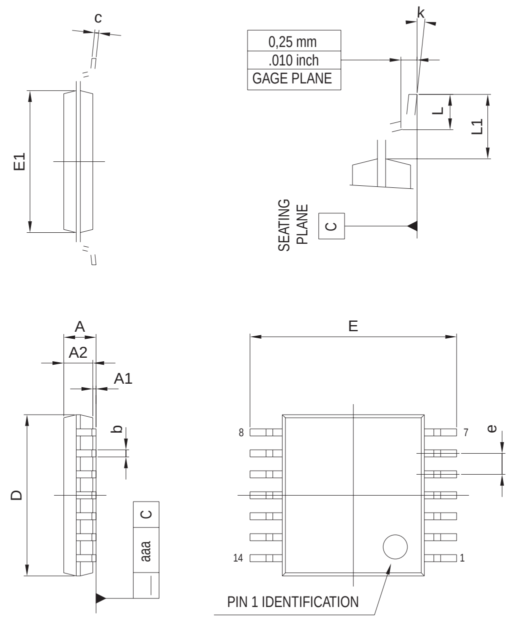


Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.2	0.004		0.008
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.020	
c1	45° (typ.)					
D (1)	8.55		8.75	0.336		0.344
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		7.62			0.300	
F (1)	3.8		4.0	0.150		0.157
G	4.6		5.3	0.181		0.208
L	0.5		1.27	0.020		0.050
M			0.68			0.027
S	8° (max.)					

Note : (1) D and F do not include mold flash or protrusions - Mold flash or protrusions shall not exceed 0.15mm (.066 inc) ONLY FOR DATA BOOK.

PACKAGE MECHANICAL DATA

14 PINS - THIN SHRINK SMALL OUTLINE PACKAGE



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.20			0.05
A1	0.05		0.15	0.01		0.006
A2	0.80	1.00	1.05	0.031	0.039	0.041
b	0.19		0.30	0.007		0.15
c	0.09		0.20	0.003		0.012
D	4.90	5.00	5.10	0.192	0.196	0.20
E		6.40			0.252	
E1	4.30	4.40	4.50	0.169	0.173	0.177
e		0.65			0.025	
k	0°		8°	0°		8°
L	0.450	0.600	0.750	0.018	0.024	0.030
L1		1.00			0.039	
aaa			0.100			0.004

TC4426
TC4427
TC4428

1.5A DUAL HIGH-SPEED POWER MOSFET DRIVERS

FEATURES

- **High Peak Output Current 1.5A**
- **Wide Operating Range .... 4.5V to 18V**
- **High Capacitive Load Drive Capability .... 1000pF in 25nsec**
- **Short Delay Time .... < 40nsec Typ.**
- **Consistent Delay Times With Changes in Supply Voltage**
- **Low Supply Current**
  - **— With Logic "1" Input 4mA**
  - **— With Logic "0" Input 400µA**
- **Low Output Impedance 7Ω**
- **Latch-Up Protected .... Will Withstand >0.5A Reverse Current .... Down to – 5V**
- **Input Will Withstand Negative Inputs**
- **ESD Protected 4kV**
- **Pinout Same as TC426/TC427/TC428**

ORDERING INFORMATION

Part No.	Package	Temperature Range
TC4426COA	8-Pin SOIC	0°C to +70°C
TC4426CPA	8-Pin Plastic DIP	0°C to +70°C
TC4426EOA	8-Pin SOIC	– 40°C to +85°C
TC4426EPA	8-Pin Plastic DIP	– 40°C to +85°C
TC4426MJA	8-Pin CerDIP	– 55°C to +125°C
TC4427COA	8-Pin SOIC	0°C to +70°C
TC4427CPA	8-Pin Plastic DIP	0°C to +70°C
TC4427EOA	8-Pin SOIC	– 40°C to +85°C
TC4427EPA	8-Pin Plastic DIP	– 40°C to +85°C
TC4427MJA	8-Pin CerDIP	– 55°C to +125°C
TC4428COA	8-Pin SOIC	0°C to +70°C
TC4428CPA	8-Pin Plastic DIP	0°C to +70°C
TC4428EOA	8-Pin SOIC	– 40°C to +85°C
TC4428EPA	8-Pin Plastic DIP	– 40°C to +85°C
TC4428MJA	8-Pin CerDIP	– 55°C to +125°C

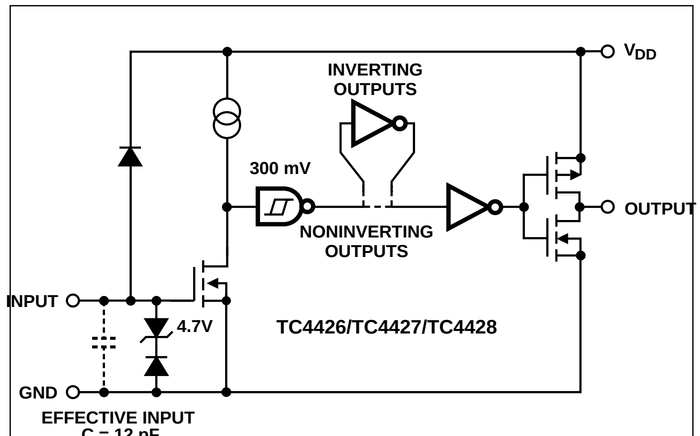
GENERAL DESCRIPTION

The TC4426/4427/4428 are improved versions of the earlier TC426/427/428 family of buffer/drivers (with which they are pin compatible). They will not latch up under any conditions within their power and voltage ratings. They are not subject to damage when up to 5V of noise spiking (of either polarity) occurs on the ground pin. They can accept, without damage or logic upset, up to 500 mA of reverse current (of either polarity) being forced back into their outputs. All terminals are fully protected against up to 4kV of electrostatic discharge.

As MOSFET drivers, the TC4426/4427/4428 can easily switch 1000pF gate capacitances in under 30nsec, and provide low enough impedances in both the ON and OFF states to ensure the MOSFET's intended state will not be affected, even by large transients.

Other compatible drivers are the TC4426A/27A/28A. These drivers have matched input to output leading edge and falling edge delays, tD1 and tD2, for processing short duration pulses in the 25 nsec range. They are pin compatible with the TC4426/27/28.

FUNCTIONAL BLOCK DIAGRAM



NOTES: 1.TC4426 has 2 inverting drivers; TC4427 has 2 noninverting drivers.
2. TC4428 has one inverting and one noninverting driver.
3. Ground any unused driver input.

