AUTOMATIC GREENHOUSE WATERING SYSTEM AND MONITORING

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AUTOMATIC GREENHOUSE WATERING SYSTEM AND MONITORING

MOHAMMAD IZHAN BIN JAFRY

A thesis submitted in fulfillment of the
requirements for the award of the degree of
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Faculty of Electrical & Electronics Engineering
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November 2007

“I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)”

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Special dedication to my parents especially my mother that always inspire, love and stand beside me, my supervisor, my fellow colleagues, and all FKEE lecturers and staffs.

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ABSTRACT

The primary issue of greenhouse based horticulture is to manage the greenhouse environment optimally in order to comply with the economic and environmental requirements. Pests and diseases, and extremes of heat and humidity, have to be controlled, and irrigation is necessary to provide water. The solution to these problems is by designing an automatic controlled system. Two sensors are used in this project. Soil moisture sensor needed to automatically control the valve of watering system. Temperature sensor will measure the condition of the greenhouse. Once the temperature sensor detect that the environment temperature is higher than the predetermined temperature value, the cooling fan will be in the on state and vice versa. Wireless monitoring using RF are used in order to monitor the condition of the greenhouse in the predetermine RF range. This project improved the irrigation system from manual to automatic to make it easier to monitor the condition of the greenhouse remotely.

ABSTRAK

Isu utama rumah hijau dalam pertanian adalah untuk mengurus keadaan rumah hijau sepenuhnya dalam memenuhi keperluan ekonomi dan persekitaran. Serangga perosak dan penyakit, suhu dan kelembapan yang keterlaluan hendaklan dikawal dan sistem pengairan adalah diperlukan untuk membekalkan air. Untuk mengatasi masalah ini adalah dengan mencipta satu system kawalan automatik. Dalam projek ini, dua sensor digunakan. Sensor kelembapan tanah diperlukan untuk mengawal injap sistem pengairan secara automatik. Sensor suhu akan meningkat keadaan suhu dalam rumah hijau. Apabila sensor suhu mengesan keadaan sekeliling lebih tinggi daripada suhu yang ditetapkan, kipas penyejuk akan dihidupkan atau sebaliknya. Pemantauan tanpa wayar dengan RF digunakan untuk mengawasi keadaan rumah hijau dalam lingkungan kawasan RF. Projek ini akan memperbaiki sistem pengairan daripada secara manual kepada automatik untuk memudahkan pengguna mengawasi keadaan rumah hijau dari jauh.

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LIST OF ABBREVIATION

RF	Radio Frequency
ADC	Analog Digital Converter
AC	Alternating Current
DC	Direct Current
GUI	Graphical User Interface
ADPU	Analog to digital power unit
CSEL	Clock select

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CHAPTER 1

INTRODUCTION

1.1 Background

A Greenhouse is a building with glass walls and roof; for the cultivation and exhibition of plants under controlled conditions. Greenhouses also are often used for growing flowers, vegetables, fruits, and tobacco plants. Pests and diseases, and extremes of heat and humidity, have to be controlled, and irrigation is necessary to provide water. Greenhouses protect crops from too much heat or cold, shield plants from dust storms and blizzards, and help to keep out pests. Light and temperature control allows greenhouses to become suitable place for growing plants. In other word, a greenhouse is a structure that provides protection and a controlled environment for raising plan indoors. The primary issue of greenhouse based horticulture is to manage the greenhouse environment optimally in order to comply with the economic and environmental requirements.

1.2 Objectives

The objective of this project is to implement automatic greenhouse watering system based on soil moisture sensor and wireless based system monitoring.

1.3 Scope

Several scopes that need to be considered in this project:

i. Sensor used to control the watering system is soil moisture sensor.
ii. Fan system control based on temperature sensor is used as greenhouse temperature controller.
iii. The condition of the Sensors & outputs are to be monitor with remote display based on wireless module.

1.4 Problem Statement

Irrigation is the important thing on a greenhouse system. The water we provide, which is the main element, will make sure the plants survive on certain circumstances. As we all know, most of the gardener use the manual system to irrigate their plant but this system is not efficient. The plants will either die if there is not enough water supply to the plant or vice versa. Plus the gardener must often monitor their greenhouse to ensure the conditions of their plant are in the good health.

In order to maintain the condition and overcome the problem, the automatic watering system and remote monitoring is used. This will reduce the time if using automatic rather than manual way of watering. Fewer workers are needed to maintain the plants or crops. The sensors such as temperature sensor and soil moisture detector are used to control the temperature and watering in the greenhouse.

The system also has the capacity to monitor the condition of greenhouse remotely from computer by using wireless module. The information will be transmitted by using radio frequency and the data will display using third party software such as visual basic. So user will know the condition of their greenhouse without going to the site and get the information.

1.5 Methodology

In order to achieve the objective of the scope few tasks need to be done for the hardware of the system and the GUI application software. For the hardware of the system there are four parts which have to be considered. They are the microcontroller board, the transmitter circuit and the receiver circuit. First of all, in this system, both of the microcontrollers have to be test and check for it functionality. It is to make sure that the microcontroller later can be initialized and the proper program can be burn into its EEPROM to do the appropriate task.

Secondly, transmitter and the receiver module need to be test for its functionality. It can be done by sending a bit of data from the transmitter to the receiver. The push button and the LED can be used as the representation of data sending and receiving. After that, the circuit can be integrating with both microcontroller and then the connection can be done.

Finally, the MAX233 is needed to test for its functionality. It is to make sure that the data can be serially send and receive through MAX233 to the microcontroller of the system. It can be made by downloading program of assembly language into the EEPROM of the microcontroller.

For the software of the system, there are two parts which have to be considered. They are the assembly language programming and the Visual Basic programming for GUI application. For the assembly language, the coding needed to be testing on the THRSim simulator software. The purpose of this simulator program is to debug errors. The Visual Basic 6 software used to make a connection to the remote monitoring using

GUI application. Hyper terminal is used to record data that have been received through the serial connection.

The last part in order to achieve the objective is to test the output of the system. The driver circuits which consist of relay and transistor are needed to be tested so that the cooling fan and the irrigation valve are functional. To test the relay is by giving appropriate power supply to its coil.

1.6 Thesis Outline

Chapter 1 discuss on the background of the project, objectives, scope of the project, problem statement, methodology and also the thesis outline.

Chapter 2 focuses on literature reviews of this project based on journals and other references.

Chapter 3 mainly discuss on the system design of the project. Details on the progress of the project are explained in this chapter.

Chapter 4 presents the results of the project. The discussion focused on the result based on the experiment.

Chapter 5 concludes overall about the project. Future recommendations and commercialization are also discussed in this chapter.

CHAPTER 2

LITERTURE REVIEW

2.0 Greenhouse

The development of models and strategies to control the environment of greenhouse crops started with the shoot environment, that is, with the greenhouse climate. One important reason was that influencing variables such as temperature, humidity, irradiation or CO_2 concentration are easier to measure and to control.
[1Hans Peter Klaring, 2000]

From this research, we can see that there are a few factors that need to be control in a greenhouse. Those factors that need to be considered are temperature, humidity, irradiation or carbon dioxide concentration. But, in this project, factors that are going to be considered are only the temperature and soil humidity in a greenhouse.

2.1 Microcontroller

A microcontroller is a computer-on-a-chip. It is a type of microprocessor emphasizing high integration, low power consumption, self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor.

Microcontrollers are frequently used in automatically controlled products and devices, such as automobile engine control systems, remote controls, office machines, appliances, power tools, and toys.
[From Wikipedia]

By reducing the size, cost, and power consumption compared to a design using a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to electronically control many more processes.

2.2 Sensors

A sensor is a device which measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.
[From Wikipedia]

Because sensors are a type of transducer, they change one form of energy into another. For this reason, sensors can be classified according to the type of energy transfer that they detect. Soil moisture measurements provide useful information for agriculture, such as grape growers, soil stability monitoring, dam monitoring and construction activities.
[R. Frank, 2000]

A typical greenhouse contains several sensors form measuring humidity, temperature, pressure, carbon dioxide, light, motion, etc, and contains several actors, such as, air conditioners, floodlights, sprinkler and water management facility, plant decks, air blowers, fans, CO2 production units, etc. In this project will only consider the temperature and the soil moisture of the greenhouse. There are many types of soil moisture sensor such as tensiometer, resistance block capacitive and etc. every types have their own characteristics and system operation.

2.2.1 Gypsum Blocks soil moisture sensor

Gypsum blocks are one of the lowest cost soil moisture monitoring products available. Their low cost and ease of interpretation makes them ideal for seasonal crops A block of gypsum placed in the soil will wet up and dry out at close to the rate of soil. When gypsum is wet it conducts electricity easily (it is low resistance), and when dry is a poor conductor (high resistance). A pair of electrodes within the block measures this change in resistance and a once off calibration equates it to soil moisture tension. It is possible to measure the resistance of the soil directly using a pair of electrodes, but the measurement would also be influenced by changes in the soil conductivity brought about by the presence of salt and other materials. The gypsum ions provides a buffer against the impact of salt and nutrients – effectively preventing the salt ions from reaching the electrodes – and ensuring the sensor is only responding to moisture levels.

2.2.2 Temperature sensor LM35

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature.
[National Semiconductor]

2.3 Wireless Data Communication

Wireless sensor data monitoring is much less labor intensive than periodic sampling by workers for most applications. Updates need be done only infrequently (e.g. daily), and only with moderate accuracy, but monitoring is often needed over a wide area and for long periods.
[Darold C. Wobschall]

This project consist transmitter and receiver to transfer data in order to monitor the greenhouse remotely. Both module are connected to the encoder and decoder also microcontroller. Radio is the wireless transmission of signals, by modulation of electromagnetic waves with frequencies below those of visible light. Electromagnetic radiation travels by means of oscillating electromagnetic fields that pass through the air and the vacuum of space. It does not require a medium of transport. Information is carried by systematically changing (modulating) some property of the radiated waves, such as their amplitude or their frequency. When radio waves pass an electrical conductor, the oscillating fields induce an alternating current in the conductor. This can be detected and transformed into sound or other signals that carry information.

2.4 Valve

Solenoid valves are electromechanical valves that are controlled by stopping or running an electrical current through a solenoid, in order to change the state of the valve. A solenoid is a coil of wire that is magnetized when electricity runs through it. The solenoid valve makes use of this solenoid in order to activate a valve, thus controlling water flow, airflow and other things with electricity.
[Jimmy Sturo, 2006]

There are many applications using valve especially for the electrical devices. By using electromagnetic, valve is automatically energize and doing its job according to the application system. The function is as replacing the conversional valve, which does need user to operate the system. It is lot easier and more reliable.

2.5 Graphical User Interface GUI

A graphical user interface (GUI) is a type of user interface which allows people to interact with electronic devices like computers, hand-held devices (MP3 Players, Portable Media Players, Gaming devices), household appliances and office equipment. A GUI offers graphical icons, and visual indicators as opposed to text-based interfaces, typed command labels or text navigation to fully represent the information and actions available to a user. The actions are usually performed through direct manipulation of the graphical elements.
[Wikipedia]

By using GUI application it is more useful and user friendly. With interpretation of graphical technique it is easy to understand and lot more easily to control and manipulate the interface.

CHAPTER 3

SYSTEM DESIGN

3.1 Introduction

In this project, there are two elements that should be considered; the Hardware and Software part. In Hardware part includes the Microcontroller 68HC11 as the control unit, both temperature and soil moisture sensor and the development of wireless module.

68HC11 evaluation board is tested before flashed with the software to know the functionality of the module. The temperature sensor used is LM35DZ that will convert the current temperature to an appropriate voltage level. The analog to digital converter will be used to convert the signal to digital value and become input to the microcontroller.

The information received from the sensor is then encoded and transmitted by using a transmitter module to the receiver. The data received will be decoded back and transfer to the microcontroller as an input before display to the computer. The steps are continued with the soil moisture sensor. The condition of the output devices; valve and fan are monitored at the receiver module.

3.2 Hardware Development

This project consists of two inputs and three outputs. The input is the temperature sensor and soil moisture sensor and the outputs are fan, valve and remote display using wireless module. The block diagram for the system is shown as in figure 3.1.

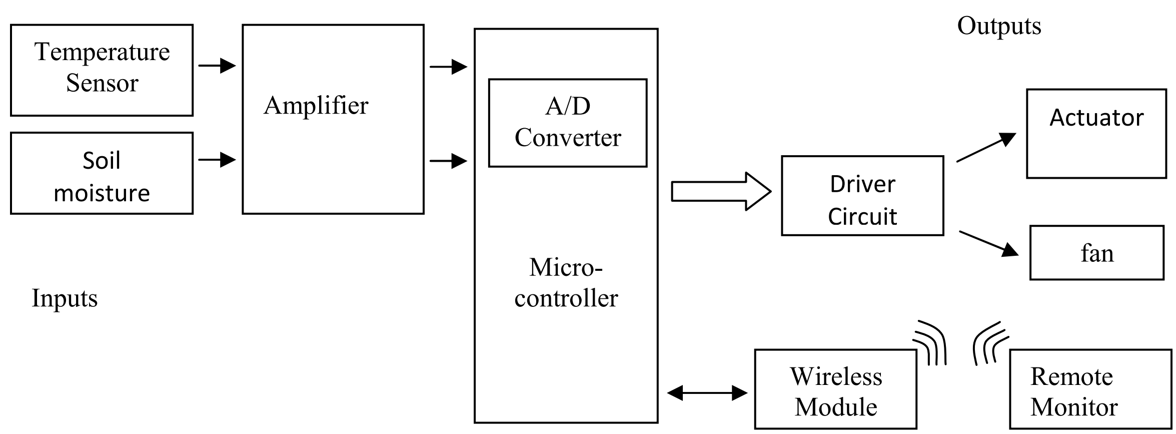


Figure 3.1 Block Diagram of the System

3.3 Microcontroller MC68HC11 Board

This project used two MC68HC11A1 microcontrollers. These microcontrollers consist of 256 RAM and one of Motorola high performance 8-bit microcontroller. On the transmitter circuit, some of port A will be the outputs, port B will be outputs for LEDs and port C will be an outputs to the decoder. Port E will be input for the sensors; temperature sensor and soil moisture sensor.

The first stage was constructing the bootstrap mode of the microcontroller. In bootstrap mode the program will be place into the EEPROM. After constructing the microcontroller circuit, the first thing is to test the microcontroller internal clock for its functionality.

The clock will be generated when the power is supplied. The output signal of clock is displayed on the oscilloscope when one wire cable is tapped to the pin 27 of the microcontroller and another wire is grounded. The waveform on oscilloscope is the waveform of the pulse generated by the microcontroller. This is to make sure the clock is generated and the functionality of the microcontroller.

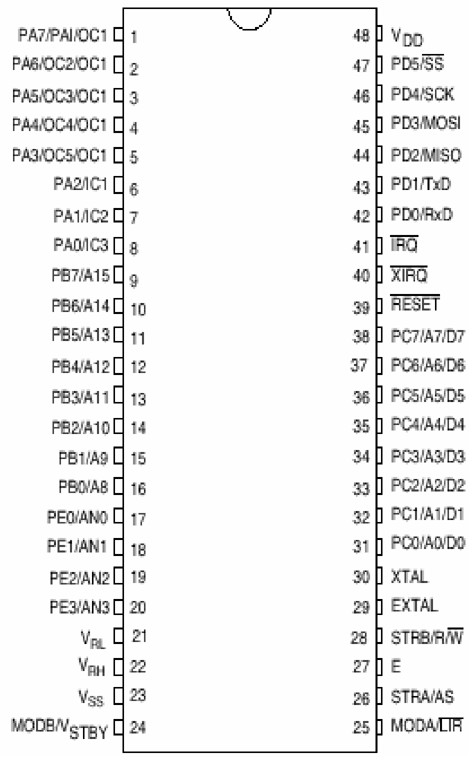


Figure 3.2 MC68HC11 pin connection.

For the connection of the system, all of the ports are used. Port A is used for the output of valve cooling fan and buzzer. Port B is used as output of LED as indicator of condition and temperature of the greenhouse. Port C is an input for the encoder before transmitting the data is done. Port D is used as input and output of MAXIM which is used to transfer the data to the computer using serial port. Port E is used as ADC connection for temperature sensor and soil moisture sensor.

3.4 Temperature Sensor

One of the inputs of the project is the temperature sensor. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The sensor used is the LM35DZ, which is the precision temperature sensor from National Semiconductor, connected to the A/D converter of the microcontroller.

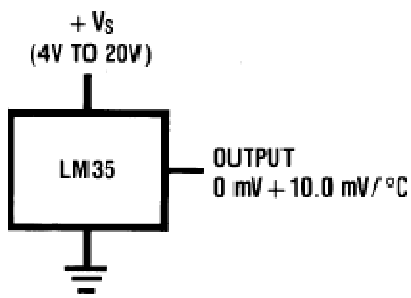


Figure 3.3 Basic Centigrade Temperature Sensor (+2°C to +150°C)

The voltage signal have to converted to an actual temperature by using the information that 10 mV is equal to 1 ^{o}C. This sensor, in the most basic configuration, has an output that is at 0.0V at 0 ^{o}C, and increases 10 mV per degree C. Thus, at 50 C, the output would be 500 mV (0.5V).

Figure 3.4 Connection Diagram for LM35DZ

Assuming 5.0V as reference for the ADC, and an ADC reading of 256 ($FF) is achieved at 100 C, then an amplifier or signal conditional circuit is needed. Also as alternative, scaling factor can be used for the output voltage signal. By using the supply voltage of 5V, only 2 degrees resolution because each bit represents 5/256 = 0.0195 volt. As long as the scaling factor is an integer, the multiplication using the MC68HC11 MUL instruction can be performed.

The output of temperature sensor is sensed by using a voltmeter. The output voltage is converted to temperature by a simple conversion method. The general equation used to convert from the output temperature to temperature is:

Temperature (°C) = V_{out} * 100 °C/V

The Analog to Digital converter (ADC) is initialized by setting the ADPU to 1 so that (ADC) is turning on. Also, CSEL is set to 0 since the internal clock is used. Then, a 100µs delay is required to stabilize the system.

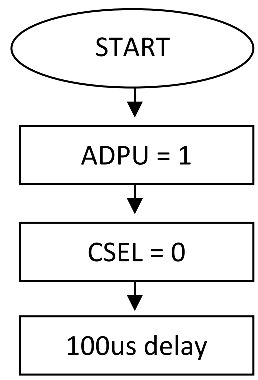


Figure 3.5 Step to initialize the Analog-to-Digital Converter (ADC).

3.5 Soil Moisture Sensor

There are many techniques for soil moisture sensor. Resistance type is the lowest cost and easier to construct. When soil is wet it conducts electricity easily (it is low resistance), and when dry is a poor conductor (high resistance). A pair of electrodes within the soil measures this change in resistance and a once off calibration equates it to soil moisture tension.

The calibration of resistivity and produces of signal (voltage output) become an input to microcontroller to drive the valve of irrigation. The specific voltage are determined and divided into several condition according to the soil, such as dry, average, wet and etc.

Because of time constrained, soil moisture sensor in this project is developed by using simple conducting method. By using two pair of copper rod, the apply supply power will be conducted through the rod if there are water in the soil. The water will be conductor and the circuit will be closed. The apply voltage will be an input to the microcontroller on port E. If 5V of voltage is applied to the rod, the soil will become a resistance. With an output voltage signal on another rod, the condition of the soil can be known and irrigation system can be done automatically.

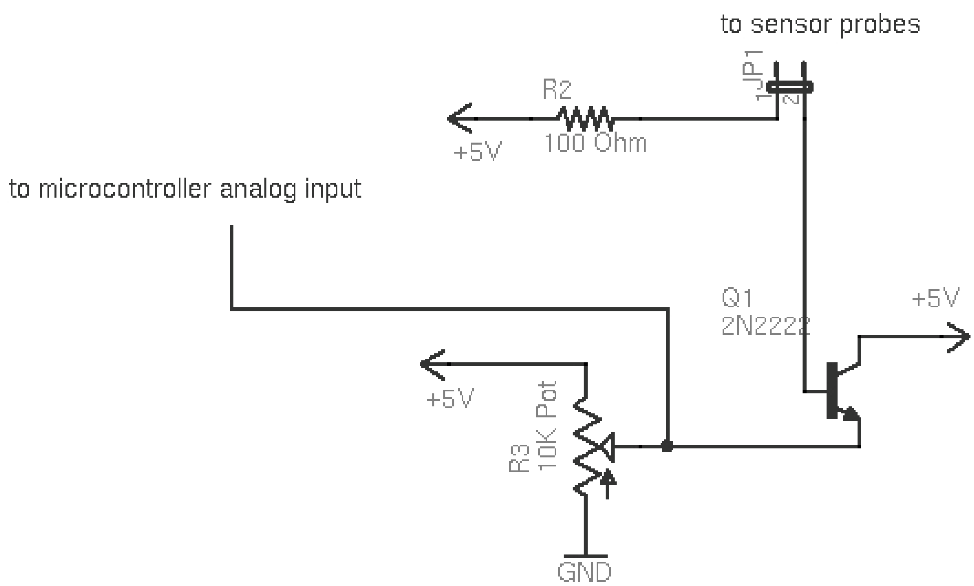


Figure 3.6 Soil moisture sensor circuit

Figure 3.7 Development of soil moisture sensor.

3.6 Relay

Relay is used for as a switch for the water valve. It is easier to switch the valve on and off because the valve currently using an AC power supply. Before that we need to test the functionality of the relay by applying simple circuit with led as an output. The detail of the circuit is shown on figure 3.8 below:

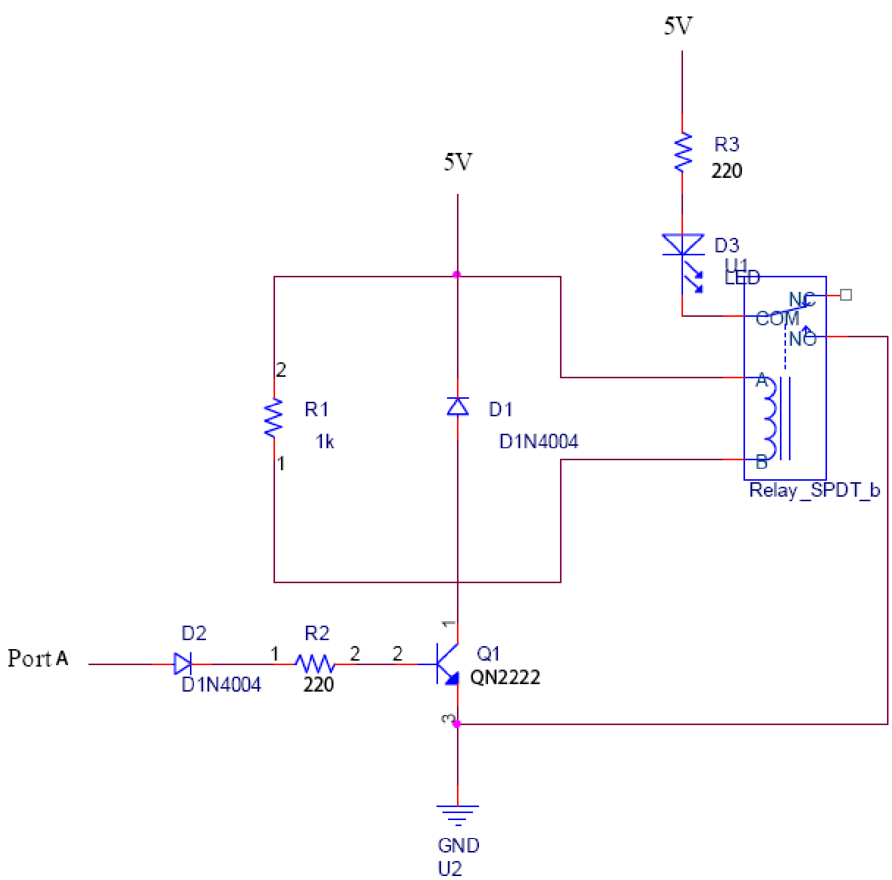


Figure 3.8 Relay connection to test the functionality of the relay

3.7 Irrigation Valve

Irrigation valve is one of the solenoid valves. A solenoid valve has two main parts; the solenoid and the valve. The solenoid converts electrical energy into mechanical energy which, opens or closes the valve mechanically. In this project, the irrigation valve works on 240Vac. The valve is tested by supplying direct 240Vac to the cable terminal. After making sure that the valve is functioning, it is connected to the relay. A relay (normally open) is needed to drive the irrigation valve. The output PortA of the microcontroller is used to turn the relay on and trigger the valve. When there is output at PortA, it will close the relay and turn on the irrigation valve. A diode is placed at PortA to avoid reverse current that can harm the microcontroller. The detail configuration is shown in Figure 3.9:

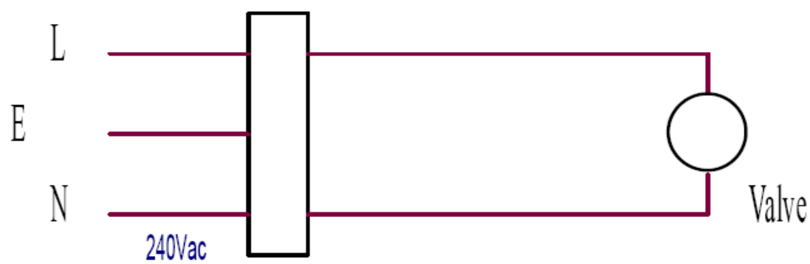


Figure 3.9 Irrigation Valve

Figure 3.10 Actual irrigation valve.