TC4426
TC4427
TC4428

ABSOLUTE MAXIMUM RATINGS*

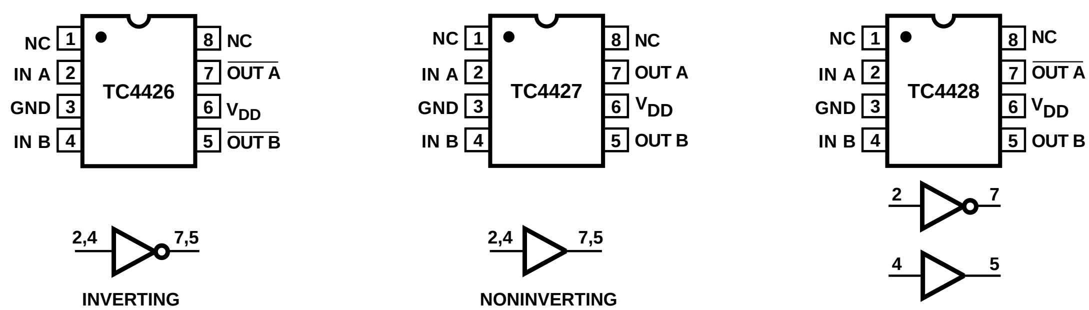
Supply Voltage .... +22V
Input Voltage, IN A or IN B . (V_{DD} + 0.3V) to (GND – 5.0V)
Maximum Chip Temperature................................. +150°C
Storage Temperature Range .... – 65°C to +150°C
Lead Temperature (Soldering, 10 sec) .... +300°C
Package Thermal Resistance
- CerDIP $R_{\theta J\text{-}A}$ .... 150°C/W
- CerDIP $R_{\theta J\text{-}C}$ .... 50°C/W
- PDIP $R_{\theta J\text{-}A}$ .... 125°C/W
- PDIP $R_{\theta J\text{-}C}$ .... 42°C/W
- SOIC $R_{\theta J\text{-}A}$ .... 155°C/W
- SOIC $R_{\theta J\text{-}C}$ .... 45°C/W

Operating Temperature Range
- C Version .... 0°C to +70°C
- E Version .... – 40°C to +85°C
- M Version .... – 55°C to +125°C

Package Power Dissipation ($T_A \leq$ 70°C)
- Plastic 730mW
- CerDIP 800mW
- SOIC 470mW

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operation sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

PIN CONFIGURATIONS



NC = NO INTERNAL CONNECTION

NOTE: SOIC pinout is identical to DIP.

ELECTRICAL CHARACTERISTICS: T_A = +25°C with 4.5V $\leq V_{DD} \leq$ 18V, unless otherwise specified.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Input						
V_{IH}	Logic 1 High Input Voltage		2.4	—	—	V
V_{IL}	Logic 0 Low Input Voltage		—	—	0.8	V
I_{IN}	Input Current	$0V \leq V_{IN} \leq V_{DD}$	– 1	—	1	µA
Output						
V_{OH}	High Output Voltage		V_{DD} – 0.025	—	—	V
V_{OL}	Low Output Voltage		—	—	0.025	V
R_O	Output Resistance	V_{DD} = 18V, I_O = 10mA	—	7	10	Ω
I_{PK}	Peak Output Current	Duty Cycle ≤ 2%, t ≤ 30µsec	—	1.5	—	A
I_{REV}	Latch-Up Protection Withstand Reverse Current	Duty Cycle ≤ 2% t ≤ 30 µsec	> 0.5	—	—	A
Switching Time (Note 1)						
t_R	Rise Time	Figure 1	—	19	30	nsec
t_F	Fall Time	Figure 1	—	19	30	nsec
t_{D1}	Delay Time	Figure 1	—	20	30	nsec
t_{D2}	Delay Time	Figure 1	—	40	50	nsec
Power Supply						
I_S	Power Supply Current	V_{IN} = 3V (Both Inputs) V_{IN} = 0V (Both Inputs)	— —	— —	4.5 0.4	mA mA

NOTE: 1. Switching times are guaranteed by design.

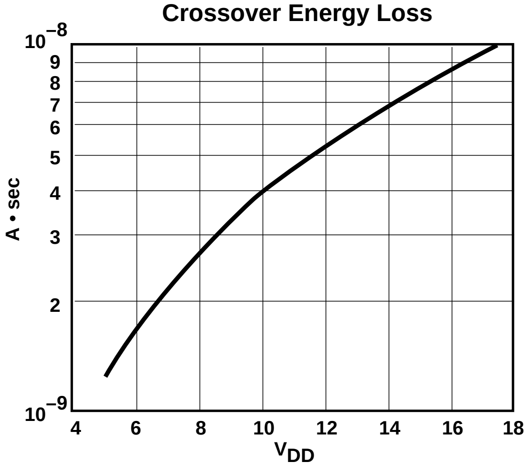
1.5A DUAL HIGH-SPEED POWER MOSFET DRIVERS

ELECTRICAL CHARACTERISTICS: Specifications measured over operating temperature range with $4.5V \le V_{DD} \le 18V$, unless otherwise specified.

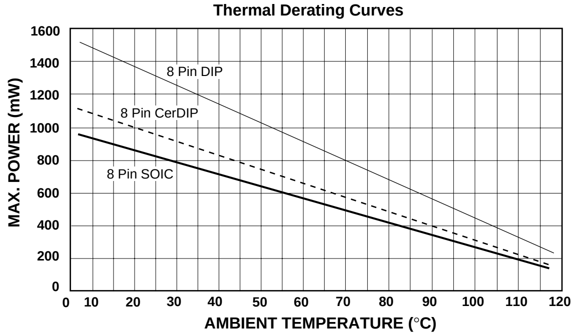
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Input						
V_{IH}	Logic 1 High Input Voltage		2.4	—	—	V
V_{IL}	Logic 0 Low Input Voltage		—	—	0.8	V
I_{IN}	Input Current	$0V \le V_{IN} \le V_{DD}$	– 10	—	10	µA
Output						
V_{OH}	High Output Voltage		V_{DD} – 0.025	—	—	V
V_{OL}	Low Output Voltage		—	—	0.025	V
R_O	Output Resistance	V_{DD} = 18V, I_O = 10mA	—	9	12	Ω
I_{PK}	Peak Output Current	Duty Cycle ≤ 2%, t ≤ 300µsec	—	1.5	—	A
I_{REV}	Latch-Up Protection Withstand Reverse Current	Duty Cycle≤ 2% t ≤ 300µsec	> 0.5	—	—	A
Switching Time (Note 1)						
t_R	Rise Time	Figure 1	—	—	40	nsec
t_F	Fall Time	Figure 1	—	—	40	nsec
t_{D1}	Delay Time	Figure 1	—	—	40	nsec
t_{D2}	Delay Time	Figure 1	—	—	60	nsec
Power Supply						
I_S	Power Supply Current	V_{IN} = 3V (Both Inputs) V_{IN} = 0V (Both Inputs)	— —	— —	8 0.6	mA mA

NOTE: 1. Switching times are guaranteed by design.

Crossover Energy Loss



Thermal Derating Curves



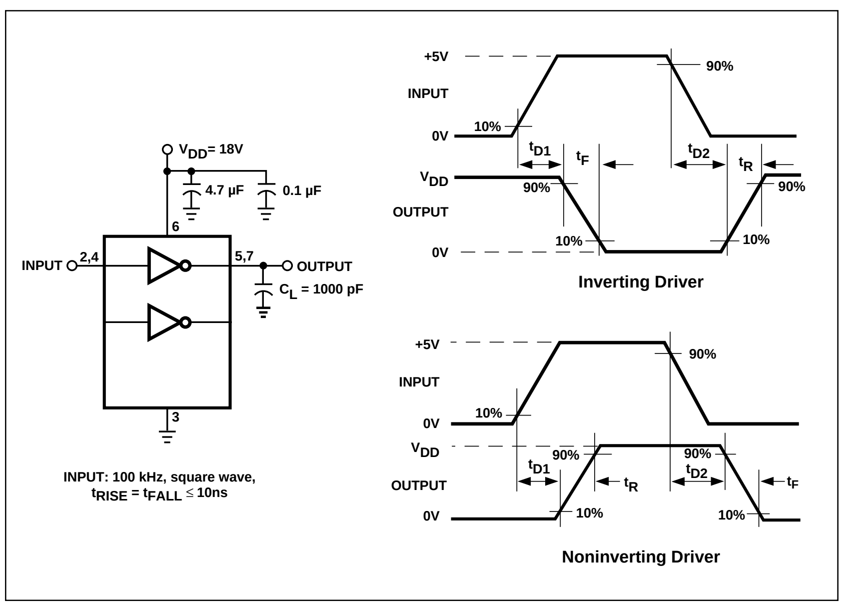
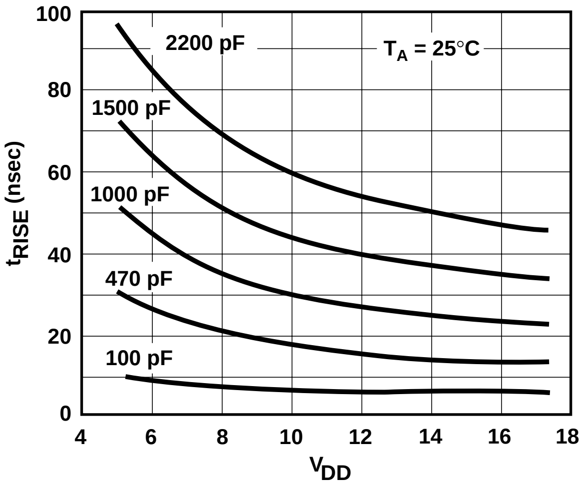


Figure 1. Switching Time Test Circuit

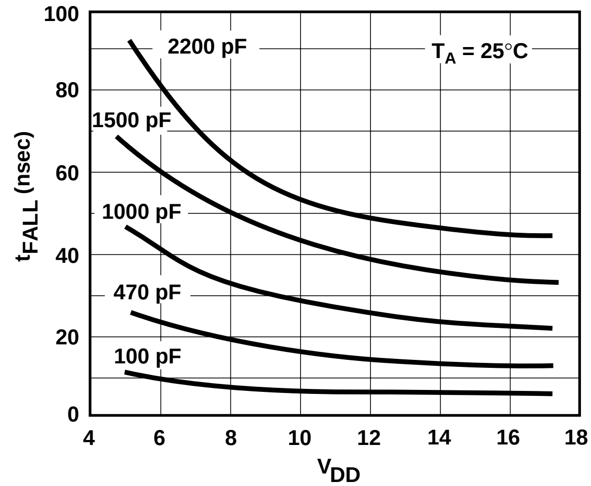
NOTE: The values on this graph represent the loss seen by both drivers in a package during one complete cycle. For a single driver, divide the stated values by 2. For a single transition of a single driver, divide the stated value by 4.