3.8 Transmitter and Receiver

Transmitter and receiver are one type of wireless module. These modules are using FM signal (433Mhz) to transmit and receive data by using serial communication. These modules must be in range in order it to get appropriate data or information. It is about 1000 feet radius maximum of range. These modules are ideal for the cost effective wireless transfer of serial data, control, or command information in the 433MHz band. The figure 3.11 and 3.12 shown below is the example connection of transmitter and receiver circuit:

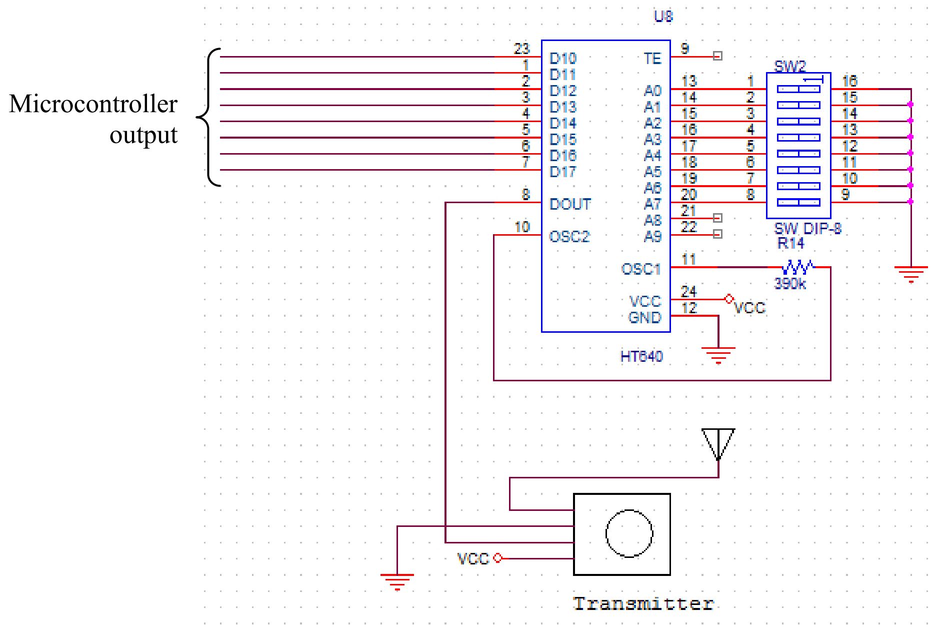


Figure 3.11 Connection of transmitter circuit.

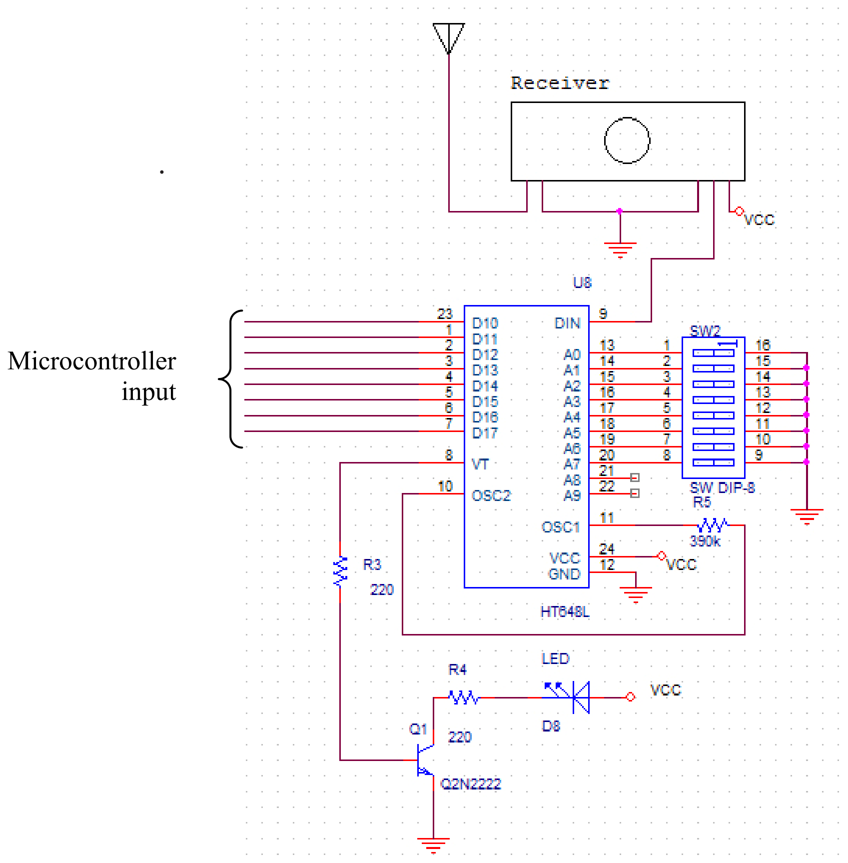


Figure 3.12 Connection of receiver circuit.

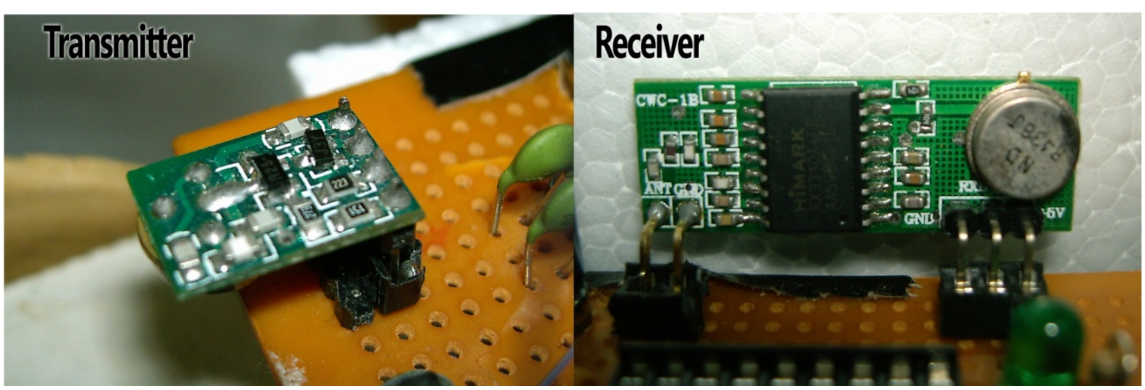


Figure 3.13 Actual transmitter and receiver module.

3.9 Four Bit Data Transmitter/Receiver

This setup consists of a transmitter and an encoder sitting on one side for transmitting four bits of data, while the receiving end consists of a decoder and a receiver. This circuit is shown in figure 3.14 which shows this exact circuit implemented on breadboard.

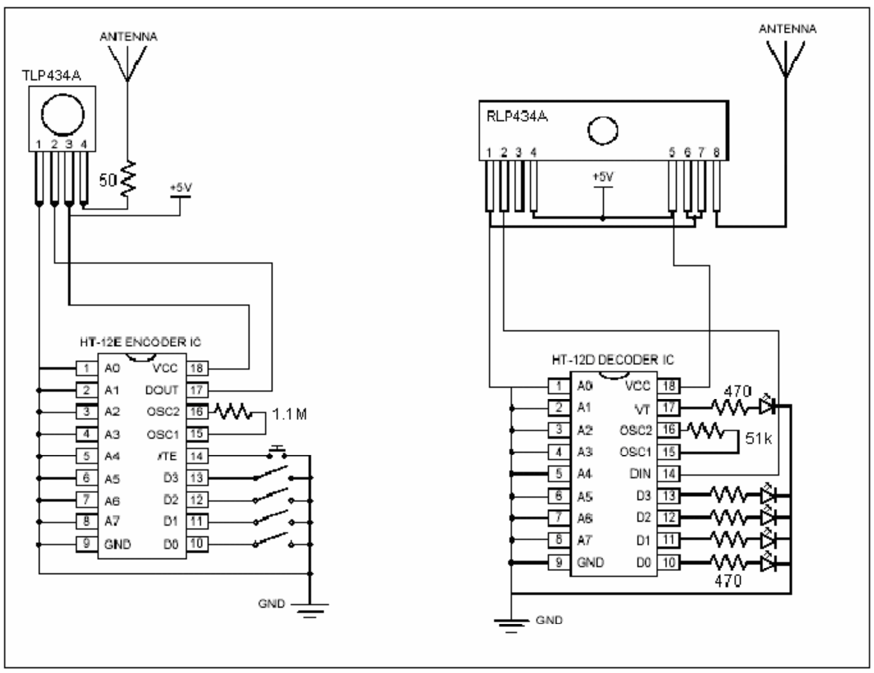


Figure 3.14 Four bit transmitter/receiver circuit

3.9.1 Operation of Four bit Circuit

Since the receiver can handle a maximum of 6V supply, the entire circuit is operated at 5V, even though the encoder, decoder and transmitter can handle supplies of up to 12V. The address lines for both the encoder and decoder are grounded for this circuit since a valid transmission only occurs if address values are same on both circuits. In order to transmit, the data switches D0-D3 on the HT12E are set to the required logic levels (closed switch to represent logic low and open switch to represent logic high) and then the transmit enable (pin 14) switch is closed to enable transmission of both the 8 bit address (all zero's in this case) and 4 bit data (set by the 4 switches).

All data information is seen on the light emitting diodes connected to the data and valid transmission pins. Hence a 4 bit data has been successfully transferred wirelessly using radio frequency. Figures 3.15 and 3.16 are show these setup photos which was implemented on breadboard and tested.

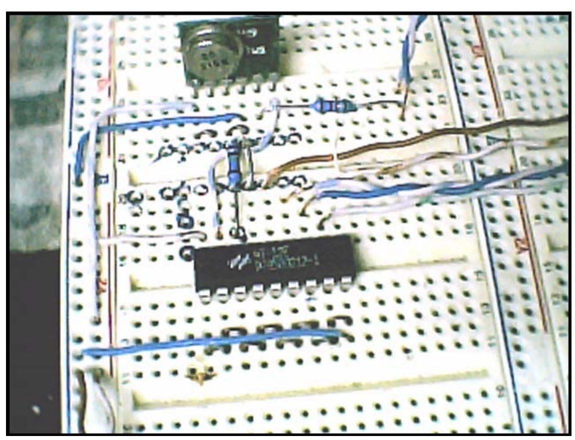


Figure 3.15 Four bit transmitter on breadboard

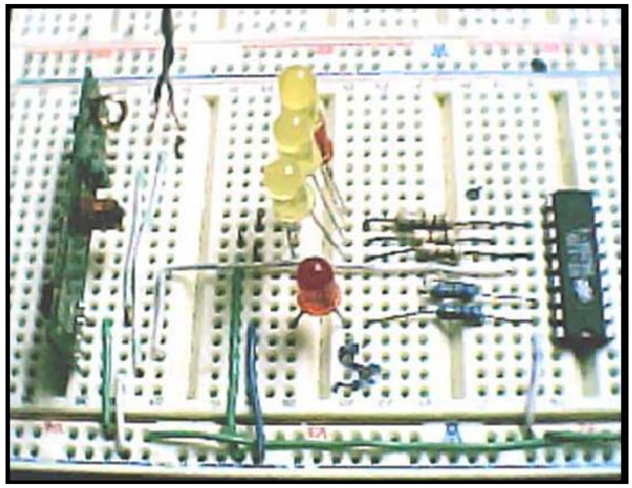


Figure 3.16 Four bit receiver on breadboard

3.10 WP11

The Motorolla MC68HC11 using assembly code as its command language. The coding which has been compiled has to burn into the microcontroller by using WP11 software. There is other software that can be used but WP11is easy and free. There are several steps to need to be followed. First of all, the microcontroller need to be initialized and performing communication test.

The communication port of the operating system must be set to Com1 and start initializing the microcontroller by pressing initialize device button as in figure 3.17. Then the microcontroller needed to be reset. After that, press OK button and then continue with burning process. Before that, it is important to delete the previous program stored in the microcontroller EEPROM memory. Erasing can be done by pressing the “Erase EEPROM Config Reg” button to perform blank check to ensure that there is no other program inside the microcontroller. Programming microcontroller is done by using “Program EEPROM” button. Finally, press the “Load from file” button to download the program to the microcontroller.

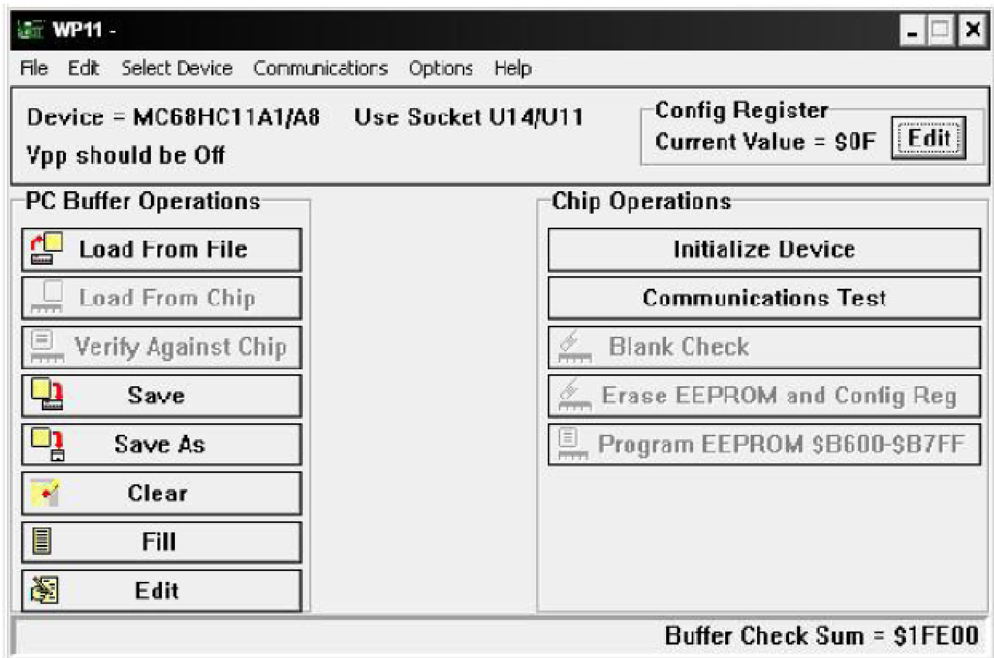


Figure 3.17 Software WP11

3.11 THRSim 11 Software

The Motorola 68HC11 microcontroller is a popular microcontroller used in many applications. Before downloading program into the microcontroller, the program needs to be assembled. With the THRSim11 program it easier to edit, assemble, simulate and debug programs for the 68HC11 on your windows PC.

First of all, programming which have been finished is compiled using THRSim software. The highlighted coding is marked as errors or syntax which has to make later debugging. The compiled file of the extension “name.LST” is used to program the microcontroller by using WP11.

While debugging the graphical user interface makes it possible to view and control every register (CPU registers and I/O registers), memory location (data, program, and stack), and pin of the simulated microcontroller even when the program is running. It is possible to stop the simulation at any combination of events. For example, stop when RxD becomes low and RAM location $003F contains $BD or I/O register TCNT is greater than $3456.

The I/O box or other output such as LEDs and switches is used as virtual device in THRSim software. The slider port E and ADC detail is used as voltage calibration of virtual input in THRSim Software. By adjusting the value the virtual ADC value, the simulator is performed as actual device. The interface of the program is shown in figure 3.18:

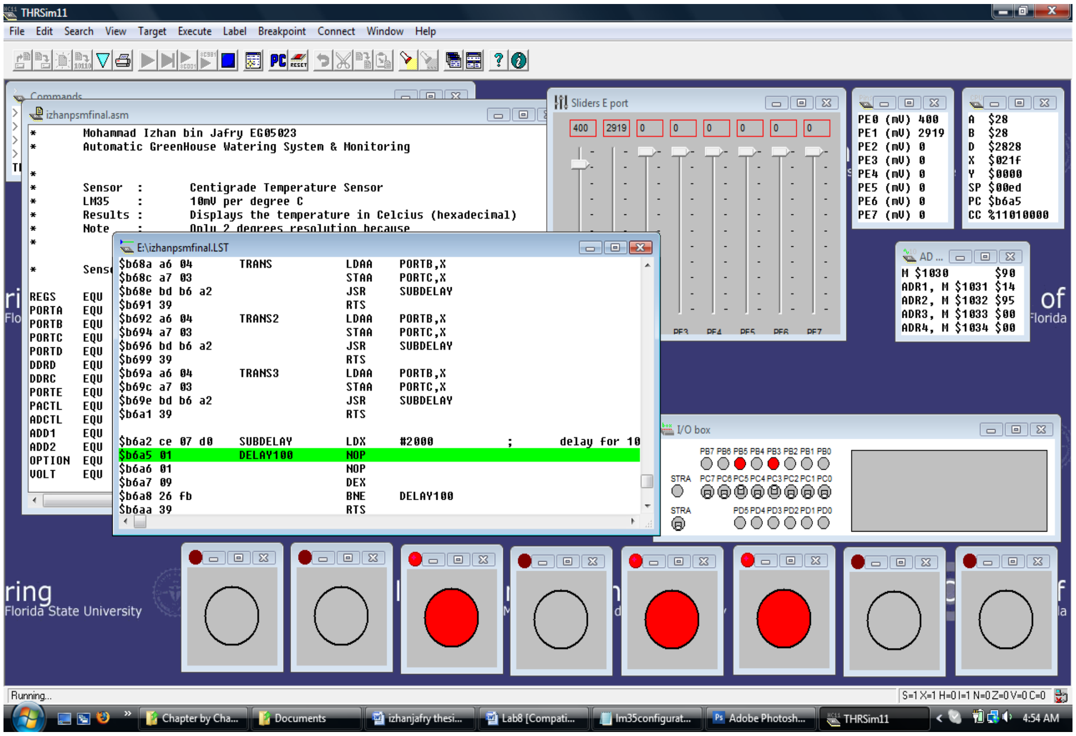
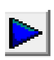


Figure 3.18 THRSim11 Software simulator

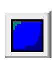
3.11.1 THRSim11 User's Manual for This Project

Click this button to assemble the program. All the programs need to be assembled before downloading it into the microcontroller. Once it is assembled, a window like this will appear. In this window, the program is assembled into assembly language.

This button is used to run the program step by step. We can easily detect the error by using this button and also we can see what is done by the microcontroller step by step.



This button is used to run the program.



This button is used to stop the running program.

3.12 MAX233

Figure 3.19 shows the interface of the EIA232. MAX 233 is used for translating signals between a microcontroller and a standard computer serial port. From Figure 3.19, we can see that the MAX 233 is connected to the PD0 (pin 42) and PD1 (pin 43). These two pins are for communications port in order to communicate with a personal computer. Then, from the MAX233 it is connected to DB9 to interface the board with the computer. DB9 interface uses pin 2, 3 and 5 of the female connector where pin 2 is for the transmission, pin 3 for receiver and pin 5 will be grounded. A flashing LED program is uploaded to test the MAX 233. The output was displayed on the LED.

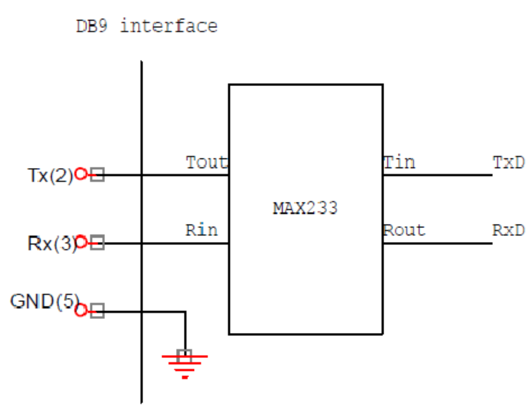


Figure 3.19 EIA232 Interface

Below is the flashing LED program that was used to test MAX 233:

```
REGS      EQU  $1000        |             BSR      DELAY
PORTB     EQU  $04          |             BCC      ULANG
          ORG       $B600   |             BRA      AGAIN
          LDX       #REGS   |  DELAY      LDY      #$1010
          AGAIN      CLC    |             REPEAT   DEY
          LDAA       #$01   |             BNE      REPEAT
          STAA P    ORTB, X |             RTS
          BSR        DELAY  |             END
          ULANG     ROLA    |
          STAA      PORTB, X|
```

CHAPTER 4

RESULTS

4.1 Microcontroller (MC68HC11)

The two of microcontroller are tested for the functionality and the results are recorded and display on the oscilloscope. From figure 4.1, the output waveform is generating at pin 27 of the microcontroller. This result shows that the internal clock of the microcontroller is functional. The clock frequency is depending on the crystal used on the circuit.

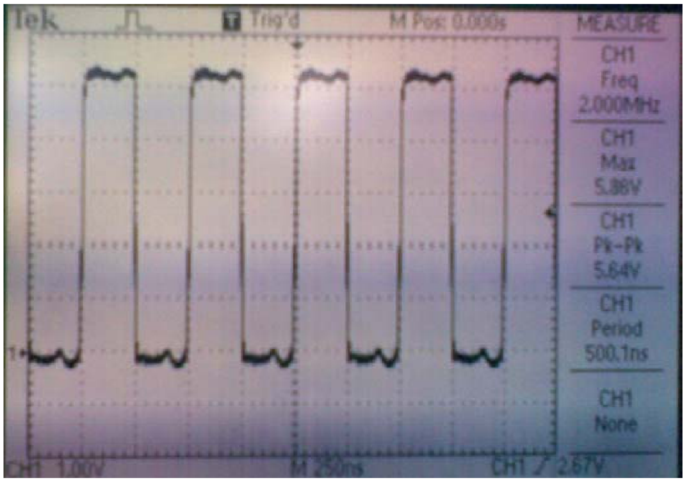


Figure 4.1 Output Waveform at Pin 27

Scale: For x axis, 1cm: 1V

For y axis, 1cm: 1V

The clock speed or frequency is:

1/4 x 8 MHz = 2 MHz

Thus, the frequency is 2MHz.

4.3 Hardware

The tank model with of waterproof material is used to demonstrate the irrigation system as shown on figure 4.2. When the valve is on, the water flow through the valve and the sensor will detect the condition of the soil. If the soil is dry (according to water level), the valve be automatically switched on and vice versa.

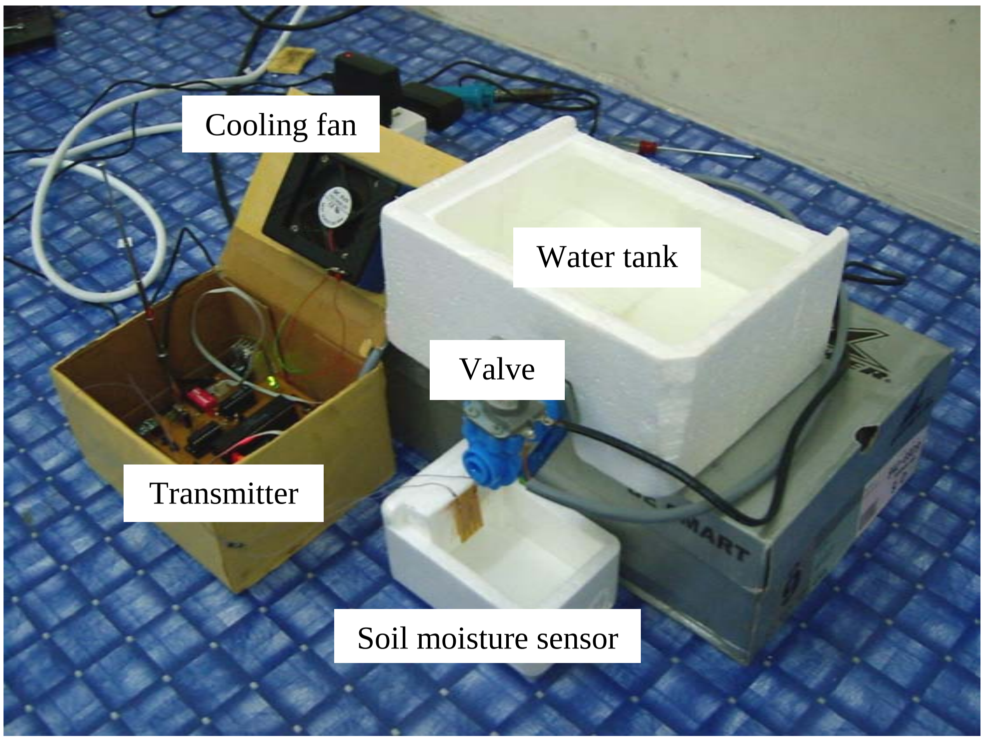


Figure 4.2 Output system and transmitter of the greenhouse

From the system, temperature sensor is controlled the condition of the cooling fan. The 40 ^{o}C is became an indicator. The condition of the cooling fan is as in table 4.1:

Condition of the greenhouse (^{o}C)	Output (cooling fan)
^{o}C<40	0V
^{o}C>40	6V

Table 4.1 Data table of cooling fan module.

For the transmitter module which is connected with the microcontroller, the data is sampled and transmitted to the receiver so that the condition of the greenhouse can be display on the remote monitor system.

For the temperature reading, the result is displayed on the microcontroller transmitter board before begin the transmitting process. Four LEDs on the board are become as indicators for four bit data representation. Table 4.2 shown the result of conversion process:

Four bit binary data				**Decimal representation**
LED4	LED3	LED2	LED1	
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

Table 4.2 Four bit binary to decimal representation

At the receiver section, the same data of four bit binary number as shown on table 4.2 are received and decoded. The data is buffered and save into the memory of the microcontroller then displayed on the GUI application of visual basic 6. The temperature will be recorded and the data is plotted on the graph. The overall receiver system as shown on figure 4.2:

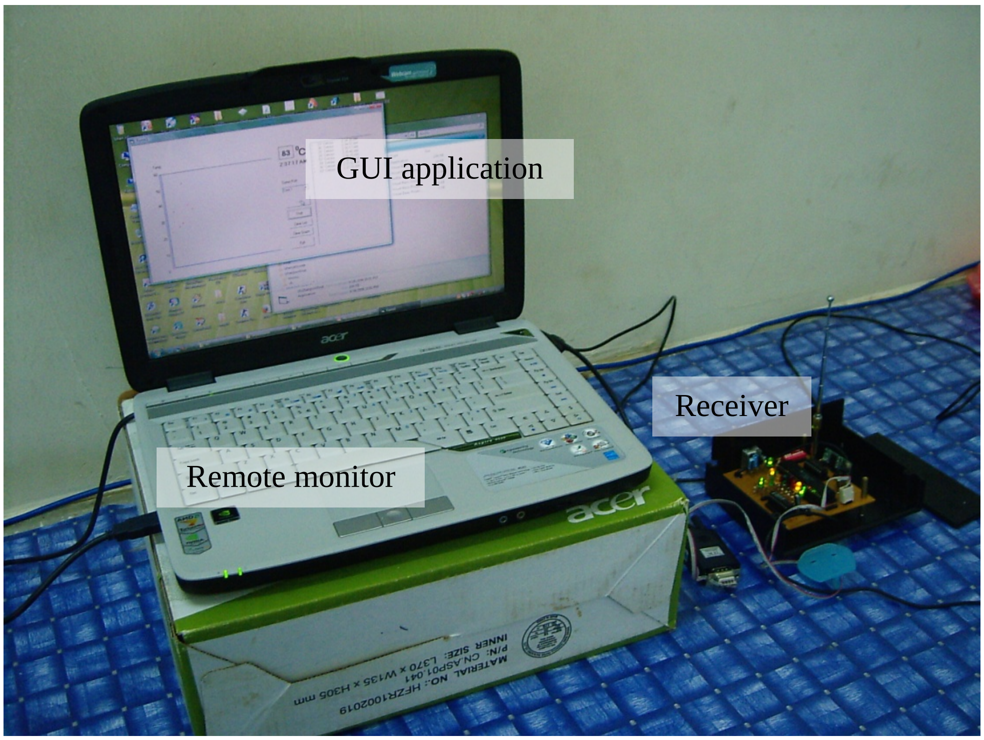


Figure 4.3 GUI application system and receiver of the greenhouse.

4.4 Software

The figure 4.3 display sampled data that have been successfully received from the receiver module. The user can easily control the application by pressing the button of the GUI in order to do the certain task. The GUI application is sampled a data in a period of time. The data is captured and recorded on GUI application every 30 second. The graph is plotted as shown on figure 4.3:

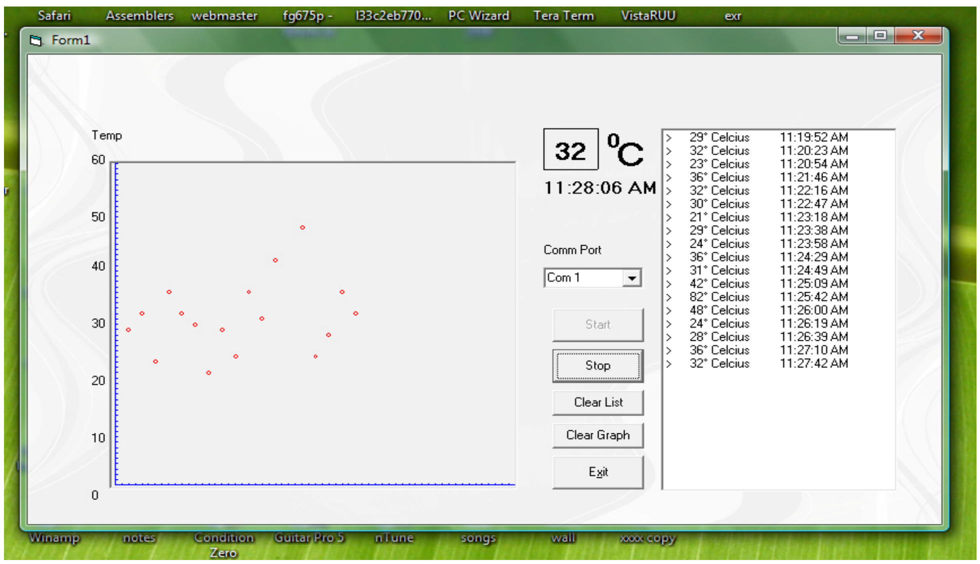


Figure 4.4 GUI application system using visual basic 6 programming.

Temperature (^{o}C)	**Current time**
29	11.19.52 AM
32	11.20.23 AM
23	11.20.54 AM
36	11.21.45 AM
32	11.22.16 AM

Table 4.3 Example result of GUI application data sampling.

Overall system designs shown on figure 4.5 and figure 4.6 are a transmitter and receiver module with its microcontroller. The output relay one and two are driver circuit for cooling fan and irrigation valve. Secondly, the addressing switches are used as RF security features for the system. LED indicator represent the reading value of ADC before beginning to transmit data to the receiver. The antennas are used to amplify the signal in order the system to get better transmission.

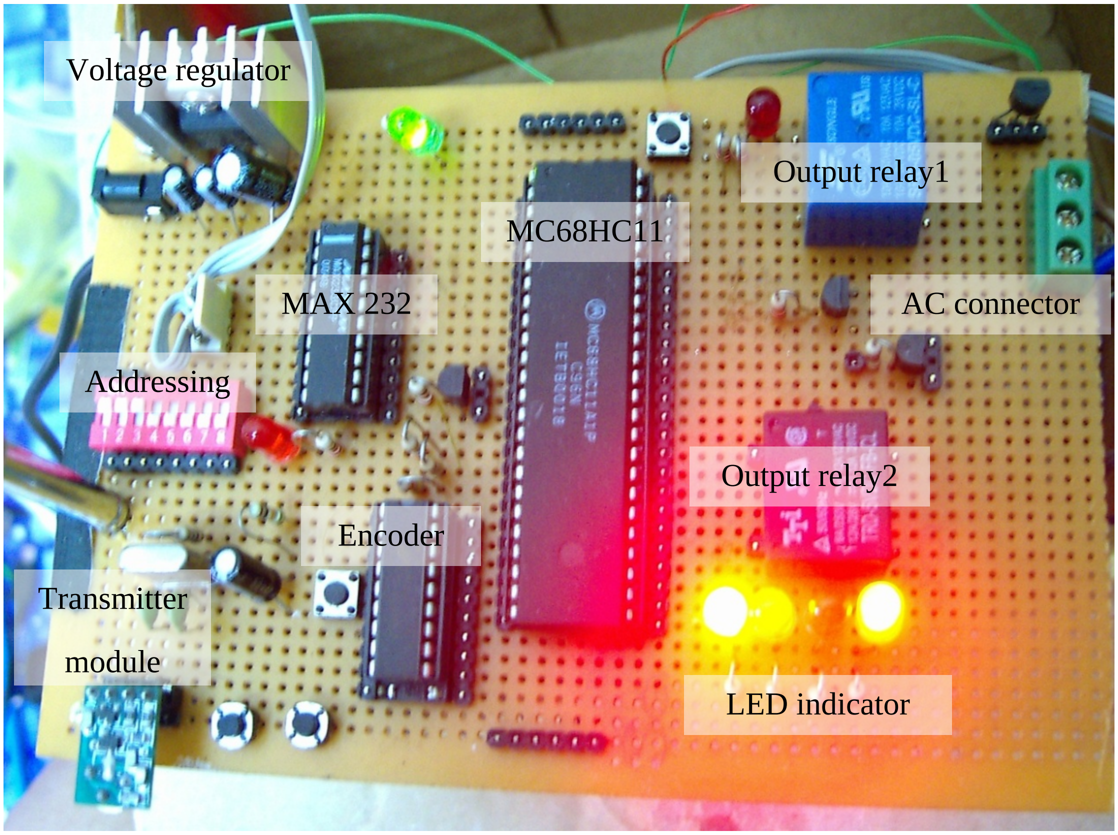


Figure 4.5 Transmitter circuit board

Figure 4.6 shown below is the receiver system consists of LED indicators displaying the transmitted data. The MAX 233 module then sends the serial data to the computer for GUI application.

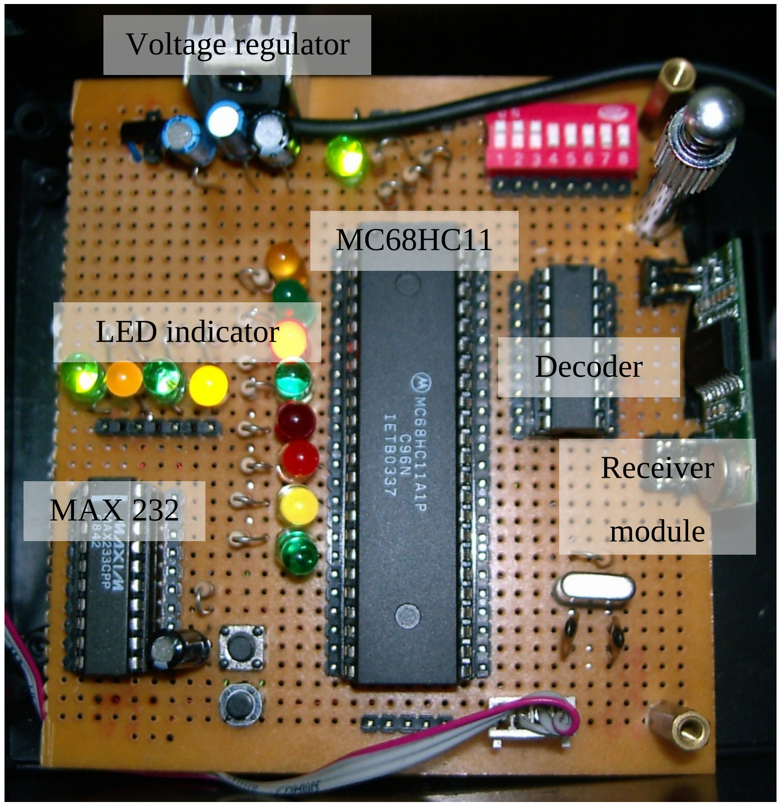


Figure 4.6 Receiver circuit board

Figure 4.6 shown the overall flow diagram of the system :

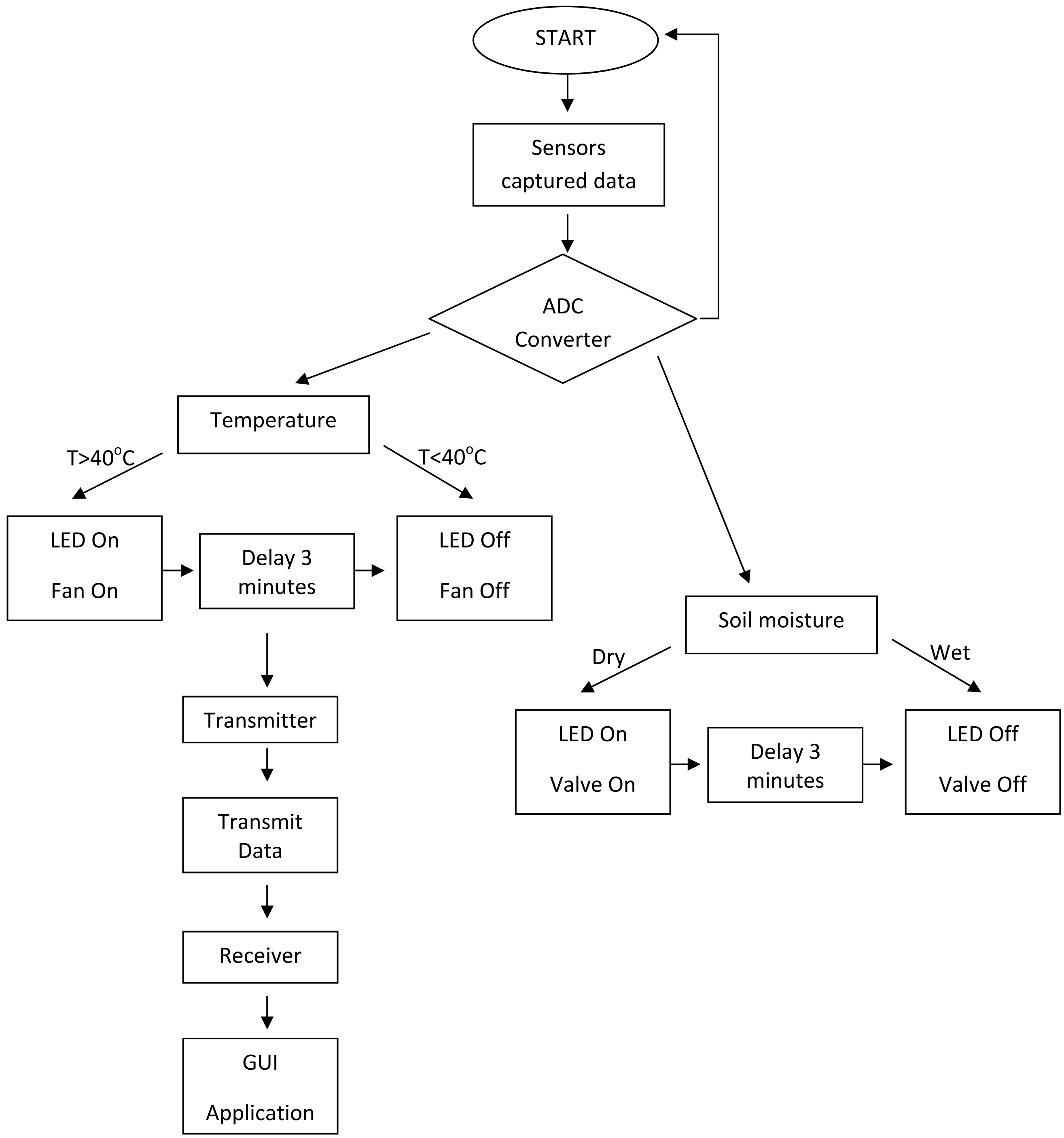


Figure 4.7 Overall flow diagram of the system

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Greenhouse is becoming popular planting habit nowadays especially in countries that have many seasons in a year such as Europe. This is due to some plants need specific environment control such as temperature and soil moisture control for growing.

In this project, the watering system can be automatically control by using the soil moisture sensor. By using basic circuit of soil moisture sensor, irrigation can be automatically done and easy to control. It is more convenient and efficient then using the manual way of irrigation. Also it will reduce cost by using this system and did not need extra worker to do a job for watering pants and crops.

Finally, with implementation of wireless monitoring of RF technology, the user can easily maintain the condition of the greenhouse without going to there because the data of the system will be sending wirelessly by distance to the user. From there user can know what really happen to the greenhouse such as temperature and others.

5.2 Recommendations

In the future, this project can be further studied by adding the some improvement. Some improvements that can be made to this project are:

i. Improvement on RF module or change to Bluetooth module.
ii. Add LCD or 7-segment display at the transmitter and receiver side that we can easily read the temperature of the system.
iii. Changing the 68HC11 to PIC since PIC has much more memory without adding other IC's such as EEPROM.
iv. Use commercial soil moisture sensor.
v. Improvement on VB application.

5.3 Costing & Commercialization

5.3.1 Costing

Table 5.1 shows the overall costing for the project:

Component	Price per Unit	Quantity	Price
MC68HC11A1 MAX233	RM 40.00	2	RM 80.00
LM35DZ	RM 8.00	1	RM 8.00
Voltage Regulator (7805)	RM 6.00	2	RM 12.00
DB9	RM 1.00	2	RM 2.00
Connector 4 Way	RM 0.17	2	RM 0.34
3 pin Plug Top Sirim	RM 2.50	1	RM 2.50
Crystal (8 MHz)	RM 1.20	2	RM 2.40
DC Jack	RM 0.60	2	RM 1.20
Heat Sink	RM 0.90	2	RM 1.80
LED	RM 0.15	16	RM 4.40
PCB Header	RM 0.50	12	RM 6.00
PCB Stand	RM 1.00	4	RM 4.00
Relay 1	RM 2.50	2	RM 5.00
Reset Button	RM 0.30	4	RM 1.20
Strip Board 1	RM 3.00	1	RM 3.00
Valve	RM 35.00	1	RM 35.00
Wire Wrapping	RM 15.00	1	RM 15.00
Capacitor (1µF) 2	RM 0.08	4	RM 0.32
Capacitor (100µF)	RM 0.15	2	RM 0.30
Capacitor (4.7µF)	RM 0.07	4	RM 0.28
Capacitor (22pF)	RM 0.08	4	RM 0.32
IC Base (48 pin)	RM 0.65	2	RM 1.30
IC Base (20 pin)	RM 0.23	4	RM 0.92
Resistor (220Ω)	RM 0.01	20	RM 2.00

Component	Price per Unit	Quantity	Price
Resistor (10kΩ)	RM 0.01	2	RM 0.02
Resistor (10MΩ)	RM 0.04	2	RM 0.08
433Mhz FM Transmitter	RM50.00	1	RM 50.00
433Mhz FM Receiver	RM50.00	1	RM 50.00
		Total	RM 288.38

Table 5.1: Cost for Project

5.3.2 Commercialization

Communities nowadays usually search for products that are users friendly. This system can be commercialized. It is because the system implements sensors which can be useful for data acquisition and measurement.

Furthermore it has wireless data transmission so that data can be easily transferred remotely to other places. Also, it has GUI application of visual basic which easy to use and user friendly. On the other hand, this product can save water, money and also time since it is automatically control.