TYPICAL CHARACTERISTICS

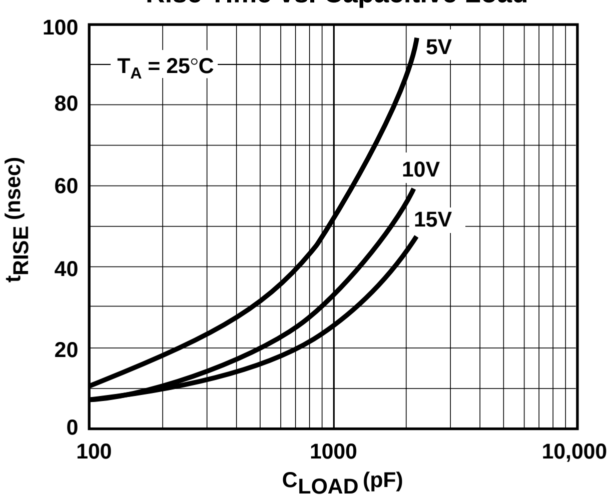
Rise Time vs. Supply Voltage



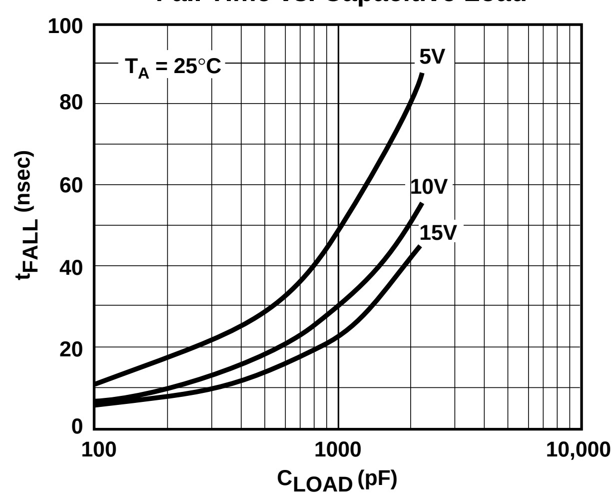
Fall Time vs. Supply Voltage



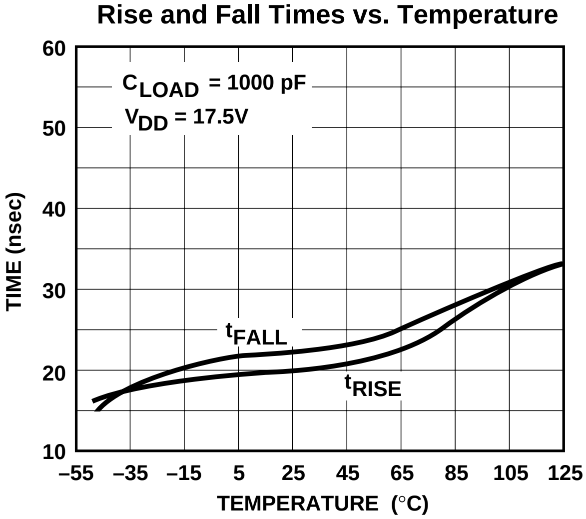
Rise TIme vs. Capacitive Load



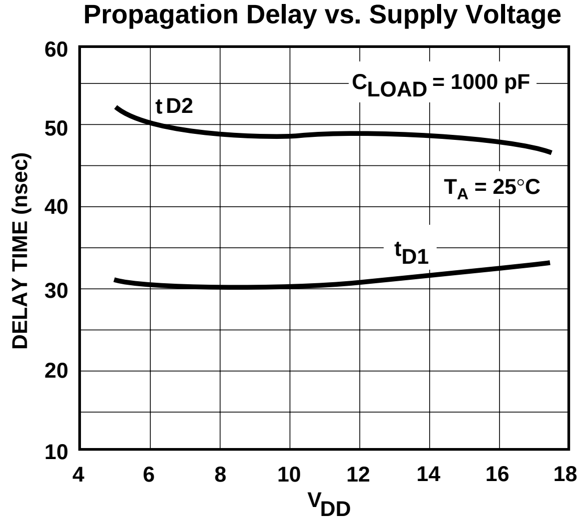
Fall TIme vs. Capacitive Load



Rise and Fall Times vs. Temperature

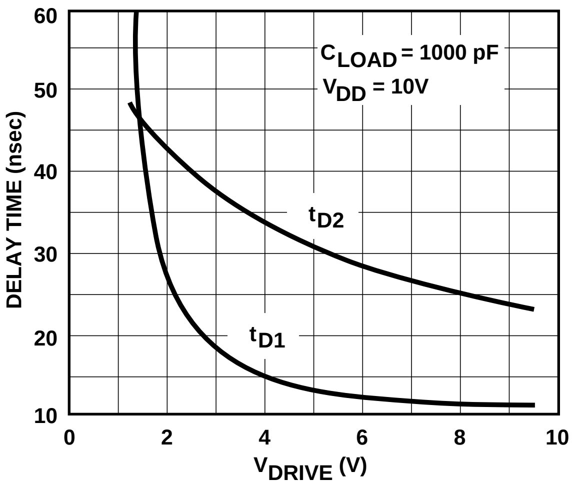


Propagation Delay vs. Supply Voltage

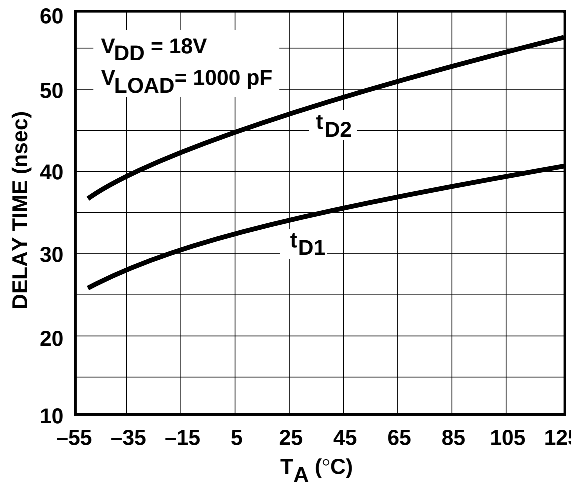


TYPICAL CHARACTERISTICS (Cont.)