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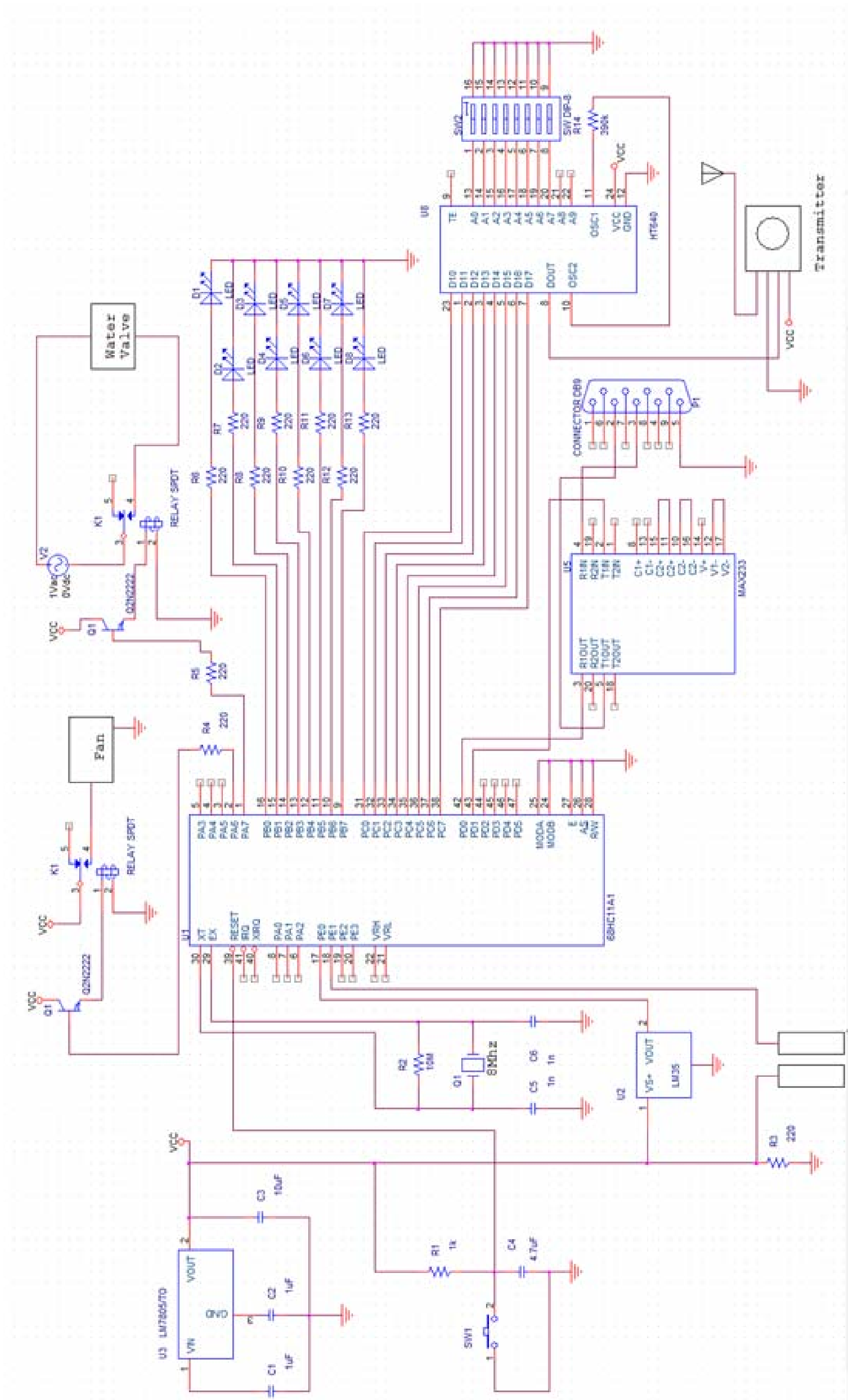
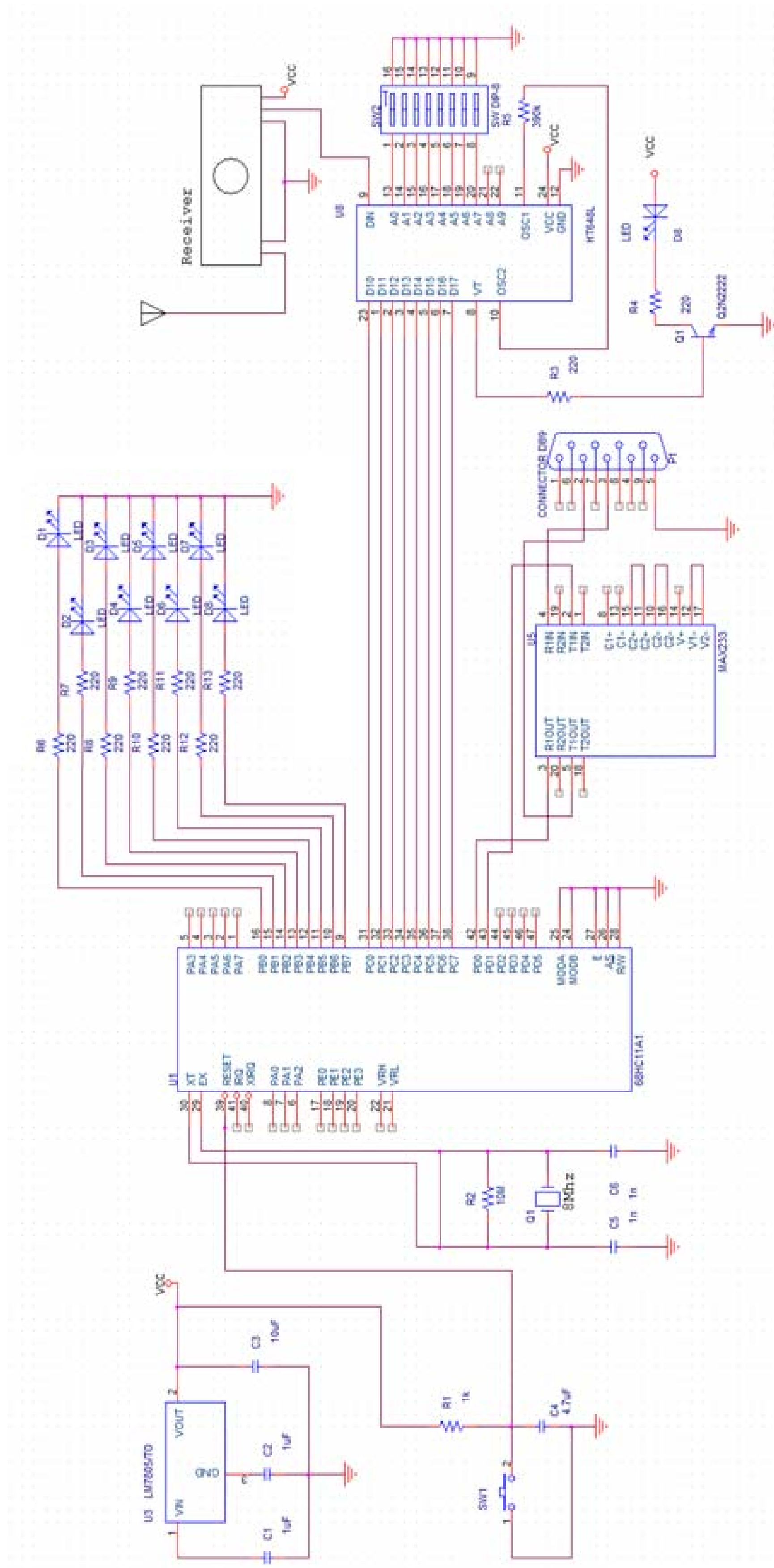
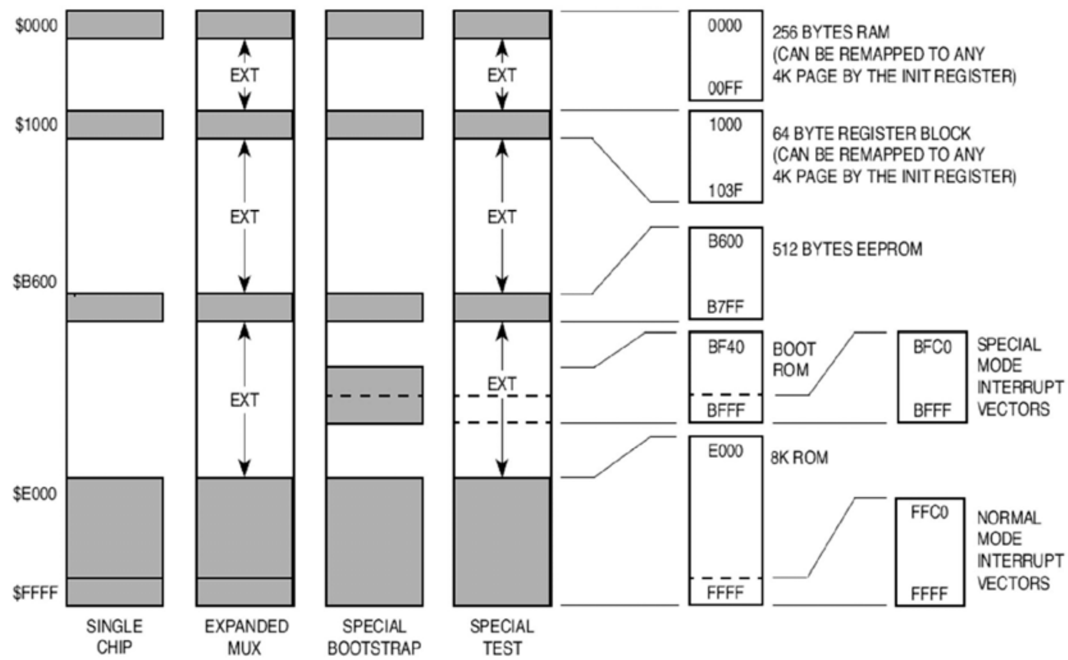
APPENDIXA1: TRANSMITTER FULL CIRCUIT DESIGN



APPENDIXA2: RECEIVER FULL CIRCUIT DESIGN



APPENDIXA3: MC68HC11 MEMORY MAP



MC68HC11 Memory map

19-4323; Rev 11; 2/03

MAXIM

+5V-Powered, Multichannel RS-232 Drivers/Receivers

MAX220–MAX249

General Description

The MAX220–MAX249 family of line drivers/receivers is intended for all EIA/TIA-232E and V.28/V.24 communications interfaces, particularly applications where ±12V is not available.

These parts are especially useful in battery-powered systems, since their low-power shutdown mode reduces power dissipation to less than 5μW. The MAX225, MAX233, MAX235, and MAX245/MAX246/MAX247 use no external components and are recommended for applications where printed circuit board space is critical.

Applications

Portable Computers

Low-Power Modems

Interface Translation

Battery-Powered RS-232 Systems

Multidrop RS-232 Networks

Features

Superior to Bipolar

- ♦ **Operate from Single +5V Power Supply (+5V and +12V—MAX231/MAX239)**
- ♦ **Low-Power Receive Mode in Shutdown (MAX223/MAX242)**
- ♦ **Meet All EIA/TIA-232E and V.28 Specifications**
- ♦ **Multiple Drivers and Receivers**
- ♦ **3-State Driver and Receiver Outputs**
- ♦ **Open-Line Detection (MAX243)**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX220CPE	0°C to +70°C	16 Plastic DIP
MAX220CSE	0°C to +70°C	16 Narrow SO
MAX220CWE	0°C to +70°C	16 Wide SO
MAX220C/D	0°C to +70°C	Dice*
MAX220EPE	-40°C to +85°C	16 Plastic DIP
MAX220ESE	-40°C to +85°C	16 Narrow SO
MAX220EWE	-40°C to +85°C	16 Wide SO
MAX220EJE	-40°C to +85°C	16 CERDIP
MAX220MJE	-55°C to +125°C	16 CERDIP

Ordering Information continued at end of data sheet.

**Contact factory for dice specifications.*

Selection Table

Part Number	Power Supply (V)	No. of RS-232 Drivers/Rx	No. of Ext. Caps	Nominal Cap. Value (μF)	SHDN & Three-State	Rx Active in SHDN	Data Rate (kbps)	Features
MAX220	+5	2/2	4	0.1	No	—	120	Ultra-low-power, industry-standard pinout
MAX222	+5	2/2	4	0.1	Yes	—	200	Low-power shutdown
MAX223 (MAX213)	+5	4/5	4	1.0 (0.1)	Yes	✔	120	MAX241 and receivers active in shutdown
MAX225	+5	5/5	0	—	Yes	✔	120	Available in SO
MAX230 (MAX200)	+5	5/0	4	1.0 (0.1)	Yes	—	120	5 drivers with shutdown
MAX231 (MAX201)	+5 and +7.5 to +13.2	2/2	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; same functions as MAX232
MAX232 (MAX202)	+5	2/2	4	1.0 (0.1)	No	—	120 (64)	Industry standard
MAX232A	+5	2/2	4	0.1	No	—	200	Higher slew rate, small caps
MAX233 (MAX203)	+5	2/2	0	—	No	—	120	No external caps
MAX233A	+5	2/2	0	—	No	—	200	No external caps, high slew rate
MAX234 (MAX204)	+5	4/0	4	1.0 (0.1)	No	—	120	Replaces 1488
MAX235 (MAX205)	+5	5/5	0	—	Yes	—	120	No external caps
MAX236 (MAX206)	+5	4/3	4	1.0 (0.1)	Yes	—	120	Shutdown, three state
MAX237 (MAX207)	+5	5/3	4	1.0 (0.1)	No	—	120	Complements IBM PC serial port
MAX238 (MAX208)	+5	4/4	4	1.0 (0.1)	No	—	120	Replaces 1488 and 1489
MAX239 (MAX209)	+5 and +7.5 to +13.2	3/5	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; single-package solution for IBM PC serial port
MAX240	+5	5/5	4	1.0	Yes	—	120	DIP or flatpack package
MAX241 (MAX211)	+5	4/5	4	1.0 (0.1)	Yes	—	120	Complete IBM PC serial port
MAX242	+5	2/2	4	0.1	Yes	✔	200	Separate shutdown and enable
MAX243	+5	2/2	4	0.1	No	—	200	Open-line detection simplifies cabling
MAX244	+5	8/10	4	1.0	No	—	120	High slew rate
MAX245	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, two shutdown modes
MAX246	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, three shutdown modes
MAX247	+5	8/9	0	—	Yes	✔	120	High slew rate, int. caps, nine operating modes
MAX248	+5	8/8	4	1.0	Yes	✔	120	High slew rate, selective half-chip enables
MAX249	+5	6/10	4	1.0	Yes	✔	120	Available in quad flatpack package

ABSOLUTE MAXIMUM RATINGS—MAX220/222/232A/233A/242/243

Supply Voltage (V_{CC}) ....-0.3V to +6V
Input Voltages
T_{IN}..-0.3V to (V_{CC} - 0.3V)
R_{IN} (Except MAX220) ....±30V
R_{IN} (MAX220)..±25V
T_{OUT} (Except MAX220) (Note 1) ....±15V
T_{OUT} (MAX220)..±13.2V
Output Voltages
T_{OUT}...±15V
R_{OUT}..-0.3V to (V_{CC} + 0.3V)
Driver/Receiver Output Short Circuited to GND.........Continuous
Continuous Power Dissipation (T_A = +70°C)
16-Pin Plastic DIP (derate 10.53mW/°C above +70°C)....842mW
18-Pin Plastic DIP (derate 11.11mW/°C above +70°C)....889mW
20-Pin Plastic DIP (derate 8.00mW/°C above +70°C) ..440mW
16-Pin Narrow SO (derate 8.70mW/°C above +70°C) ...696mW
16-Pin Wide SO (derate 9.52mW/°C above +70°C)......762mW
18-Pin Wide SO (derate 9.52mW/°C above +70°C)......762mW
20-Pin Wide SO (derate 10.00mW/°C above +70°C)....800mW
20-Pin SSOP (derate 8.00mW/°C above +70°C) 640mW
16-Pin CERDIP (derate 10.00mW/°C above +70°C).....800mW
18-Pin CERDIP (derate 10.53mW/°C above +70°C).....842mW
Operating Temperature Ranges
MAX2_ _AC_ _, MAX2_ _C_ _.............................0°C to +70°C
MAX2_ _AE_ _, MAX2_ _E_ _ ....-40°C to +85°C
MAX2_ _AM_ _, MAX2_ _M_ _.......................-55°C to +125°C
Storage Temperature Range ....-65°C to +160°C
Lead Temperature (soldering, 10s) ....+300°C

Note 1: Input voltage measured with T_{OUT} in high-impedance state, $\overline{SHDN}$ or V_{CC} = 0V.
Note 2: For the MAX220, V+ and V- can have a maximum magnitude of 7V, but their absolute difference cannot exceed 13V.

Stresses beyond 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 beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, MAX220, C1 = 0.047µF, C2–C4 = 0.33µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
RS-232 TRANSMITTERS						
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to GND		±5	±8		V
Input Logic Threshold Low				1.4	0.8	V
Input Logic Threshold High	All devices except MAX220		2	1.4		V
	MAX220: V_{CC} = 5.0V		2.4			
Logic Pull-Up/Input Current	All except MAX220, normal operation			5	40	µA
	$\overline{SHDN}$ = 0V, MAX222/242, shutdown, MAX220			±0.01	±1	
Output Leakage Current	V_{CC} = 5.5V, $\overline{SHDN}$ = 0V, V_{OUT} = ±15V, MAX222/242			±0.01	±10	µA
	V_{CC} = $\overline{SHDN}$ = 0V, V_{OUT} = ±15V			±0.01	±10	
Data Rate				200	116	kbps
Transmitter Output Resistance	V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V		300	10M		Ω
Output Short-Circuit Current	V_{OUT} = 0V		±7	±22		mA
RS-232 RECEIVERS						
RS-232 Input Voltage Operating Range					±30	V
RS-232 Input Threshold Low	V_{CC} = 5V	All except MAX243 $R2_{IN}$	0.8	1.3		V
		MAX243 $R2_{IN}$ (Note 2)	-3			
RS-232 Input Threshold High	V_{CC} = 5V	All except MAX243 $R2_{IN}$		1.8	2.4	V
		MAX243 $R2_{IN}$ (Note 2)		-0.5	-0.1	
RS-232 Input Hysteresis	All except MAX243, V_{CC} = 5V, no hysteresis in shdn.		0.2	0.5	1	V
	MAX243			1		
RS-232 Input Resistance			3	5	7	kΩ
TTL/CMOS Output Voltage Low	I_{OUT} = 3.2mA			0.2	0.4	V
TTL/CMOS Output Voltage High	I_{OUT} = -1.0mA		3.5	V_{CC} - 0.2		V
TTL/CMOS Output Short-Circuit Current	Sourcing V_{OUT} = GND		-2	-10		mA
	Shrinking V_{OUT} = V_{CC}		10	30		

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243 (continued)

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, MAX220, C1 = 0.047µF, C2–C4 = 0.33µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
TTL/CMOS Output Leakage Current	$\overline{SHDN}$ = V_{CC} or $\overline{EN}$ = V_{CC} ($\overline{SHDN}$ = 0V for MAX222), 0V ≤ V_{OUT} ≤ V_{CC}			±0.05	±10	µA
$\overline{EN}$ Input Threshold Low	MAX242			1.4	0.8	V
$\overline{EN}$ Input Threshold High	MAX242		2.0	1.4		V
Operating Supply Voltage			4.5		5.5	V
V_{CC} Supply Current ($\overline{SHDN}$ = V_{CC}), Figures 5, 6, 11, 19	No load	MAX220		0.5	2	mA
		MAX222/232A/233A/242/243		4	10	
	3kΩ load both inputs	MAX220		12		
		MAX222/232A/233A/242/243		15		
Shutdown Supply Current	MAX222/242	T_A = +25°C		0.1	10	µA
		T_A = 0°C to +70°C		2	50	
		T_A = -40°C to +85°C		2	50	
		T_A = -55°C to +125°C		35	100	
$\overline{SHDN}$ Input Leakage Current	MAX222/242				±1	µA
$\overline{SHDN}$ Threshold Low	MAX222/242			1.4	0.8	V
$\overline{SHDN}$ Threshold High	MAX222/242		2.0	1.4		V
Transition Slew Rate	C_L = 50pF to 2500pF, R_L = 3kΩ to 7kΩ, V_{CC} = 5V, T_A = +25°C, measured from +3V to -3V or -3V to +3V	MAX222/232A/233A/242/243	6	12	30	V/µs
		MAX220	1.5	3	30	
Transmitter Propagation Delay TLL to RS-232 (Normal Operation), Figure 1	t_{PHLT}	MAX222/232A/233A/242/243		1.3	3.5	µs
		MAX220		4	10	
	t_{PLHT}	MAX222/232A/233A/242/243		1.5	3.5	
		MAX220		5	10	
Receiver Propagation Delay RS-232 to TLL (Normal Operation), Figure 2	t_{PHLR}	MAX222/232A/233A/242/243		0.5	1	µs
		MAX220		0.6	3	
	t_{PLHR}	MAX222/232A/233A/242/243		0.6	1	
		MAX220		0.8	3	
Receiver Propagation Delay RS-232 to TLL (Shutdown), Figure 2	t_{PHLS}	MAX242		0.5	10	µs
	t_{PLHS}	MAX242		2.5	10	
Receiver-Output Enable Time, Figure 3	t_{ER}	MAX242		125	500	ns
Receiver-Output Disable Time, Figure 3	t_{DR}	MAX242		160	500	ns
Transmitter-Output Enable Time ($\overline{SHDN}$ Goes High), Figure 4	t_{ET}	MAX222/242, 0.1µF caps (includes charge-pump start-up)		250		µs
Transmitter-Output Disable Time ($\overline{SHDN}$ Goes Low), Figure 4	t_{DT}	MAX222/242, 0.1µF caps		600		ns
Transmitter + to - Propagation Delay Difference (Normal Operation)	t_{PHLT} - t_{PLHT}	MAX222/232A/233A/242/243		300		ns
		MAX220		2000		
Receiver + to - Propagation Delay Difference (Normal Operation)	t_{PHLR} - t_{PLHR}	MAX222/232A/233A/242/243		100		ns
		MAX220		225		

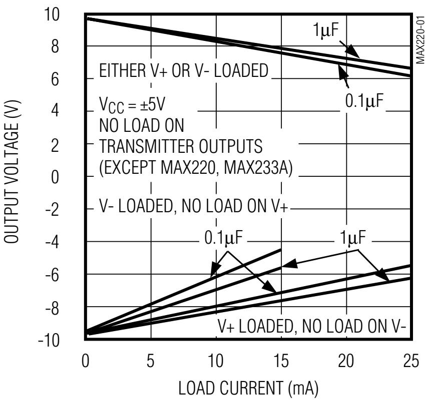
Note 3: MAX243 $R2_{OUT}$ is guaranteed to be low when $R2_{IN}$ is ≥ 0V or is floating.

+5V-Powered, Multichannel RS-232 Drivers/Receivers

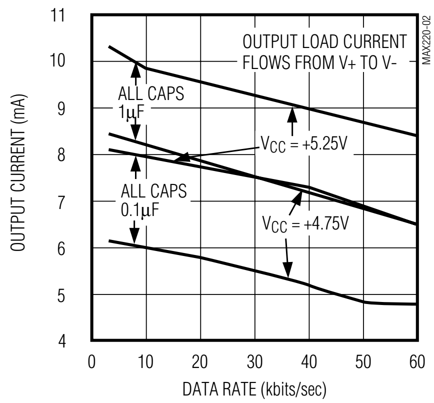
Typical Operating Characteristics

MAX220/MAX222/MAX232A/MAX233A/MAX242/MAX243

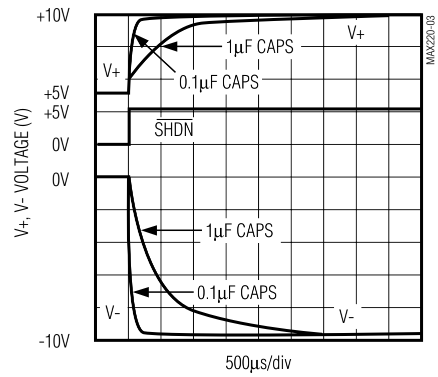
OUTPUT VOLTAGE vs. LOAD CURRENT



AVAILABLE OUTPUT CURRENT vs. DATA RATE



MAX222/MAX242 ON-TIME EXITING SHUTDOWN



ABSOLUTE MAXIMUM RATINGS—MAX223/MAX230–MAX241

V_{CC} ....-0.3V to +6V
V+ ....(V_{CC} - 0.3V) to +14V
V- ....+0.3V to -14V
Input Voltages
T_{IN} ....-0.3V to (V_{CC} + 0.3V)
R_{IN}...±30V
Output Voltages
T_{OUT} ....(V+ + 0.3V) to (V- - 0.3V)
R_{OUT}..-0.3V to (V_{CC} + 0.3V)
Short-Circuit Duration, T_{OUT} ....Continuous
Continuous Power Dissipation (T_A = +70°C)
14-Pin Plastic DIP (derate 10.00mW/°C above +70°C)....800mW
16-Pin Plastic DIP (derate 10.53mW/°C above +70°C)....842mW
20-Pin Plastic DIP (derate 11.11mW/°C above +70°C)....889mW
24-Pin Narrow Plastic DIP
(derate 13.33mW/°C above +70°C) 1.07W
24-Pin Plastic DIP (derate 9.09mW/°C above +70°C)......500mW
16-Pin Wide SO (derate 9.52mW/°C above +70°C).........762mW
20-Pin Wide SO (derate 10 00mW/°C above +70°C).......800mW
24-Pin Wide SO (derate 11.76mW/°C above +70°C).......941mW
28-Pin Wide SO (derate 12.50mW/°C above +70°C) 1W
44-Pin Plastic FP (derate 11.11mW/°C above +70°C) 889mW
14-Pin CERDIP (derate 9.09mW/°C above +70°C)..........727mW
16-Pin CERDIP (derate 10.00mW/°C above +70°C)........800mW
20-Pin CERDIP (derate 11.11mW/°C above +70°C)........889mW
24-Pin Narrow CERDIP
(derate 12.50mW/°C above +70°C) 1W
24-Pin Sidebraze (derate 20.0mW/°C above +70°C)..........1.6W
28-Pin SSOP (derate 9.52mW/°C above +70°C).............762mW
Operating Temperature Ranges
MAX2 _ _ C _ _...0°C to +70°C
MAX2 _ _ E _ _..-40°C to +85°C
MAX2 _ _ M _ _ ....-55°C to +125°C
Storage Temperature Range ....-65°C to +160°C
Lead Temperature (soldering, 10s) ....+300°C

Stresses beyond 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 beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX223/MAX230–MAX241

(MAX223/230/232/234/236/237/238/240/241, V_{CC} = +5V ±10; MAX233/MAX235, V_{CC} = 5V ±5%, C1–C4 = 1.0µF; MAX231/MAX239, V_{CC} = 5V ±10%; V+ = 7.5V to 13.2V; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to ground		±5.0	±7.3		V
V_{CC} Power-Supply Current	No load, T_A = +25°C	MAX232/233		5	10	mA
		MAX223/230/234–238/240/241		7	15	
		MAX231/239		0.4	1	
V+ Power-Supply Current		MAX231		1.8	5	mA
		MAX239		5	15	
Shutdown Supply Current	T_A = +25°C	MAX223		15	50	µA
		MAX230/235/236/240/241		1	10	
Input Logic Threshold Low	T_{IN}; EN, $\overline{SHDN}$ (MAX233); $\overline{EN}$, SHDN (MAX230/235–241)				0.8	V
Input Logic Threshold High	T_{IN}		2.0			V
	EN, $\overline{SHDN}$ (MAX223); $\overline{EN}$, SHDN (MAX230/235/236/240/241)		2.4			
Logic Pull-Up Current	T_{IN} = 0V			1.5	200	µA
Receiver Input Voltage Operating Range			-30		30	V

ELECTRICAL CHARACTERISTICS—MAX223/MAX230–MAX241 (continued)

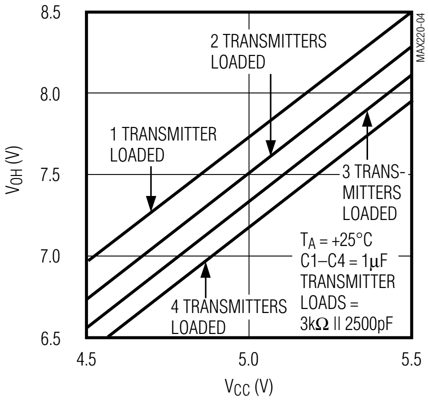
(MAX223/230/232/234/236/237/238/240/241, V_{CC} = +5V ±10; MAX233/MAX235, V_{CC} = 5V ±5%, C1–C4 = 1.0µF; MAX231/MAX239, V_{CC} = 5V ±10%; V+ = 7.5V to 13.2V; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
RS-232 Input Threshold Low	T_A = +25°C, V_{CC} = 5V; Normal operation: $\overline{SHDN}$ = 5V (MAX223), SHDN = 0V (MAX235/236/240/241)	0.8	1.2		V
	T_A = +25°C, V_{CC} = 5V; Shutdown (MAX223): $\overline{SHDN}$ = 0V, EN = 5V ($R4_{IN}$, $R5_{IN}$)	0.6	1.5		V
RS-232 Input Threshold High	T_A = +25°C, V_{CC} = 5V; Normal operation: $\overline{SHDN}$ = 5V (MAX223), SHDN = 0V (MAX235/236/240/241)		1.7	2.4	V
	T_A = +25°C, V_{CC} = 5V; Shutdown (MAX223): $\overline{SHDN}$ = 0V, EN = 5V ($R4_{IN}$, $R5_{IN}$)		1.5	2.4	V
RS-232 Input Hysteresis	V_{CC} = 5V, no hysteresis in shutdown	0.2	0.5	1.0	V
RS-232 Input Resistance	T_A = +25°C, V_{CC} = 5V	3	5	7	kΩ
TTL/CMOS Output Voltage Low	I_{OUT} = 1.6mA (MAX231/232/233, I_{OUT} = 3.2mA)			0.4	V
TTL/CMOS Output Voltage High	I_{OUT} = -1mA	3.5	V_{CC} - 0.4		V
TTL/CMOS Output Leakage Current	0V ≤ R_{OUT} ≤ V_{CC}; EN = 0V (MAX223); $\overline{EN}$ = V_{CC} (MAX235–241)		0.05	±10	µA
Receiver Output Enable Time	Normal operation; MAX223		600		ns
	Normal operation; MAX235/236/239/240/241		400		ns
Receiver Output Disable Time	Normal operation; MAX223		900		ns
	Normal operation; MAX235/236/239/240/241		250		ns
Propagation Delay	RS-232 IN to TTL/CMOS OUT, C_L = 150pF; Normal operation		0.5	10	µs
	RS-232 IN to TTL/CMOS OUT, C_L = 150pF; $\overline{SHDN}$ = 0V (MAX223); t_{PHLS}		4	40	µs
	RS-232 IN to TTL/CMOS OUT, C_L = 150pF; $\overline{SHDN}$ = 0V (MAX223); t_{PLHS}		6	40	µs
Transition Region Slew Rate	MAX223/MAX230/MAX234–241, T_A = +25°C, V_{CC} = 5V, R_L = 3kΩ to 7kΩ, C_L = 50pF to 2500pF, measured from +3V to -3V or -3V to +3V	3	5.1	30	V/µs
	MAX231/MAX232/MAX233, T_A = +25°C, V_{CC} = 5V, R_L = 3kΩ to 7kΩ, C_L = 50pF to 2500pF, measured from +3V to -3V or -3V to +3V		4	30	V/µs
Transmitter Output Resistance	V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V	300			Ω
Transmitter Output Short-Circuit Current			±10		mA

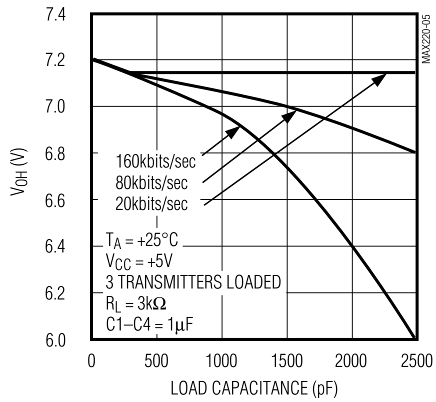
Typical Operating Characteristics

MAX223/MAX230–MAX241

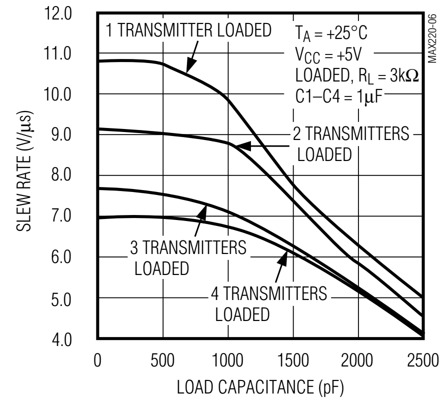
TRANSMITTER OUTPUT VOLTAGE (V_{OH}) vs. V_{CC}



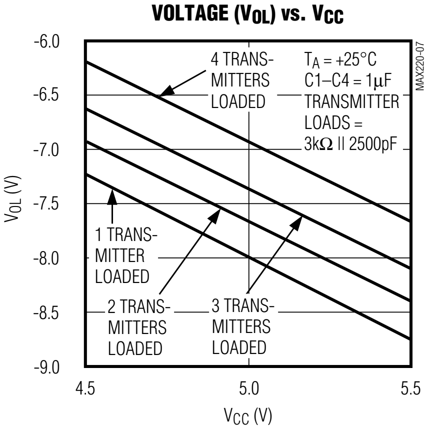
TRANSMITTER OUTPUT VOLTAGE (V_{OH}) vs. LOAD CAPACITANCE AT DIFFERENT DATA RATES



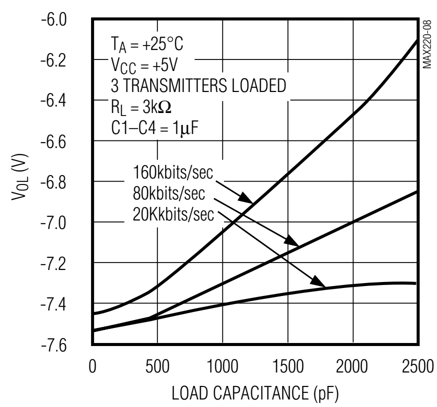
TRANSMITTER SLEW RATE vs. LOAD CAPACITANCE



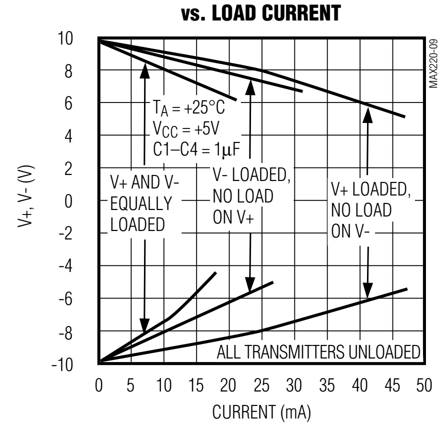
TRANSMITTER OUTPUT VOLTAGE (V_{OL}) vs. V_{CC}



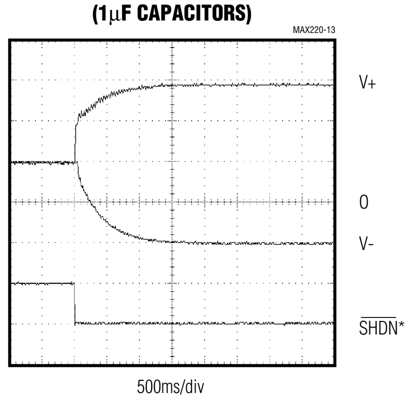
TRANSMITTER OUTPUT VOLTAGE (V_{OL}) vs. LOAD CAPACITANCE AT DIFFERENT DATA RATES



TRANSMITTER OUTPUT VOLTAGE (V+, V-) vs. LOAD CURRENT



V+, V- WHEN EXITING SHUTDOWN (1μF CAPACITORS)



*SHUTDOWN POLARITY IS REVERSED FOR NON MAX241 PARTS

+5V-Powered, Multichannel RS-232 Drivers/Receivers

ABSOLUTE MAXIMUM RATINGS—MAX225/MAX244–MAX249

Supply Voltage (V_{CC}) ....-0.3V to +6V
Input Voltages
  T_{IN}, $\overline{\text{ENA}}$, $\overline{\text{ENB}}$, $\overline{\text{ENR}}$, $\overline{\text{ENT}}$, $\overline{\text{ENRA}}$,
  $\overline{\text{ENRB}}$, $\overline{\text{ENTA}}$, $\overline{\text{ENTB}}$.................................-0.3V to (V_{CC} + 0.3V)
  R_{IN} ....±25V
  T_{OUT} (Note 3)...±15V
  R_{OUT} ....-0.3V to (V_{CC} + 0.3V)
Short Circuit (one output at a time)
  T_{OUT} to GND ....Continuous
  R_{OUT} to GND...Continuous

Continuous Power Dissipation (T_A = +70°C)
  28-Pin Wide SO (derate 12.50mW/°C above +70°C) 1W
  40-Pin Plastic DIP (derate 11.11mW/°C above +70°C) ...611mW
  44-Pin PLCC (derate 13.33mW/°C above +70°C) 1.07W
Operating Temperature Ranges
  MAX225C_ _, MAX24_C_ _ ....0°C to +70°C
  MAX225E_ _, MAX24_E_ _ ....-40°C to +85°C
Storage Temperature Range ....-65°C to +160°C
Lead Temperature (soldering,10s) ....+300°C

Note 4: Input voltage measured with transmitter output in a high-impedance state, shutdown, or V_{CC} = 0V.

Stresses beyond 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 beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX225/MAX244–MAX249

(MAX225, V_{CC} = 5.0V ±5%; MAX244–MAX249, V_{CC} = +5.0V ±10%, external capacitors C1–C4 = 1µF; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
RS-232 TRANSMITTERS						
Input Logic Threshold Low				1.4	0.8	V
Input Logic Threshold High			2	1.4		V
Logic Pull-Up/Input Current	Tables 1a–1d	Normal operation		10	50	µA
		Shutdown		±0.01	±1	
Data Rate	Tables 1a–1d, normal operation			120	64	kbps
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to GND		±5	±7.5		V
Output Leakage Current (Shutdown)	Tables 1a–1d	$\overline{\text{ENA}}$, $\overline{\text{ENB}}$, $\overline{\text{ENT}}$, $\overline{\text{ENTA}}$, $\overline{\text{ENTB}}$ = V_{CC}, V_{OUT} = ±15V		±0.01	±25	µA
		V_{CC} = 0V, V_{OUT} = ±15V		±0.01	±25	
Transmitter Output Resistance	V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V (Note 4)		300	10M		Ω
Output Short-Circuit Current	V_{OUT} = 0V		±7	±30		mA
RS-232 RECEIVERS						
RS-232 Input Voltage Operating Range					±25	V
RS-232 Input Threshold Low	V_{CC} = 5V		0.8	1.3		V
RS-232 Input Threshold High	V_{CC} = 5V			1.8	2.4	V
RS-232 Input Hysteresis	V_{CC} = 5V		0.2	0.5	1.0	V
RS-232 Input Resistance			3	5	7	kΩ
TTL/CMOS Output Voltage Low	I_{OUT} = 3.2mA			0.2	0.4	V
TTL/CMOS Output Voltage High	I_{OUT} = -1.0mA		3.5	V_{CC} - 0.2		V
TTL/CMOS Output Short-Circuit Current	Sourcing V_{OUT} = GND		-2	-10		mA
	Shrinking V_{OUT} = V_{CC}		10	30		
TTL/CMOS Output Leakage Current	Normal operation, outputs disabled, Tables 1a–1d, 0V ≤ V_{OUT} ≤ V_{CC}, $\overline{\text{ENR}}$_ = V_{CC}			±0.05	±0.10	µA

ELECTRICAL CHARACTERISTICS—MAX225/MAX244–MAX249 (continued)

(MAX225, V_{CC} = 5.0V ±5%; MAX244–MAX249, V_{CC} = +5.0V ±10%, external capacitors C1–C4 = 1µF; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
POWER SUPPLY AND CONTROL LOGIC						
Operating Supply Voltage		MAX225	4.75		5.25	V
		MAX244–MAX249	4.5		5.5	
V_{CC} Supply Current (Normal Operation)	No load	MAX225		10	20	mA
		MAX244–MAX249		11	30	
	3kΩ loads on all outputs	MAX225		40		
		MAX244–MAX249		57		
Shutdown Supply Current	T_A = +25°C			8	25	µA
	T_A = T_{MIN} to T_{MAX}				50	
Control Input	Leakage current				±1	µA
	Threshold low			1.4	0.8	V
	Threshold high		2.4	1.4		
AC CHARACTERISTICS						
Transition Slew Rate	C_L = 50pF to 2500pF, R_L = 3kΩ to 7kΩ, V_{CC} = 5V, T_A = +25°C, measured from +3V to -3V or -3V to +3V		5	10	30	V/µs
Transmitter Propagation Delay TLL to RS-232 (Normal Operation), Figure 1	t_{PHLT}			1.3	3.5	µs
	t_{PLHT}			1.5	3.5	
Receiver Propagation Delay TLL to RS-232 (Normal Operation), Figure 2	t_{PHLR}			0.6	1.5	µs
	t_{PLHR}			0.6	1.5	
Receiver Propagation Delay TLL to RS-232 (Low-Power Mode), Figure 2	t_{PHLS}			0.6	10	µs
	t_{PLHS}			3.0	10	
Transmitter + to - Propagation Delay Difference (Normal Operation)	t_{PHLT} - t_{PLHT}			350		ns
Receiver + to - Propagation Delay Difference (Normal Operation)	t_{PHLR} - t_{PLHR}			350		ns
Receiver-Output Enable Time, Figure 3	t_{ER}			100	500	ns
Receiver-Output Disable Time, Figure 3	t_{DR}			100	500	ns
Transmitter Enable Time	t_{ET}	MAX246–MAX249 (excludes charge-pump startup)		5		µs
		MAX225/MAX245–MAX249 (includes charge-pump startup)		10		ms
Transmitter Disable Time, Figure 4	t_{DT}			100		ns

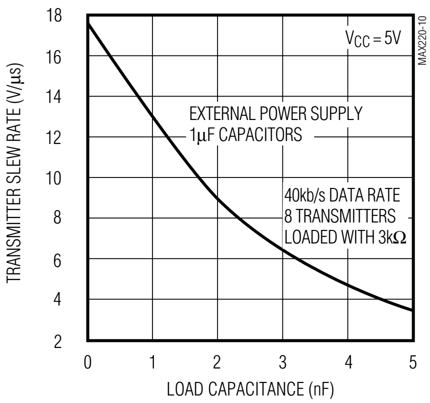
Note 5: The 300Ω minimum specification complies with EIA/TIA-232E, but the actual resistance when in shutdown mode or V_{CC} = 0V is 10MΩ as is implied by the leakage specification.

+5V-Powered, Multichannel RS-232 Drivers/Receivers

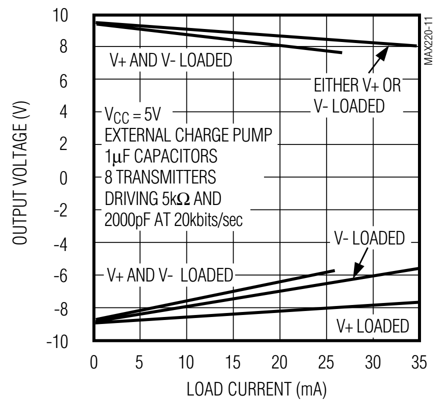
Typical Operating Characteristics

MAX225/MAX244–MAX249

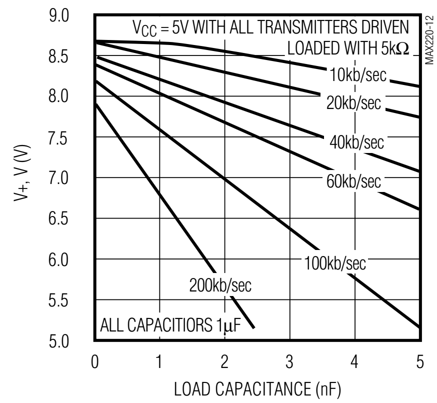
TRANSMITTER SLEW RATE vs. LOAD CAPACITANCE



OUTPUT VOLTAGE vs. LOAD CURRENT FOR V+ AND V-



TRANSMITTER OUTPUT VOLTAGE (V+, V-) vs. LOAD CAPACITANCE AT DIFFERENT DATA RATES



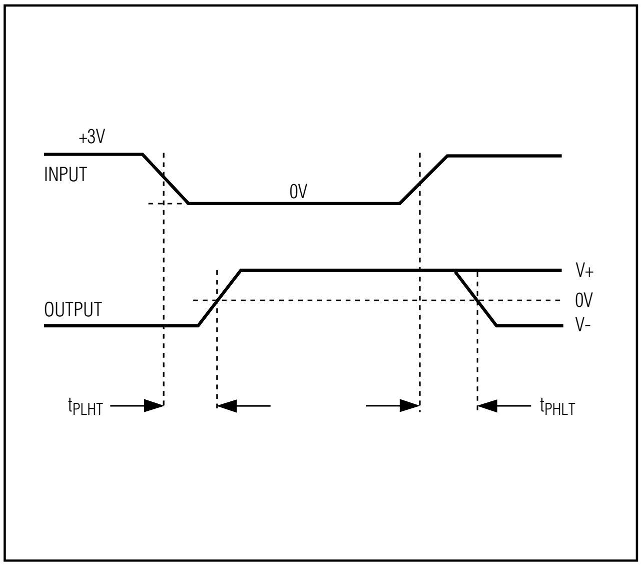


Figure 1. Transmitter Propagation-Delay Timing

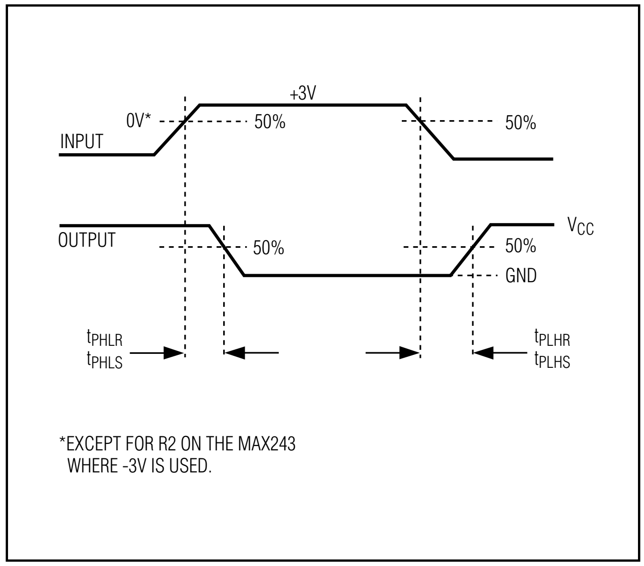


Figure 2. Receiver Propagation-Delay Timing

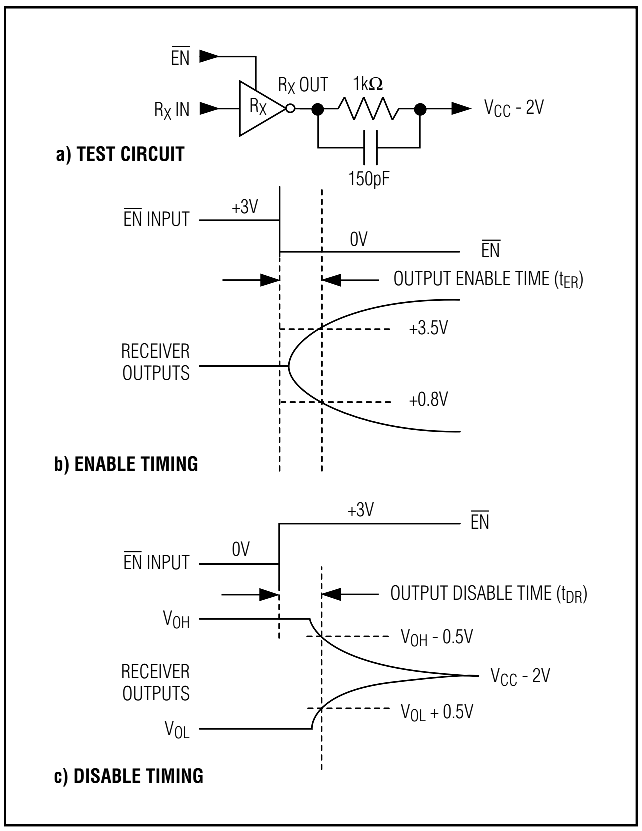


Figure 3. Receiver-Output Enable and Disable Timing

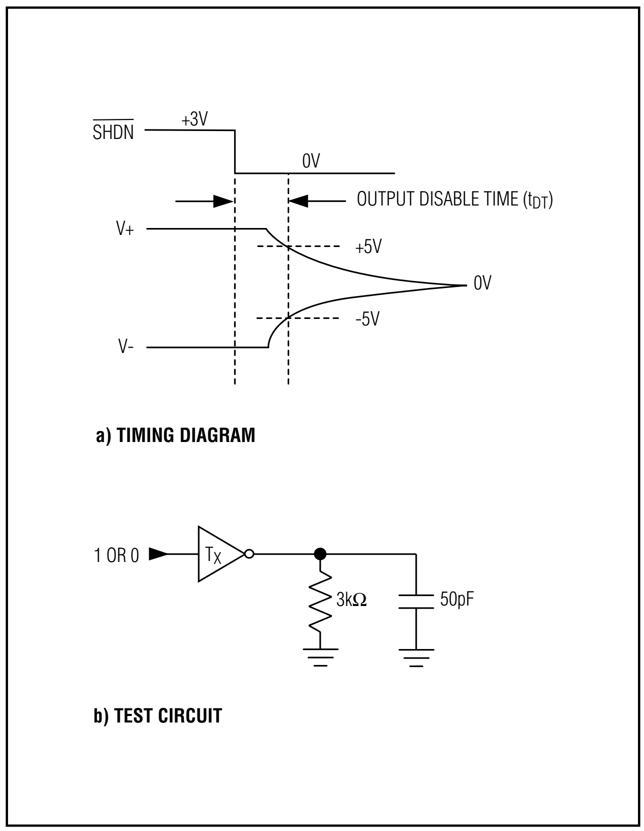


Figure 4. Transmitter-Output Disable Timing

Table 1a. MAX245 Control Pin Configurations

$\overline{ENT}$	$\overline{ENR}$	OPERATION STATUS	TRANSMITTERS	RECEIVERS
0	0	Normal Operation	All Active	All Active
0	1	Normal Operation	All Active	All 3-State
1	0	Shutdown	All 3-State	All Low-Power Receive Mode
1	1	Shutdown	All 3-State	All 3-State

Table 1b. MAX245 Control Pin Configurations

$\overline{ENT}$	$\overline{ENR}$	OPERATION STATUS	TRANSMITTERS		RECEIVERS	
			TA1–TA4	TB1–TB4	RA1–RA5	RB1–RB5
0	0	Normal Operation	All Active	All Active	All Active	All Active
0	1	Normal Operation	All Active	All Active	RA1–RA4 3-State, RA5 Active	RB1–RB4 3-State, RB5 Active
1	0	Shutdown	All 3-State	All 3-State	All Low-Power Receive Mode	All Low-Power Receive Mode
1	1	Shutdown	All 3-State	All 3-State	RA1–RA4 3-State, RA5 Low-Power Receive Mode	RB1–RB4 3-State, RB5 Low-Power Receive Mode

Table 1c. MAX246 Control Pin Configurations

$\overline{ENA}$	$\overline{ENB}$	OPERATION STATUS	TRANSMITTERS		RECEIVERS	
			TA1–TA4	TB1–TB4	RA1–RA5	RB1–RB5
0	0	Normal Operation	All Active	All Active	All Active	All Active
0	1	Normal Operation	All Active	All 3-State	All Active	RB1–RB4 3-State, RB5 Active
1	0	Shutdown	All 3-State	All Active	RA1–RA4 3-State, RA5 Active	All Active
1	1	Shutdown	All 3-State	All 3-State	RA1–RA4 3-State, RA5 Low-Power Receive Mode	RB1–RB4 3-State, RA5 Low-Power Receive Mode

Table 1d. MAX247/MAX248/MAX249 Control Pin Configurations

$\overline{\text{ENTA}}$	$\overline{\text{ENTB}}$	$\overline{\text{ENRA}}$	$\overline{\text{ENRB}}$	OPERATION STATUS		TRANSMITTERS		RECEIVERS	
					MAX247	TA1–TA4	TB1–TB4	RA1–RA4	RB1–RB5
					MAX248	TA1–TA4	TB1–TB4	RA1–RA4	RB1–RB4
					MAX249	TA1–TA3	TB1–TB3	RA1–RA5	RB1–RB5
0	0	0	0	Normal Operation		All Active	All Active	All Active	All Active
0	0	0	1	Normal Operation		All Active	All Active	All Active	All 3-State, except RB5 stays active on MAX247
0	0	1	0	Normal Operation		All Active	All Active	All 3-State	All Active
0	0	1	1	Normal Operation		All Active	All Active	All 3-State	All 3-State, except RB5 stays active on MAX247
0	1	0	0	Normal Operation		All Active	All 3-State	All Active	All Active
0	1	0	1	Normal Operation		All Active	All 3-State	All Active	All 3-State, except RB5 stays active on MAX247
0	1	1	0	Normal Operation		All Active	All 3-State	All 3-State	All Active
0	1	1	1	Normal Operation		All Active	All 3-State	All 3-State	All 3-State, except RB5 stays active on MAX247
1	0	0	0	Normal Operation		All 3-State	All Active	All Active	All Active
1	0	0	1	Normal Operation		All 3-State	All Active	All Active	All 3-State, except RB5 stays active on MAX247
1	0	1	0	Normal Operation		All 3-State	All Active	All 3-State	All Active
1	0	1	1	Normal Operation		All 3-State	All Active	All 3-State	All 3-State, except RB5 stays active on MAX247
1	1	0	0	Shutdown		All 3-State	All 3-State	Low-Power Receive Mode	Low-Power Receive Mode
1	1	0	1	Shutdown		All 3-State	All 3-State	Low-Power Receive Mode	All 3-State, except RB5 stays active on MAX247
1	1	1	0	Shutdown		All 3-State	All 3-State	All 3-State	Low-Power Receive Mode
1	1	1	1	Shutdown		All 3-State	All 3-State	All 3-State	All 3-State, except RB5 stays active on MAX247

Detailed Description

The MAX220–MAX249 contain four sections: dual charge-pump DC-DC voltage converters, RS-232 drivers, RS-232 receivers, and receiver and transmitter enable control inputs.