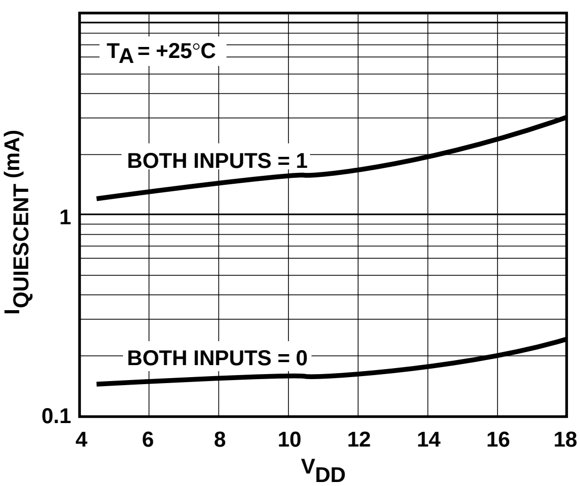
Effect of Input Amplitude on Delay Time



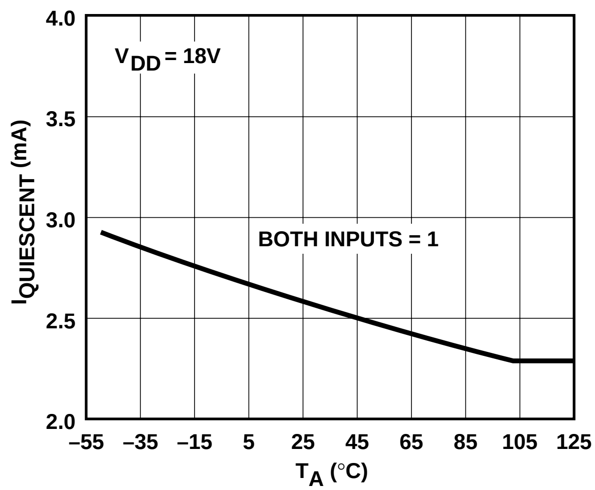
Propagation Delay Time vs. Temperature



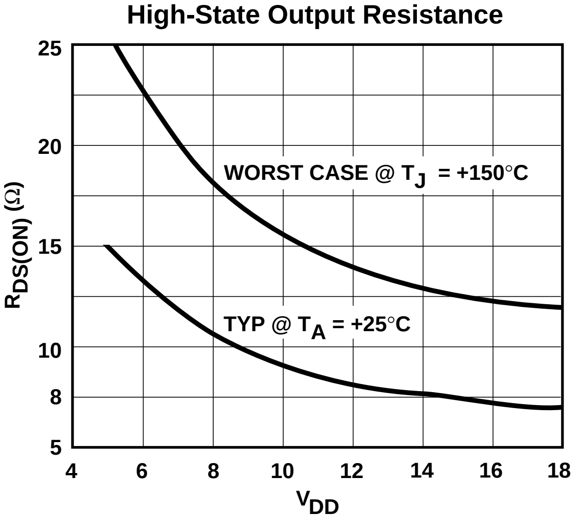
Quiescent Supply Current vs. Voltage



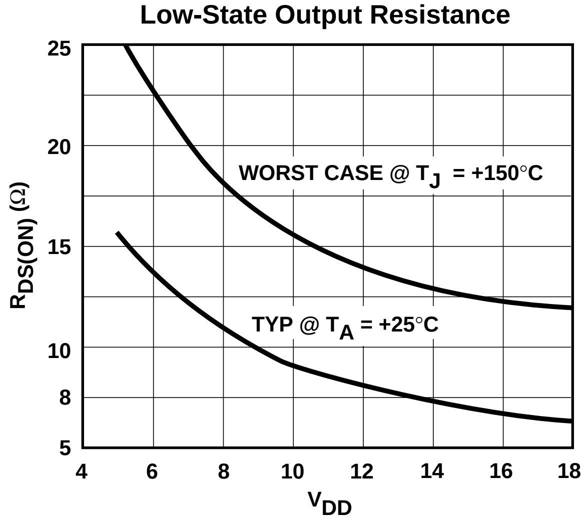
Quiescent Supply Current vs. Temperature