Dual Charge-Pump Voltage Converter

The MAX220–MAX249 have two internal charge-pumps that convert +5V to ±10V (unloaded) for RS-232 driver operation. The first converter uses capacitor C1 to double the +5V input to +10V on C3 at the V+ output. The second converter uses capacitor C2 to invert +10V to -10V on C4 at the V- output.

A small amount of power may be drawn from the +10V (V+) and -10V (V-) outputs to power external circuitry (see the *Typical Operating Characteristics* section), except on the MAX225 and MAX245–MAX247, where these pins are not available. V+ and V- are not regulated, so the output voltage drops with increasing load current. Do not load V+ and V- to a point that violates the minimum ±5V EIA/TIA-232E driver output voltage when sourcing current from V+ and V- to external circuitry.

When using the shutdown feature in the MAX222, MAX225, MAX230, MAX235, MAX236, MAX240, MAX241, and MAX245–MAX249, avoid using V+ and V- to power external circuitry. When these parts are shut down, V- falls to 0V, and V+ falls to +5V. For applications where a +10V external supply is applied to the V+ pin (instead of using the internal charge pump to generate +10V), the C1 capacitor must not be installed and the $\overline{SHDN}$ pin must be tied to V_{CC}. This is because V+ is internally connected to V_{CC} in shutdown mode.

RS-232 Drivers

The typical driver output voltage swing is ±8V when loaded with a nominal 5kΩ RS-232 receiver and V_{CC} = +5V. Output swing is guaranteed to meet the EIA/TIA-232E and V.28 specification, which calls for ±5V minimum driver output levels under worst-case conditions. These include a minimum 3kΩ load, V_{CC} = +4.5V, and maximum operating temperature. Unloaded driver output voltage ranges from (V+ -1.3V) to (V- +0.5V).

Input thresholds are both TTL and CMOS compatible. The inputs of unused drivers can be left unconnected since 400kΩ input pull-up resistors to V_{CC} are built in (except for the MAX220). The pull-up resistors force the outputs of unused drivers low because all drivers invert. The internal input pull-up resistors typically source 12µA, except in shutdown mode where the pull-ups are disabled. Driver outputs turn off and enter a high-impedance state—where leakage current is typically microamperes (maximum 25µA)—when in shutdown mode, in three-state mode, or when device power is removed. Outputs can be driven to ±15V. The power-supply current typically drops to 8µA in shutdown mode. The MAX220 does not have pull-up resistors to force the outputs of the unused drivers low. Connect unused inputs to GND or V_{CC}.

The MAX239 has a receiver three-state control line, and the MAX223, MAX225, MAX235, MAX236, MAX240, and MAX241 have both a receiver three-state control line and a low-power shutdown control. Table 2 shows the effects of the shutdown control and receiver three-state control on the receiver outputs.

The receiver TTL/CMOS outputs are in a high-impedance, three-state mode whenever the three-state enable line is high (for the MAX225/MAX235/MAX236/MAX239–MAX241), and are also high-impedance whenever the shutdown control line is high.

When in low-power shutdown mode, the driver outputs are turned off and their leakage current is less than 1µA with the driver output pulled to ground. The driver output leakage remains less than 1µA, even if the transmitter output is backdriven between 0V and (V_{CC} + 6V). Below -0.5V, the transmitter is diode clamped to ground with 1kΩ series impedance. The transmitter is also zener clamped to approximately V_{CC} + 6V, with a series impedance of 1kΩ.

The driver output slew rate is limited to less than 30V/µs as required by the EIA/TIA-232E and V.28 specifications. Typical slew rates are 24V/µs unloaded and 10V/µs loaded with 3Ω and 2500pF.

RS-232 Receivers

EIA/TIA-232E and V.28 specifications define a voltage level greater than 3V as a logic 0, so all receivers invert. Input thresholds are set at 0.8V and 2.4V, so receivers respond to TTL level inputs as well as EIA/TIA-232E and V.28 levels.

The receiver inputs withstand an input overvoltage up to ±25V and provide input terminating resistors with

Table 2. Three-State Control of Receivers

PART	SHDN	$\overline{SHDN}$	EN	$\overline{EN}(\overline{R})$	RECEIVERS
MAX223	—	Low High High	X Low High	—	High Impedance Active High Impedance
MAX225	—	—	—	Low High	High Impedance Active
MAX235 MAX236 MAX240	Low Low High	—	—	Low High X	High Impedance Active High Impedance

nominal 5kΩ values. The receivers implement Type 1 interpretation of the fault conditions of V.28 and EIA/TIA-232E.

The receiver input hysteresis is typically 0.5V with a guaranteed minimum of 0.2V. This produces clear output transitions with slow-moving input signals, even with moderate amounts of noise and ringing. The receiver propagation delay is typically 600ns and is independent of input swing direction.

Low-Power Receive Mode

The low-power receive-mode feature of the MAX223, MAX242, and MAX245–MAX249 puts the IC into shutdown mode but still allows it to receive information. This is important for applications where systems are periodically awakened to look for activity. Using low-power receive mode, the system can still receive a signal that will activate it on command and prepare it for communication at faster data rates. This operation conserves system power.

Negative Threshold—MAX243

The MAX243 is pin compatible with the MAX232A, differing only in that RS-232 cable fault protection is removed on one of the two receiver inputs. This means that control lines such as CTS and RTS can either be driven or left floating without interrupting communication. Different cables are not needed to interface with different pieces of equipment.

The input threshold of the receiver without cable fault protection is -0.8V rather than +1.4V. Its output goes positive only if the input is connected to a control line that is actively driven negative. If not driven, it defaults to the 0 or “OK to send” state. Normally, the MAX243’s other receiver (+1.4V threshold) is used for the data line (TD or RD), while the negative threshold receiver is connected to the control line (DTR, DTS, CTS, RTS, etc.).

Other members of the RS-232 family implement the optional cable fault protection as specified by EIA/TIA-232E specifications. This means a receiver output goes high whenever its input is driven negative, left floating, or shorted to ground. The high output tells the serial communications IC to stop sending data. To avoid this, the control lines must either be driven or connected with jumpers to an appropriate positive voltage level.

Shutdown—MAX222–MAX242

On the MAX222, MAX235, MAX236, MAX240, and MAX241, all receivers are disabled during shutdown. On the MAX223 and MAX242, two receivers continue to operate in a reduced power mode when the chip is in shutdown. Under these conditions, the propagation delay increases to about 2.5µs for a high-to-low input transition. When in shutdown, the receiver acts as a CMOS inverter with no hysteresis. The MAX223 and MAX242 also have a receiver output enable input ($\overline{EN}$ for the MAX242 and EN for the MAX223) that allows receiver output control independent of $\overline{SHDN}$ (SHDN for MAX241). With all other devices, $\overline{SHDN}$ (SHDN for MAX241) also disables the receiver outputs.

The MAX225 provides five transmitters and five receivers, while the MAX245 provides ten receivers and eight transmitters. Both devices have separate receiver and transmitter-enable controls. The charge pumps turn off and the devices shut down when a logic high is applied to the ENT input. In this state, the supply current drops to less than 25µA and the receivers continue to operate in a low-power receive mode. Driver outputs enter a high-impedance state (three-state mode). On the MAX225, all five receivers are controlled by the $\overline{ENR}$ input. On the MAX245, eight of the receiver outputs are controlled by the $\overline{ENR}$ input, while the remaining two receivers (RA5 and RB5) are always active. RA1–RA4 and RB1–RB4 are put in a three-state mode when $\overline{ENR}$ is a logic high.

Receiver and Transmitter Enable Control Inputs

The MAX225 and MAX245–MAX249 feature transmitter and receiver enable controls.

The receivers have three modes of operation: full-speed receive (normal active), three-state (disabled), and low-power receive (enabled receivers continue to function at lower data rates). The receiver enable inputs control the full-speed receive and three-state modes. The transmitters have two modes of operation: full-speed transmit (normal active) and three-state (disabled). The transmitter enable inputs also control the shutdown mode. The device enters shutdown mode when all transmitters are disabled. Enabled receivers function in the low-power receive mode when in shutdown.

+5V-Powered, Multichannel RS-232 Drivers/Receivers

Tables 1a–1d define the control states. The MAX244 has no control pins and is not included in these tables.

The MAX246 has ten receivers and eight drivers with two control pins, each controlling one side of the device. A logic high at the A-side control input ($\overline{ENA}$) causes the four A-side receivers and drivers to go into a three-state mode. Similarly, the B-side control input ($\overline{ENB}$) causes the four B-side drivers and receivers to go into a three-state mode. As in the MAX245, one A-side and one B-side receiver (RA5 and RB5) remain active at all times. The entire device is put into shutdown mode when both the A and B sides are disabled ($\overline{ENA}$ = $\overline{ENB}$ = +5V).

The MAX247 provides nine receivers and eight drivers with four control pins. The $\overline{ENRA}$ and $\overline{ENRB}$ receiver enable inputs each control four receiver outputs. The $\overline{ENTA}$ and $\overline{ENTB}$ transmitter enable inputs each control four drivers. The ninth receiver (RB5) is always active. The device enters shutdown mode with a logic high on both $\overline{ENTA}$ and $\overline{ENTB}$.

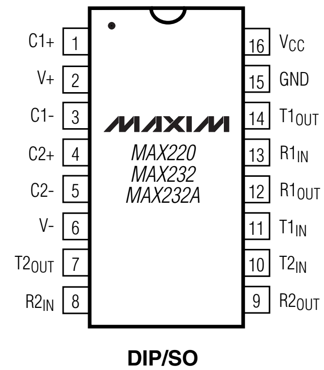
The MAX248 provides eight receivers and eight drivers with four control pins. The $\overline{ENRA}$ and $\overline{ENRB}$ receiver enable inputs each control four receiver outputs. The $\overline{ENTA}$ and $\overline{ENTB}$ transmitter enable inputs control four drivers each. This part does not have an always-active receiver. The device enters shutdown mode and transmitters go into a three-state mode with a logic high on both $\overline{ENTA}$ and $\overline{ENTB}$.

The MAX249 provides ten receivers and six drivers with four control pins. The $\overline{ENRA}$ and $\overline{ENRB}$ receiver enable inputs each control five receiver outputs. The $\overline{ENTA}$ and $\overline{ENTB}$ transmitter enable inputs control three drivers each. There is no always-active receiver. The device enters shutdown mode and transmitters go into a three-state mode with a logic high on both $\overline{ENTA}$ and $\overline{ENTB}$. In shutdown mode, active receivers operate in a low-power receive mode at data rates up to 20kbits/sec.

Applications Information

Figures 5 through 25 show pin configurations and typical operating circuits. In applications that are sensitive to power-supply noise, V_{CC} should be decoupled to ground with a capacitor of the same value as C1 and C2 connected as close as possible to the device.

TOP VIEW



CAPACITANCE (μF)					
DEVICE	C1	C2	C3	C4	C5
MAX220	4.7	4.7	10	10	4.7
MAX232	1.0	1.0	1.0	1.0	1.0
MAX232A	0.1	0.1	0.1	0.1	0.1

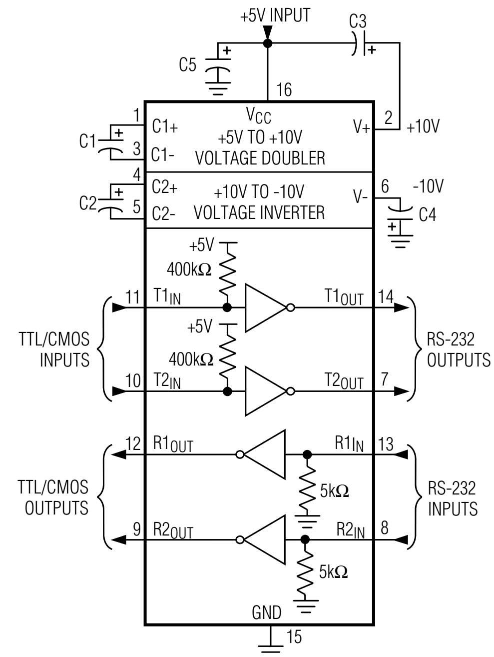
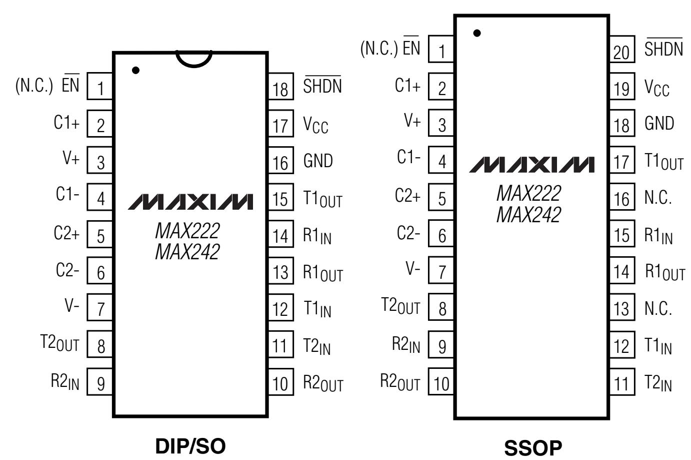
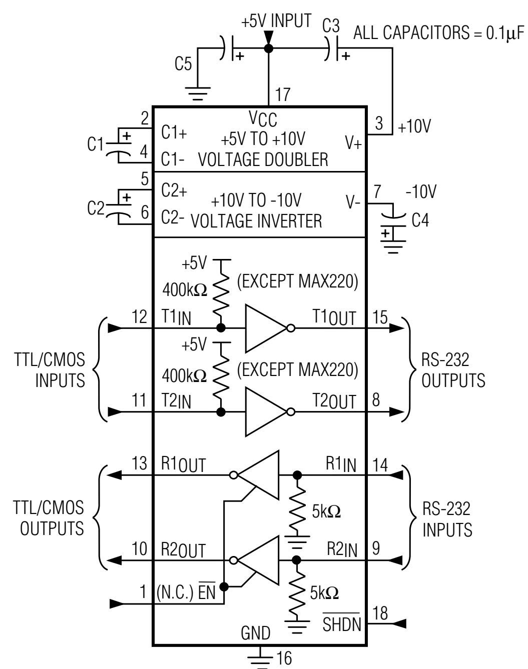


Figure 5. MAX220/MAX232/MAX232A Pin Configuration and Typical Operating Circuit

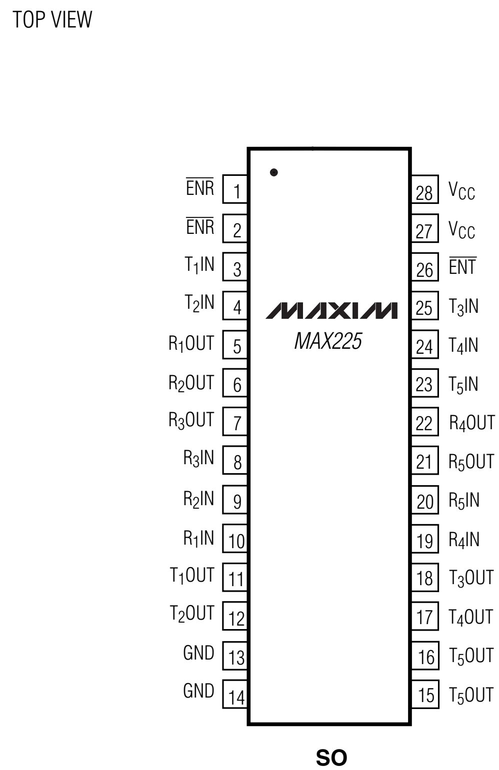
TOP VIEW

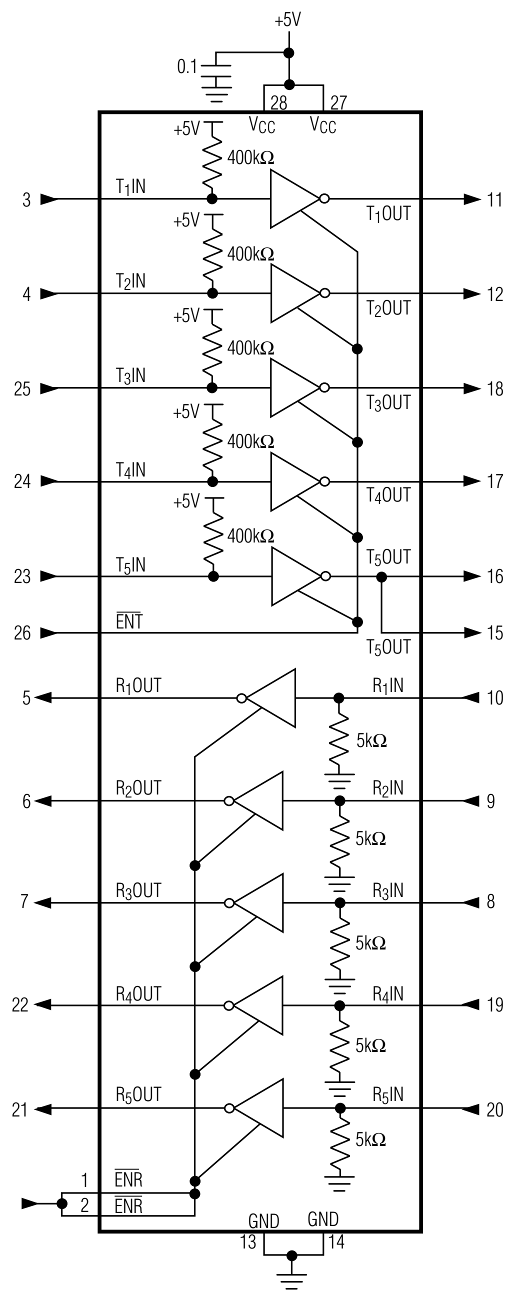




( ) ARE FOR MAX222 ONLY.
PIN NUMBERS IN TYPICAL OPERATING CIRCUIT ARE FOR DIP/SO PACKAGES ONLY.

Figure 6. MAX222/MAX242 Pin Configurations and Typical Operating Circuit





MAX225 FUNCTIONAL DESCRIPTION

5 RECEIVERS
5 TRANSMITTERS
2 CONTROL PINS
  1 RECEIVER ENABLE ($\overline{ENR}$)
  1 TRANSMITTER ENABLE ($\overline{ENT}$)

PINS ($\overline{ENR}$, GND, V_{CC}, T_5OUT) ARE INTERNALLY CONNECTED.
CONNECT EITHER OR BOTH EXTERNALLY. T_5OUT IS A SINGLE DRIVER.