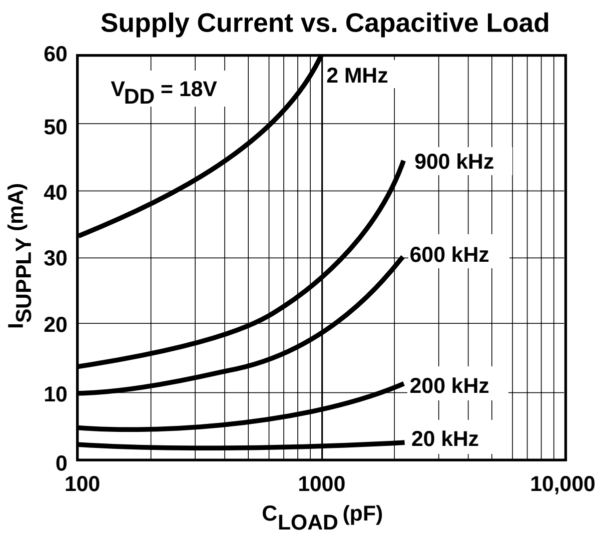
High-State Output Resistance

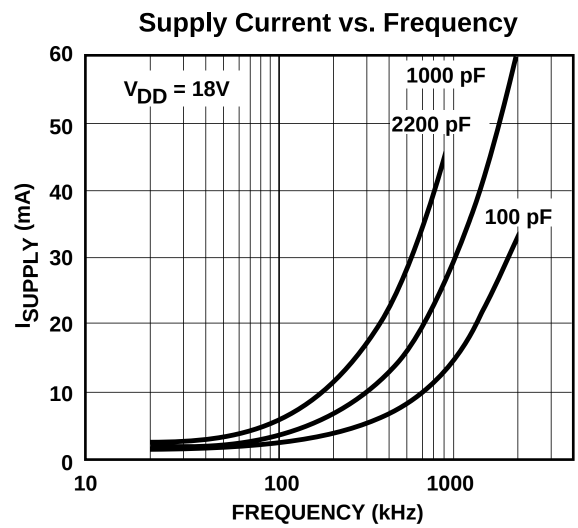


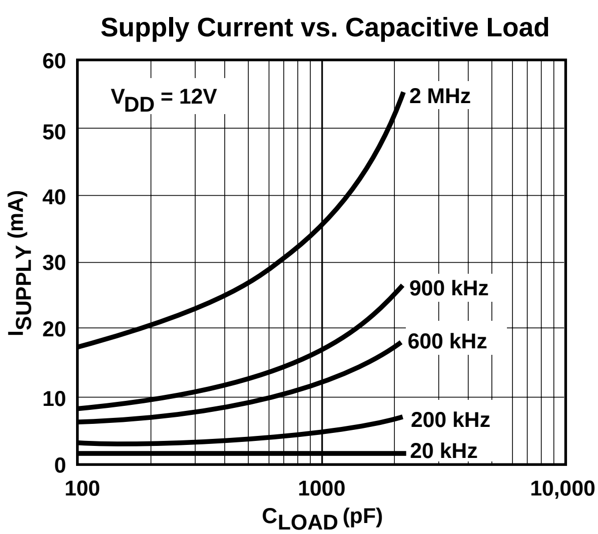
Low-State Output Resistance

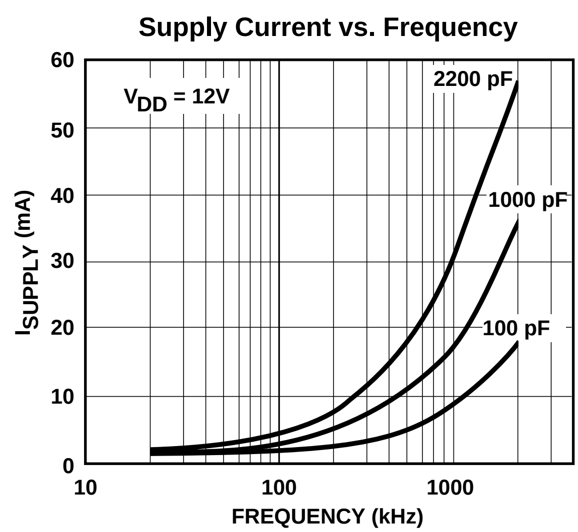


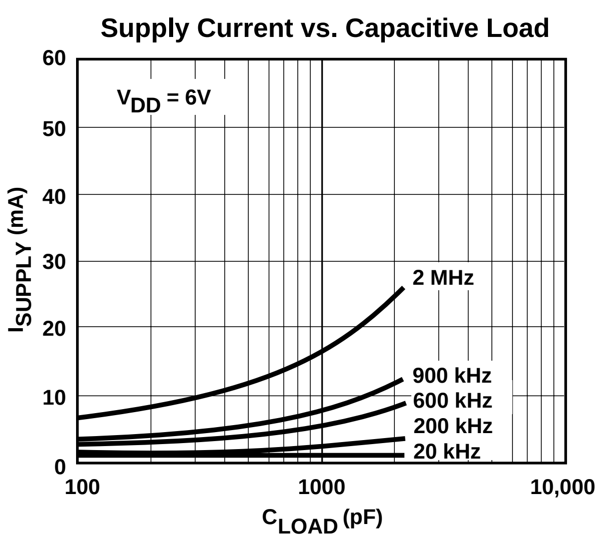
SUPPLY CURRENT CHARACTERISTICS (Load on Single Output Only)