Figure 7. MAX225 Pin Configuration and Typical Operating Circuit

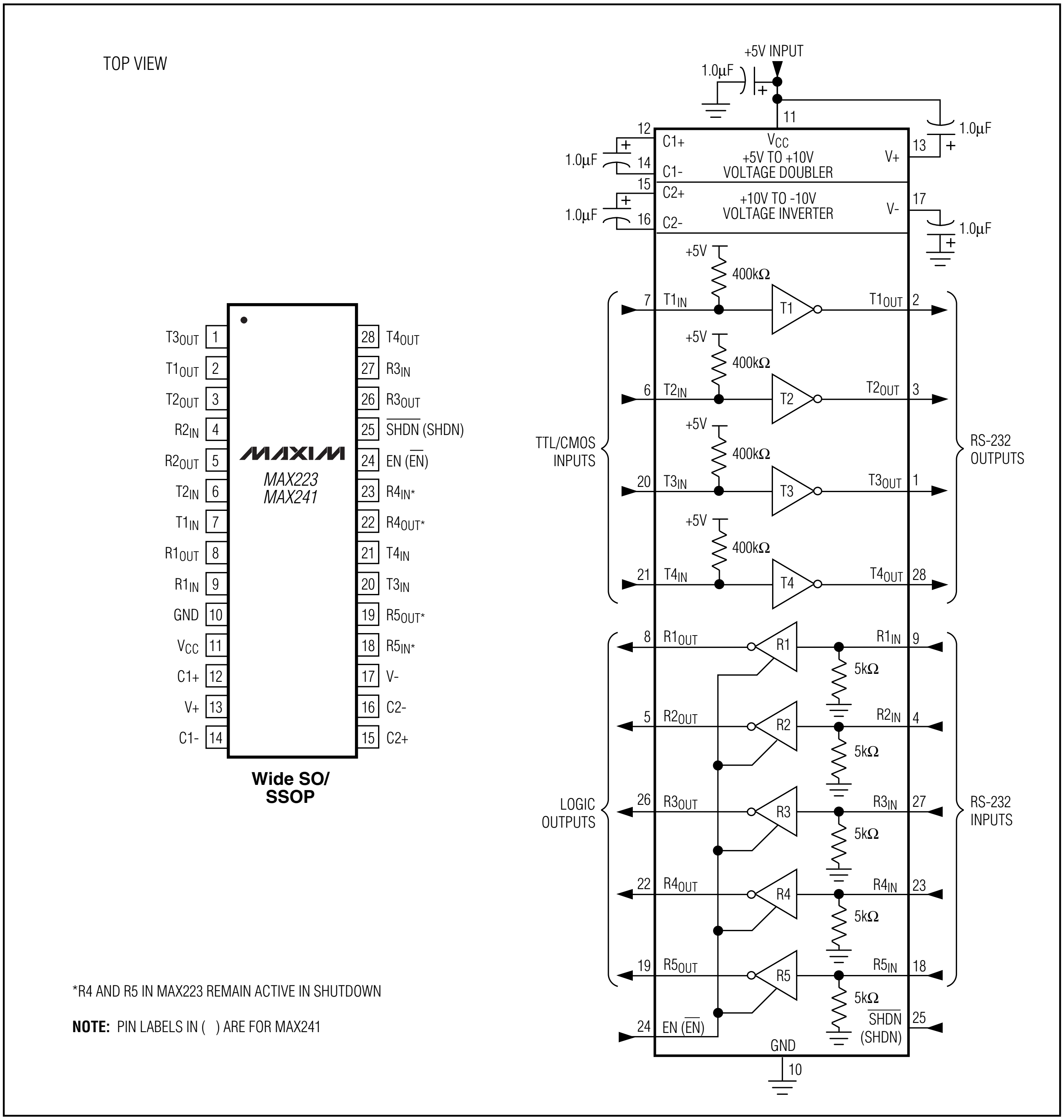


Figure 8. MAX223/MAX241 Pin Configuration and Typical Operating Circuit

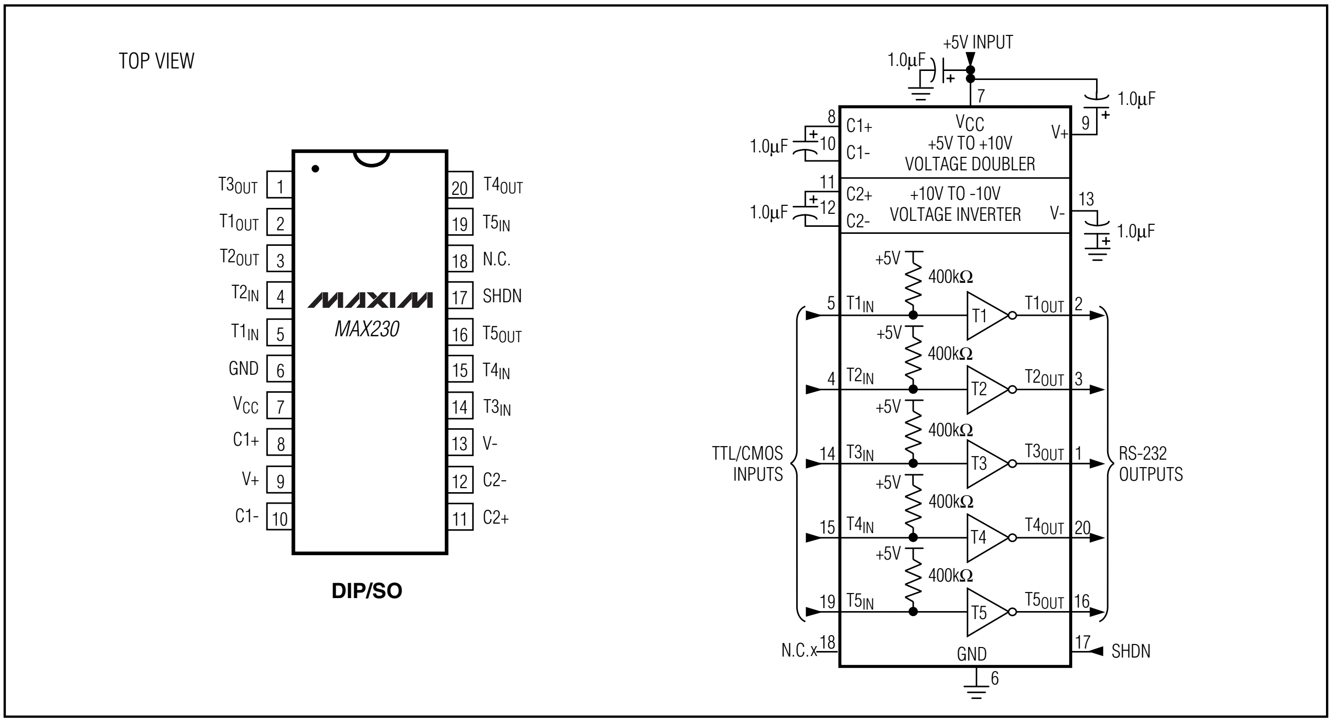


Figure 9. MAX230 Pin Configuration and Typical Operating Circuit

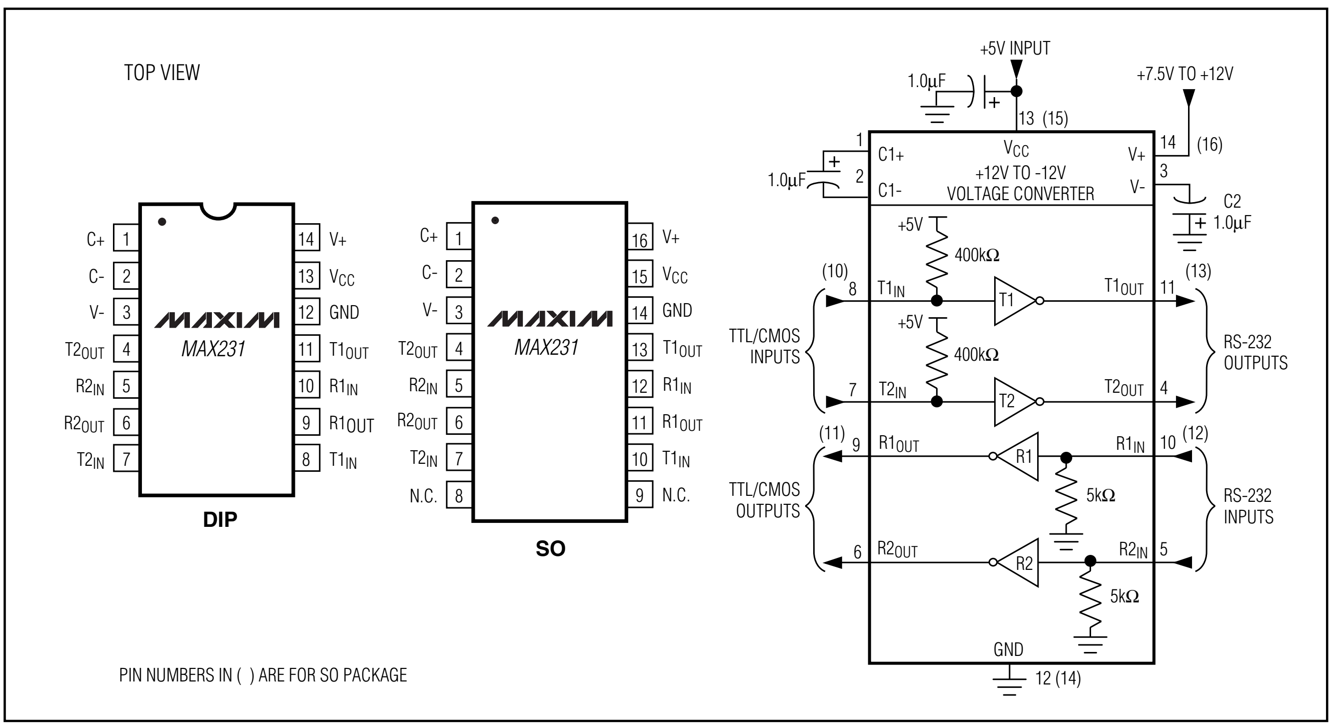


Figure 10. MAX231 Pin Configurations and Typical Operating Circuit

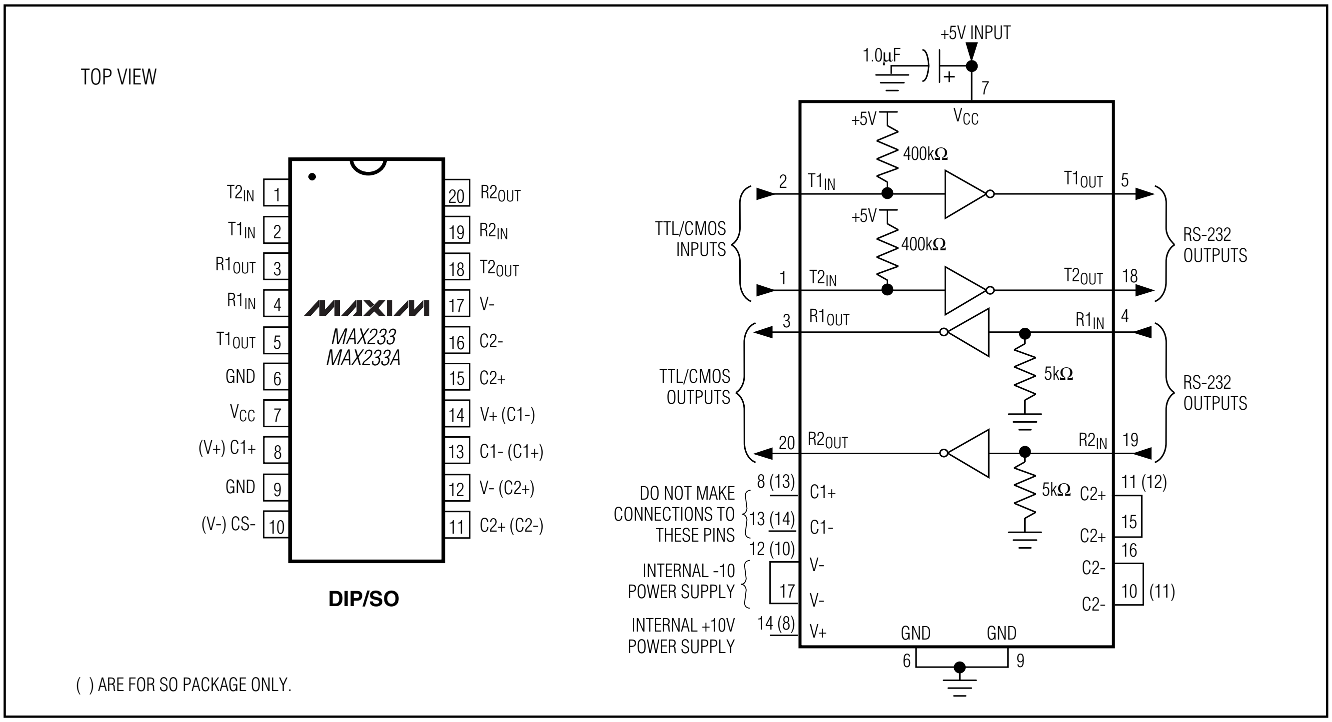


Figure 11. MAX233/MAX233A Pin Configuration and Typical Operating Circuit

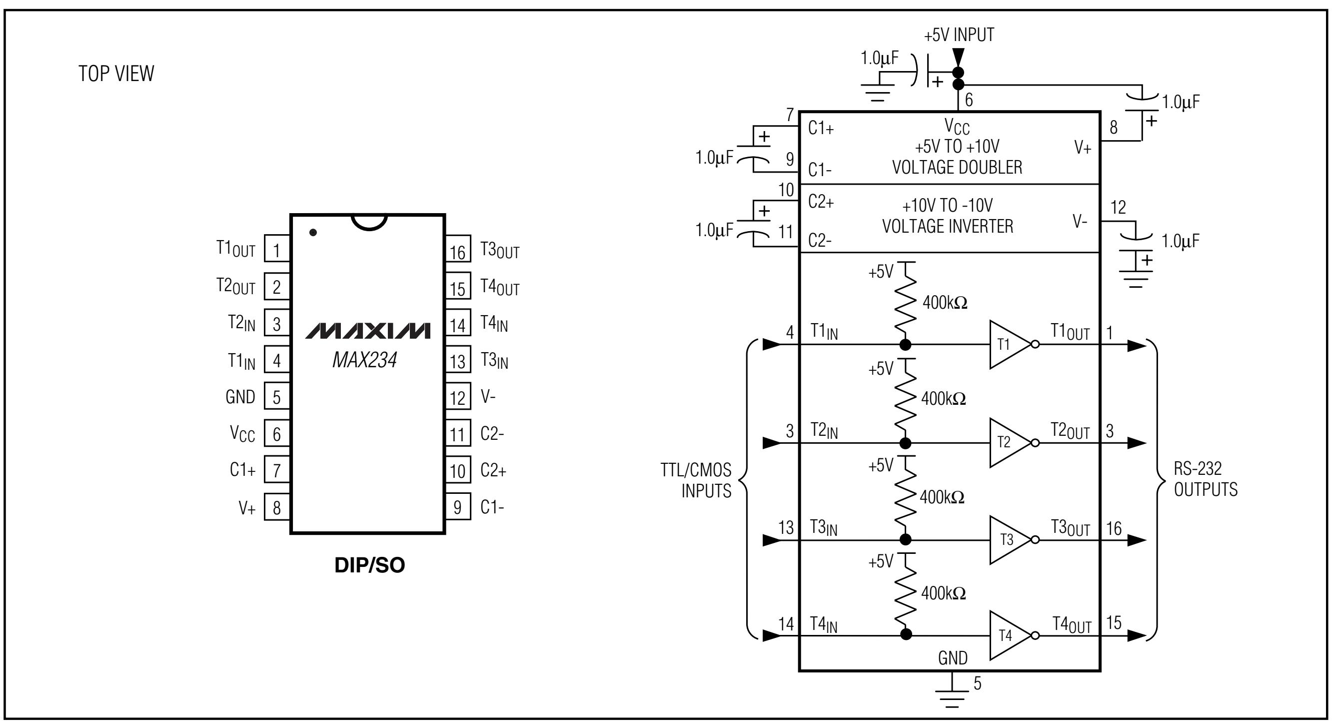


Figure 12. MAX234 Pin Configuration and Typical Operating Circuit

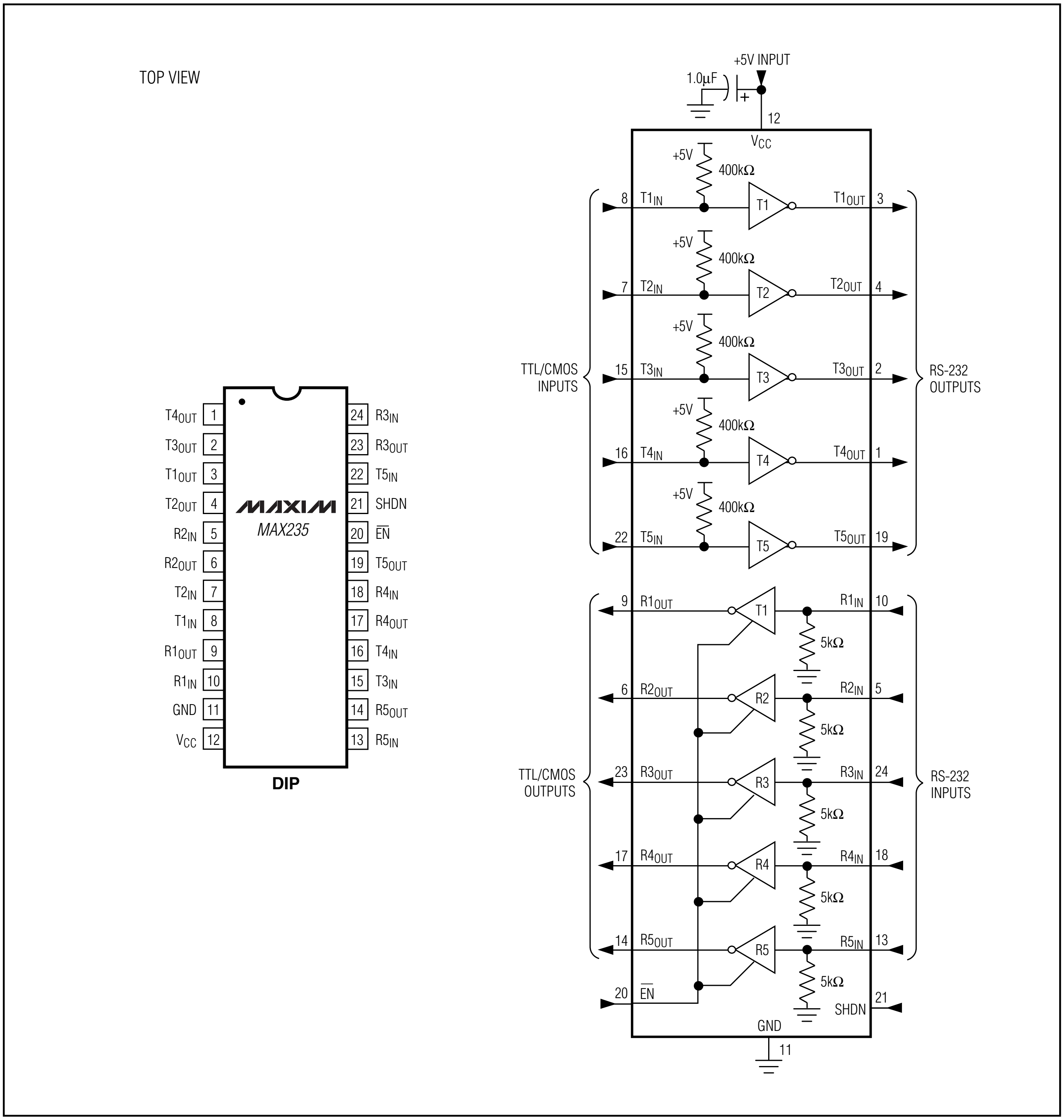


Figure 13. MAX235 Pin Configuration and Typical Operating Circuit

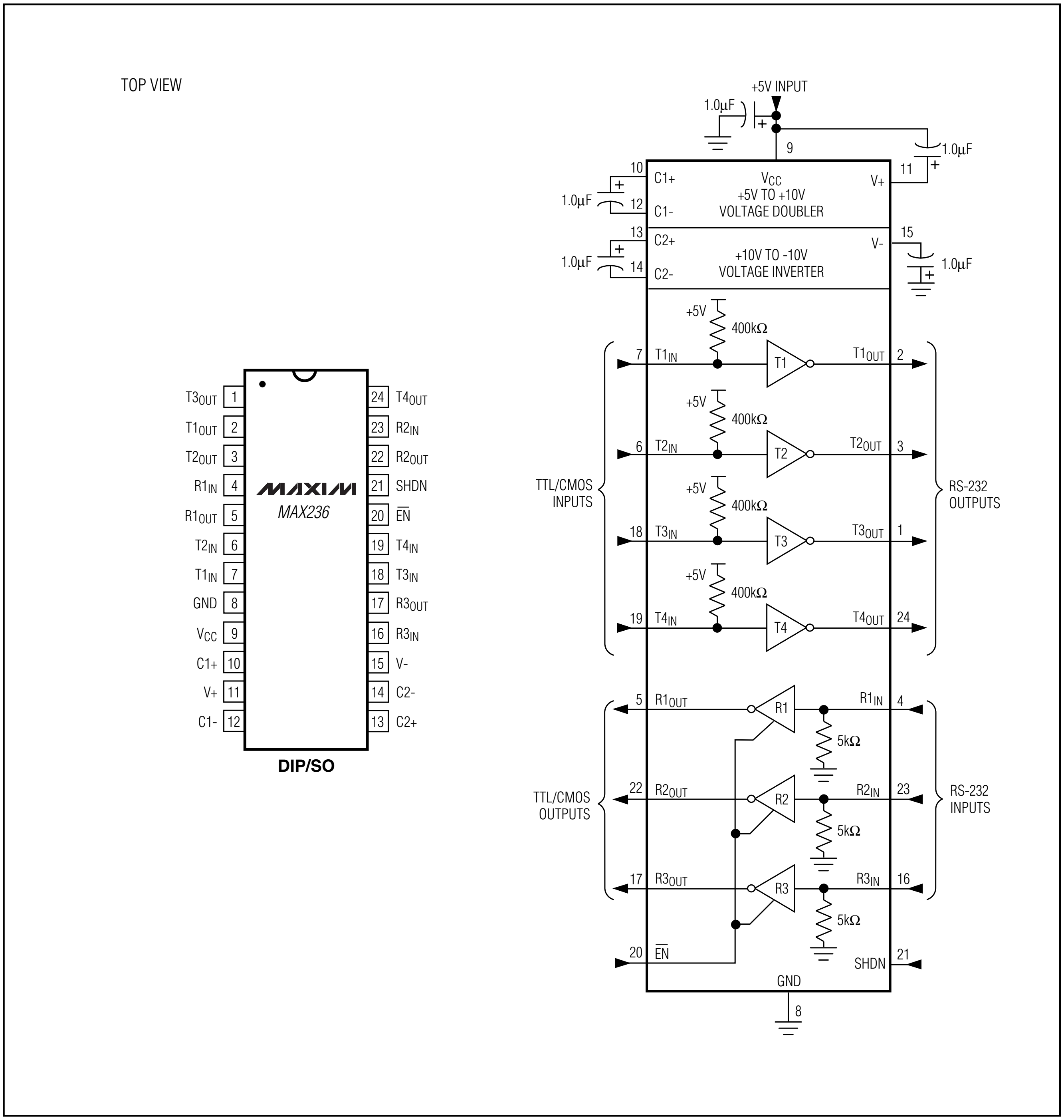


Figure 14. MAX236 Pin Configuration and Typical Operating Circuit

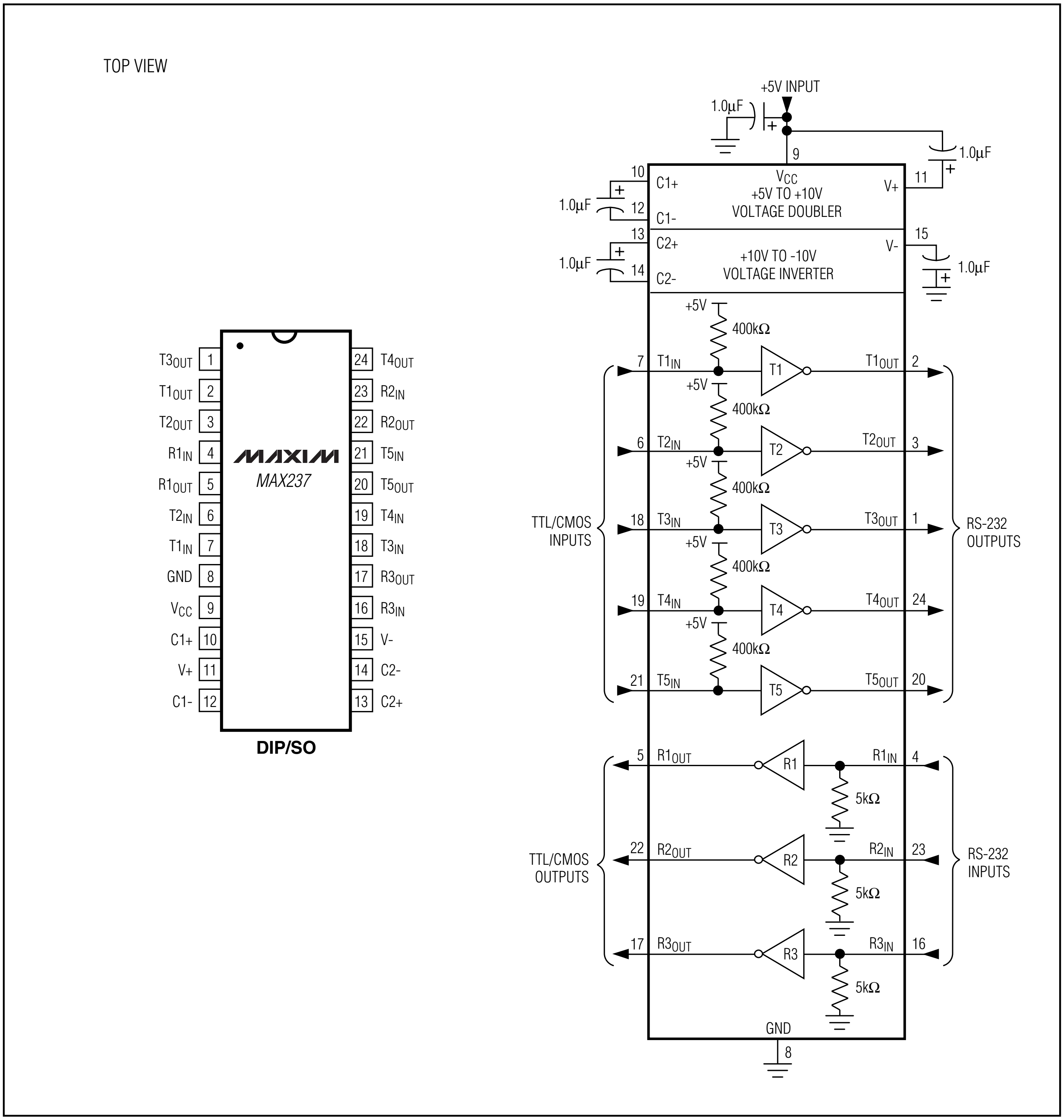


Figure 15. MAX237 Pin Configuration and Typical Operating Circuit

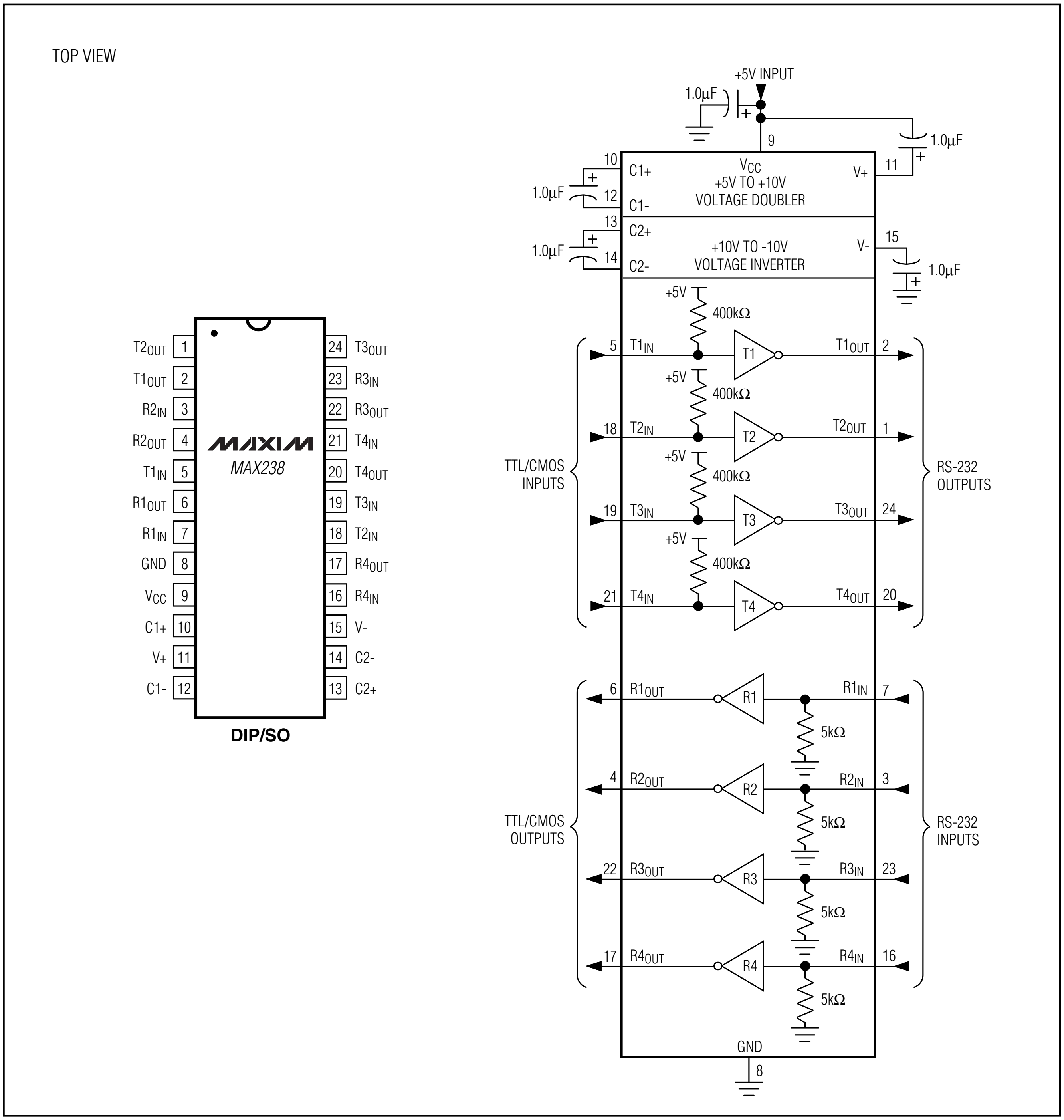


Figure 16. MAX238 Pin Configuration and Typical Operating Circuit

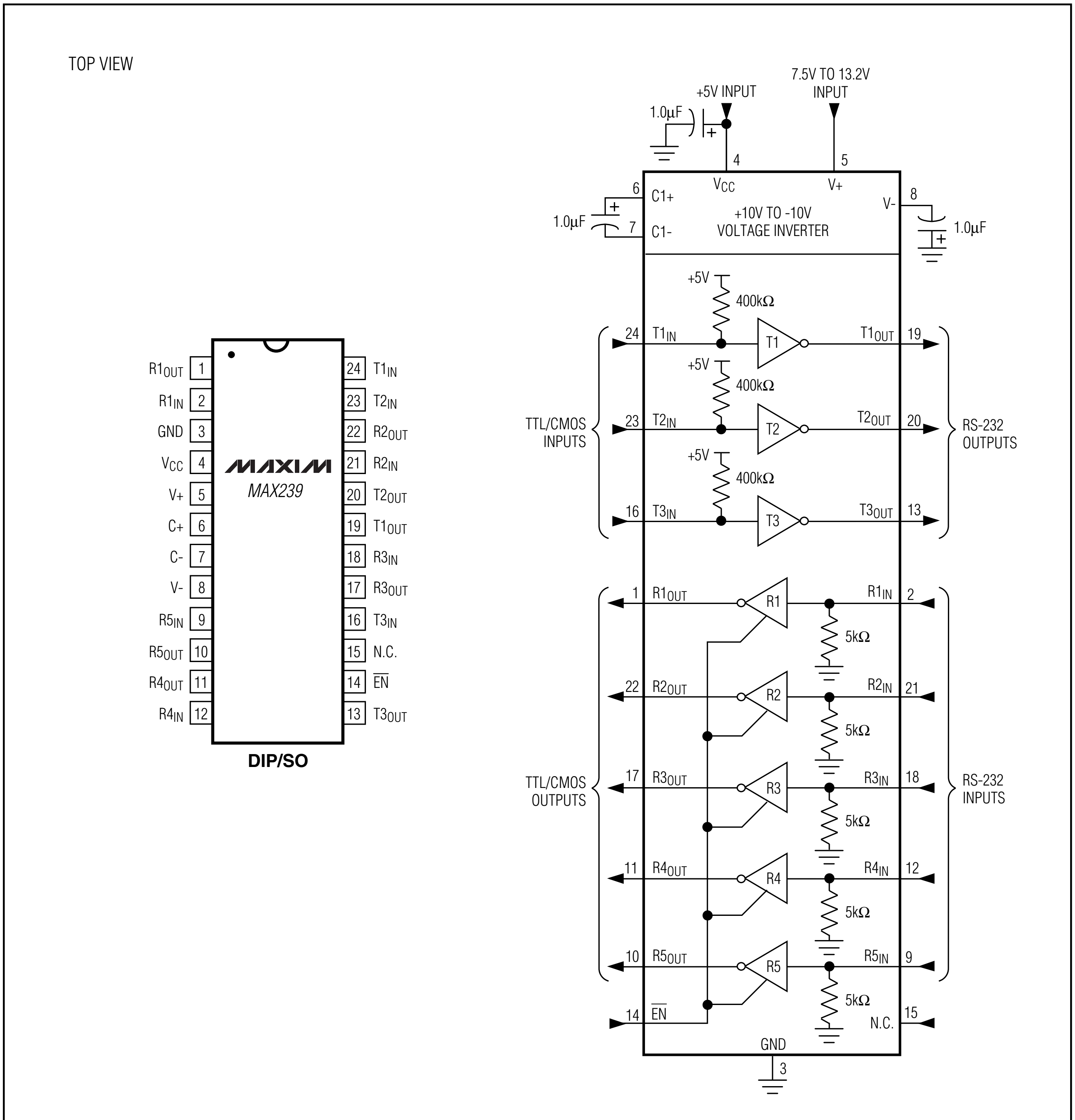


Figure 17. MAX239 Pin Configuration and Typical Operating Circuit

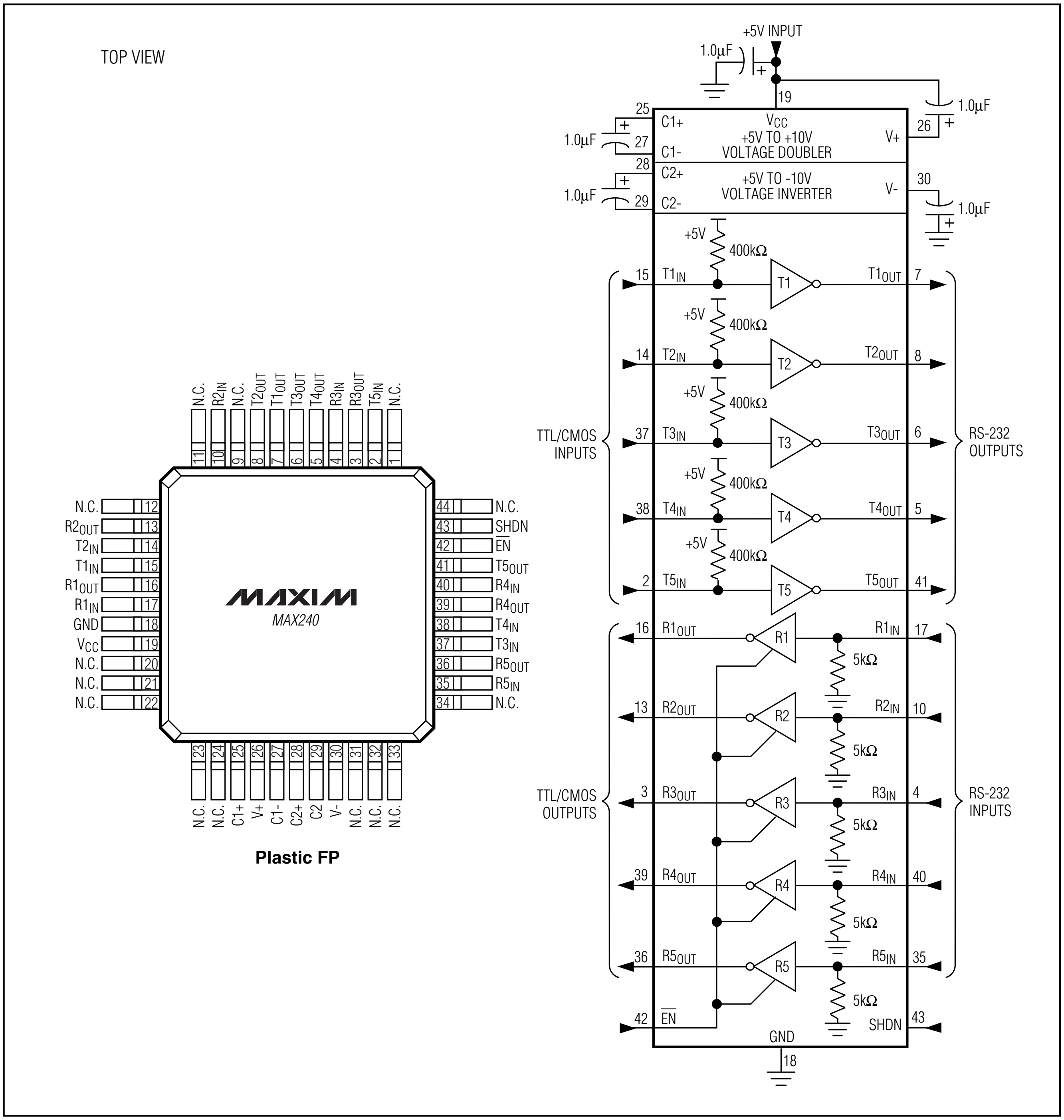
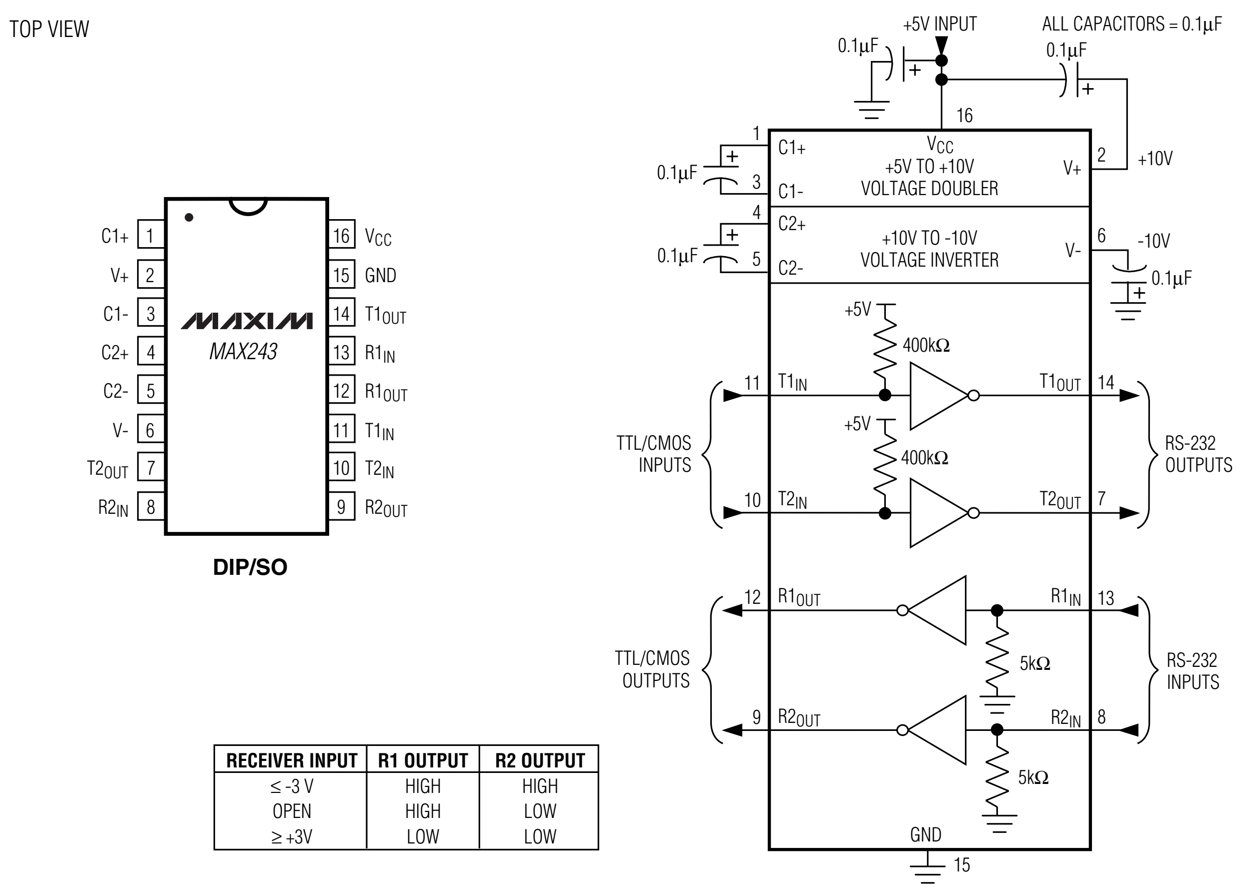


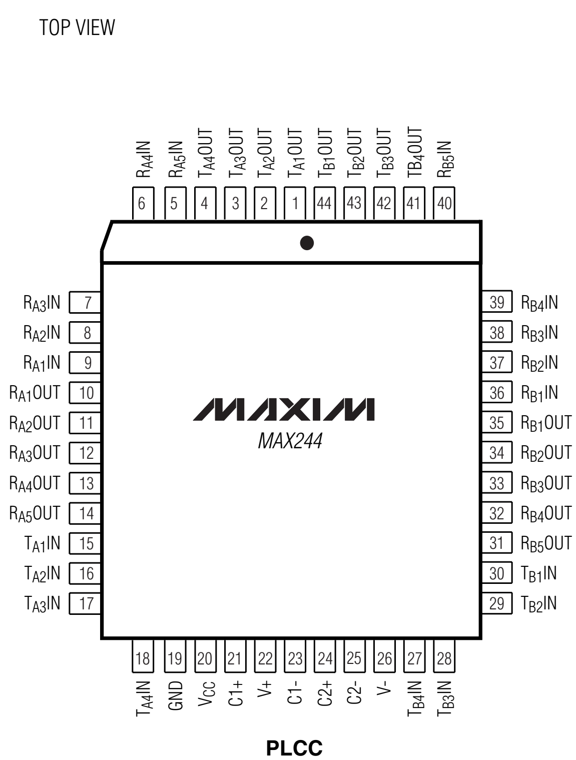