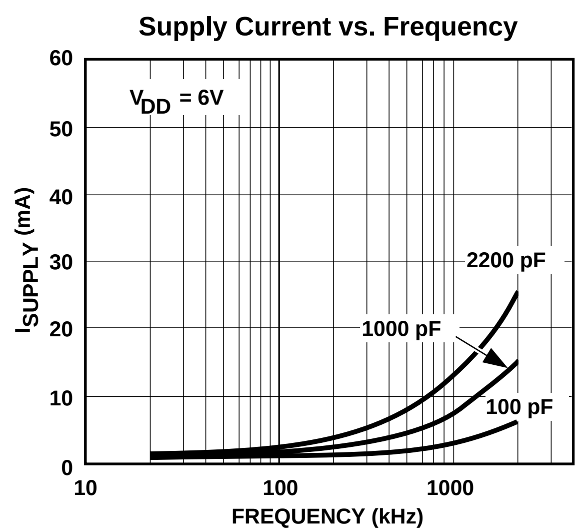






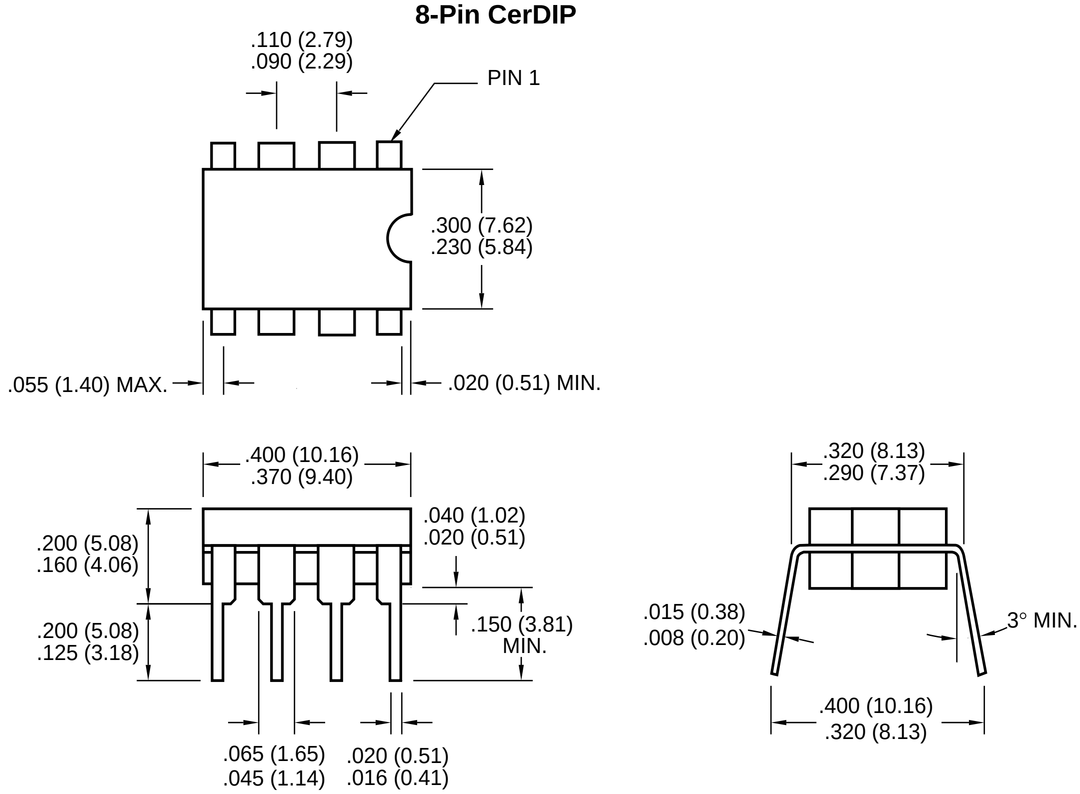




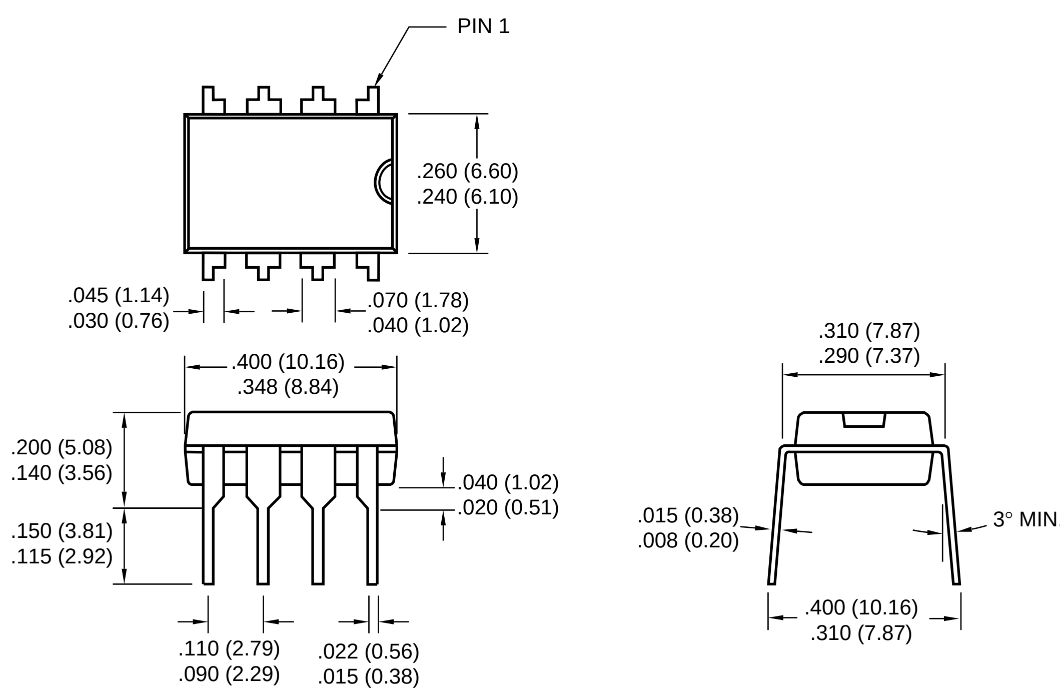


PACKAGE DIMENSIONS

8-Pin CerDIP



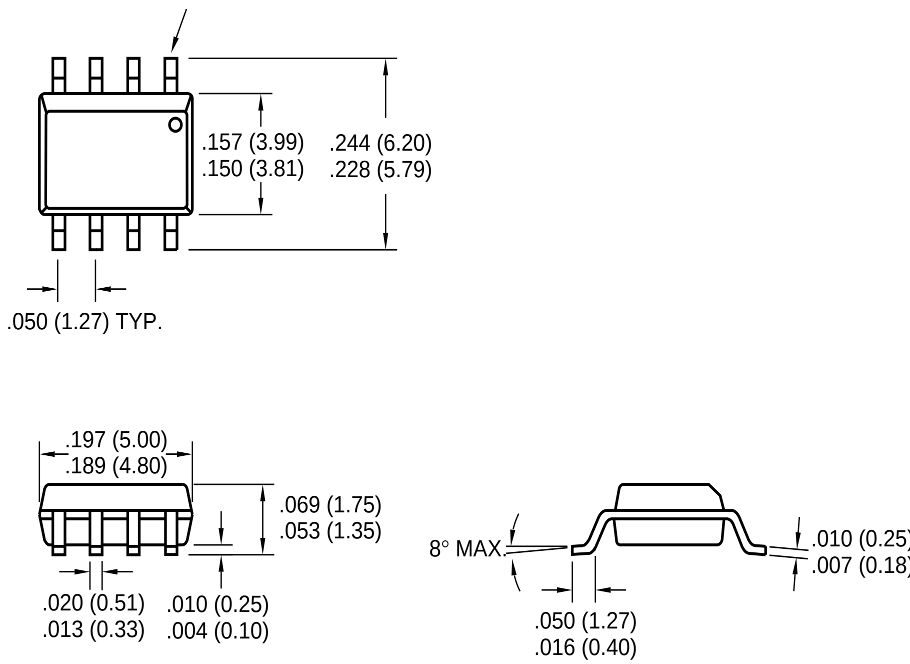
8-Pin Plastic DIP



Dimensions: inches (mm)

PACKAGE DIMENSIONS Cont.)

8-Pin SOIC



Dimensions: inches (mm)

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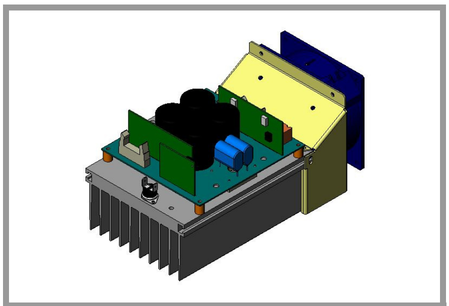
01/09/01

SEMISTACK - IGBT



SEMITOP Stack [1)]

Single-phase inverter

SKS 15F B2CI 03 V12

SK 30 GH 123

P0,71/190F

SKHI 20opA

Preliminary Data

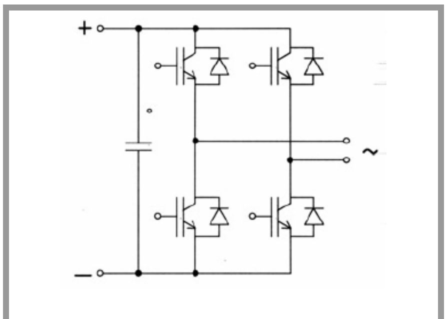
Features

- Compact design
- Vce monitoring
- Low tail current with low temperature dependance

Typical Applications

- Inverters
- UPS
- SMPS

1) Photo non- contractual

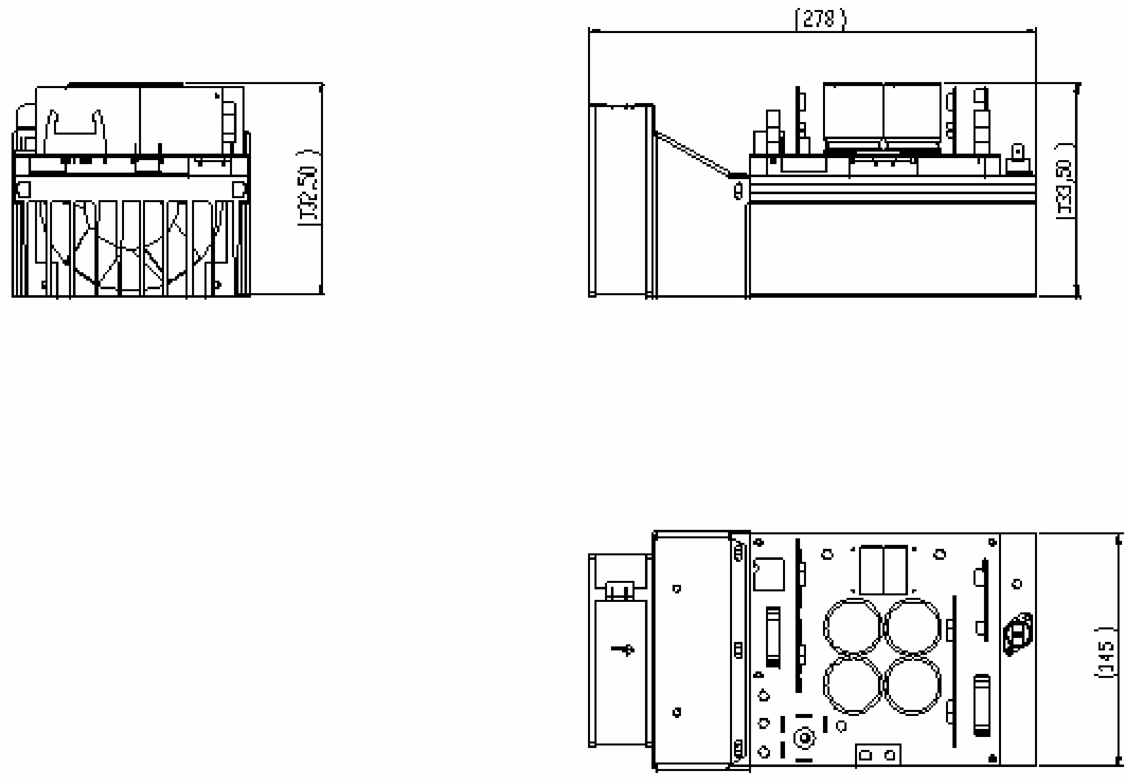


B2CI

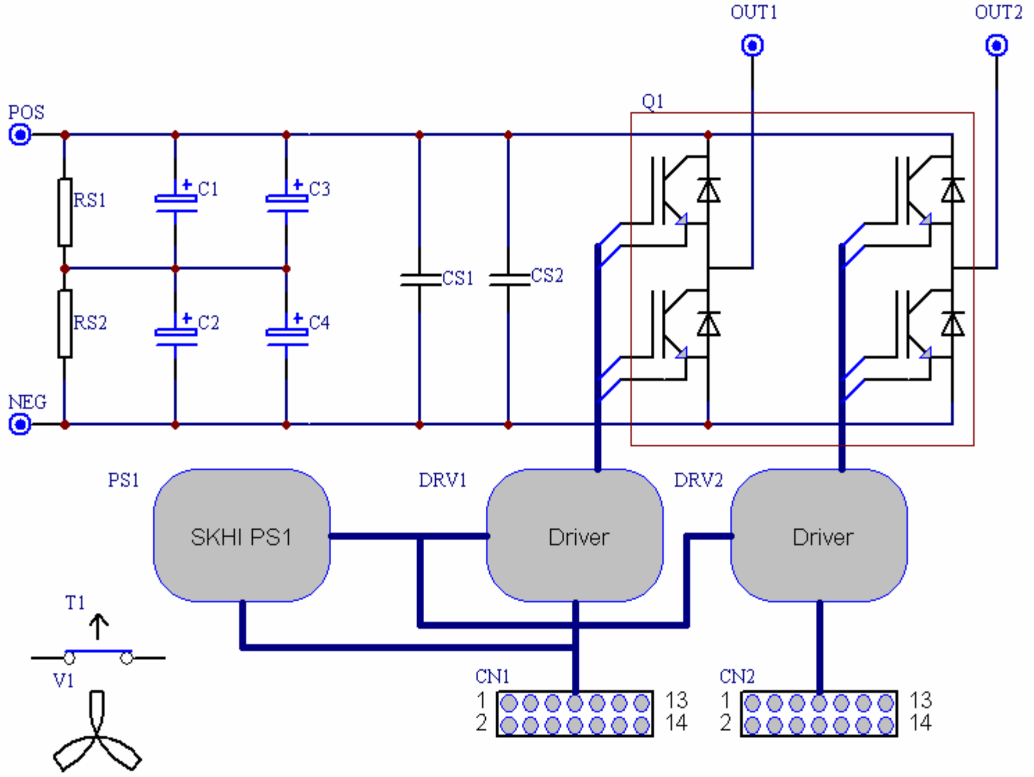
Circuit	I_{rms}	V_{ac} (V_{dc})	Types
B2CI	15	240 (450)	SKS 15F B2CI 03 V12

Symbol	Conditions	Values	Units
I_{rms} max T_{amb} = 35 °C	No overload; 20 kHz 150% overload, 60s every 10min (I_{ov}/I_N) 200% overload, 10s every 10min (I_{ov}/I_N)	15 20/13 22/11	A A A
V_{ce}max		1200	V
f_{sw}max f_{SW}maxCsl	Absolute maximum switching frequency Advise maximum switching frequency	20 20	kHz kHz
C C_{eqvl} $T_{ds\%}$ V_{DC}max	Type EPCOS B43840A2108 Equivalent capacitor bank Discharge time of the capacitor bank Max DC voltage applied to capacitor bank	1000/250 1000/450 - 450	µF/V µF/V s V
Rectifier V_{net}max	 Max network voltage (line side)	- -20%/+15%	V_{ac}
T_{vj} T_{stg} T_{amb}	Junction temperature for continous operation without requirement of reforming of capacitors	-40…+150 -40…+85 -20…+50	ºC ºC ºC
V_{isol}	60Hz/1min	2500	V
w	Aprox. total weight	3.2	Kg
Cooling	Fan, AC power supply (60 Hz) Current Consumption (per fan) Required air flow (per fan)	220 0.12 117	V A m^3/h
Losses	B2CI , Converter at P_{max}, T_{amb}= 35 ºC Efficiency	188 96	W %
Current sensor			
Thermal trip	normally closed	85	ºC
Others components			
Options			
Tests	Functional Test Visual Inspection - -		

Dimensions in mm



Stack design may vary depending upon the version. Please contact SEMIKRON for further details



Electrical Data

Connector SKHI 20 OPA Primary side array						
Connector Pin	Symbol	Description	Values			Units
CN1, CN2			min.	typical	max.	
CNX:1	GND	Ground	0			V
CNX:2	BOT	BOTTOM IGBT Input Signal	0/15 (CMOS)			V
CNX:3	ERROR	Vce Error Signal	0/15 (CMOS)			V
CNX:4	TOP	TOP IGBT Input Signal	0/15 (CMOS)			V
CNX:5	RESET	Reset	0			V
CNX:6		NC				
CNX:7		NC				
CNX:8	+Vs	Supply voltage	14,0	15,0	15,6	V
CNX:9	+Vs	Supply voltage	14,0	15,0	15,6	V
CNX:10	GND	Ground		0		V
CNX:11	GND	Ground		0		V
CNX:12	NC	No connected				
CNX:13	NC	No connected				
CNX:14	NC	No connected				