Figure 18. MAX240 Pin Configuration and Typical Operating Circuit

+5V-Powered, Multichannel RS-232 Drivers/Receivers



RECEIVER INPUT	R1 OUTPUT	R2 OUTPUT
≤ -3 V	HIGH	HIGH
OPEN	HIGH	LOW
≥ +3V	LOW	LOW

Figure 19. MAX243 Pin Configuration and Typical Operating Circuit



MAX249 FUNCTIONAL DESCRIPTION

10 RECEIVERS
- 5 A-SIDE RECEIVER
- 5 B-SIDE RECEIVER

8 TRANSMITTERS
- 4 A-SIDE TRANSMITTERS
- 4 B-SIDE TRANSMITTERS

NO CONTROL PINS

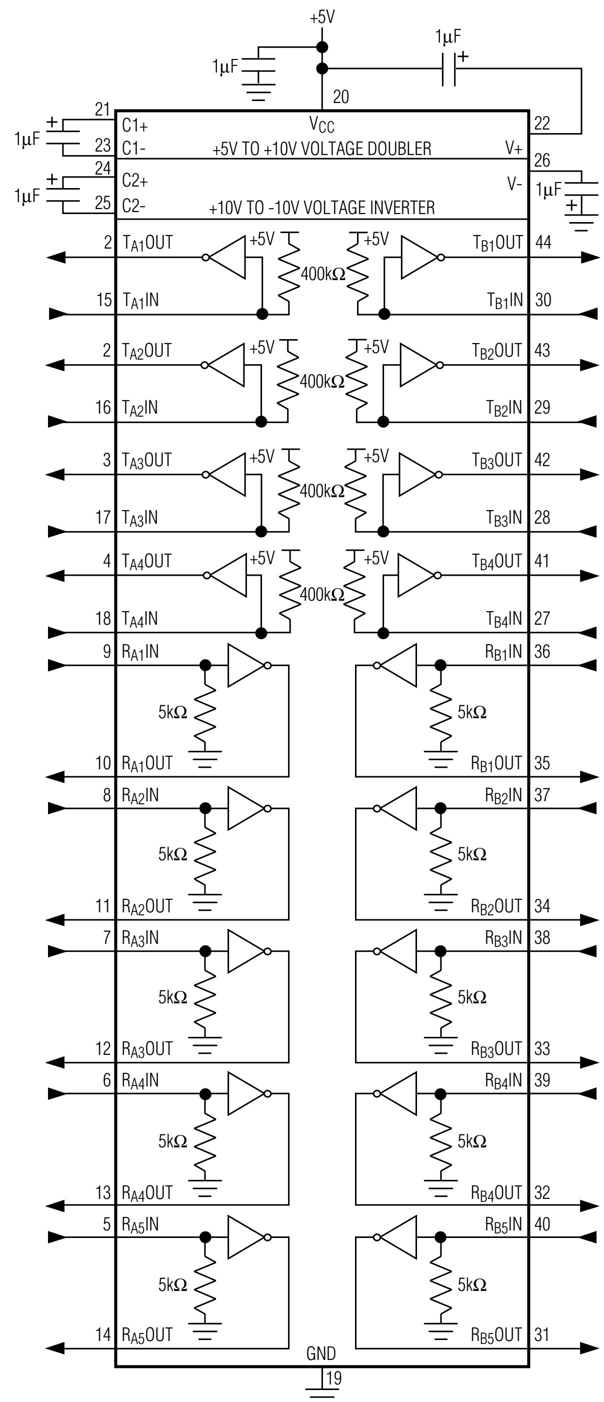
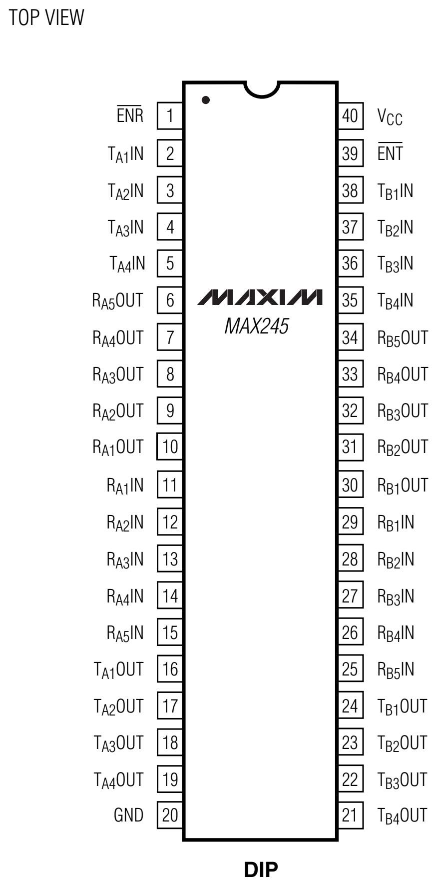
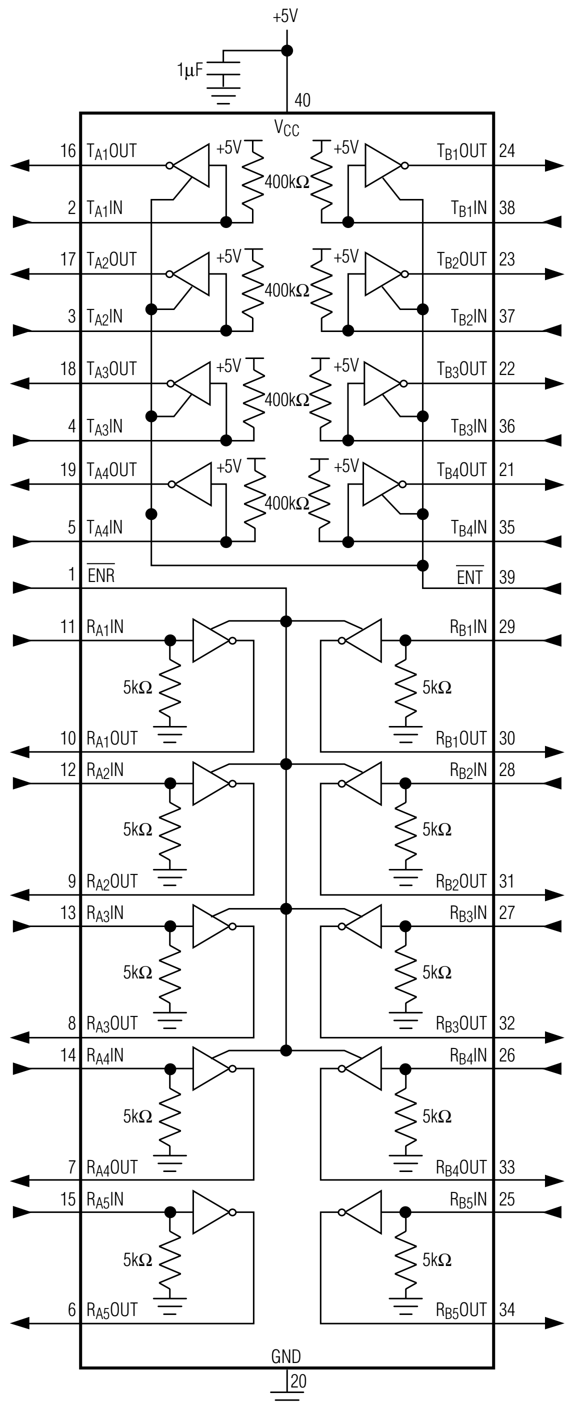


Figure 20. MAX244 Pin Configuration and Typical Operating Circuit





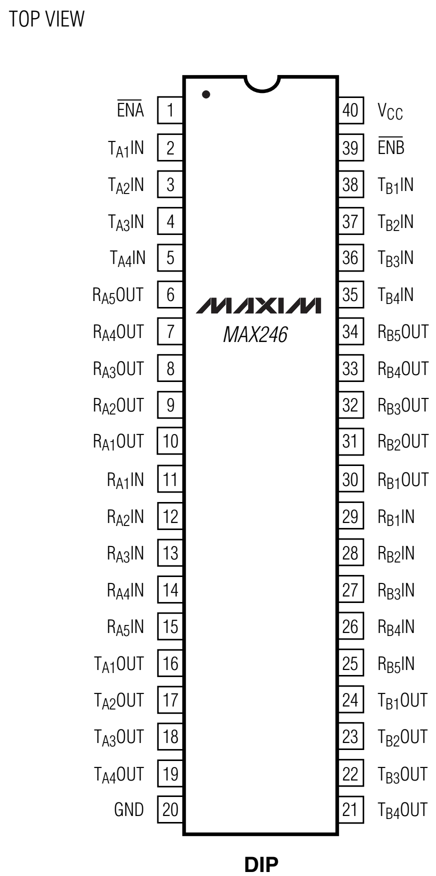
MAX245 FUNCTIONAL DESCRIPTION

10 RECEIVERS
- 5 A-SIDE RECEIVERS (R_{A5} ALWAYS ACTIVE)
- 5 B-SIDE RECEIVERS (R_{B5} ALWAYS ACTIVE)

8 TRANSMITTTERS
- 4 A-SIDE TRANSMITTERS

2 CONTROL PINS
- 1 RECEIVER ENABLE ($\overline{\text{ENR}}$)
- 1 TRANSMITTER ENABLE ($\overline{\text{ENT}}$)

Figure 21. MAX245 Pin Configuration and Typical Operating Circuit



MAX246 FUNCTIONAL DESCRIPTION

10 RECEIVERS
- 5 A-SIDE RECEIVERS (RA5 ALWAYS ACTIVE)
- 5 B-SIDE RECEIVERS (RB5 ALWAYS ACTIVE)

8 TRANSMITTERS
- 4 A-SIDE TRANSMITTERS
- 4 B-SIDE TRANSMITTERS

2 CONTROL PINS
- ENABLE A-SIDE ($\overline{ENA}$)
- ENABLE B-SIDE ($\overline{ENB}$)

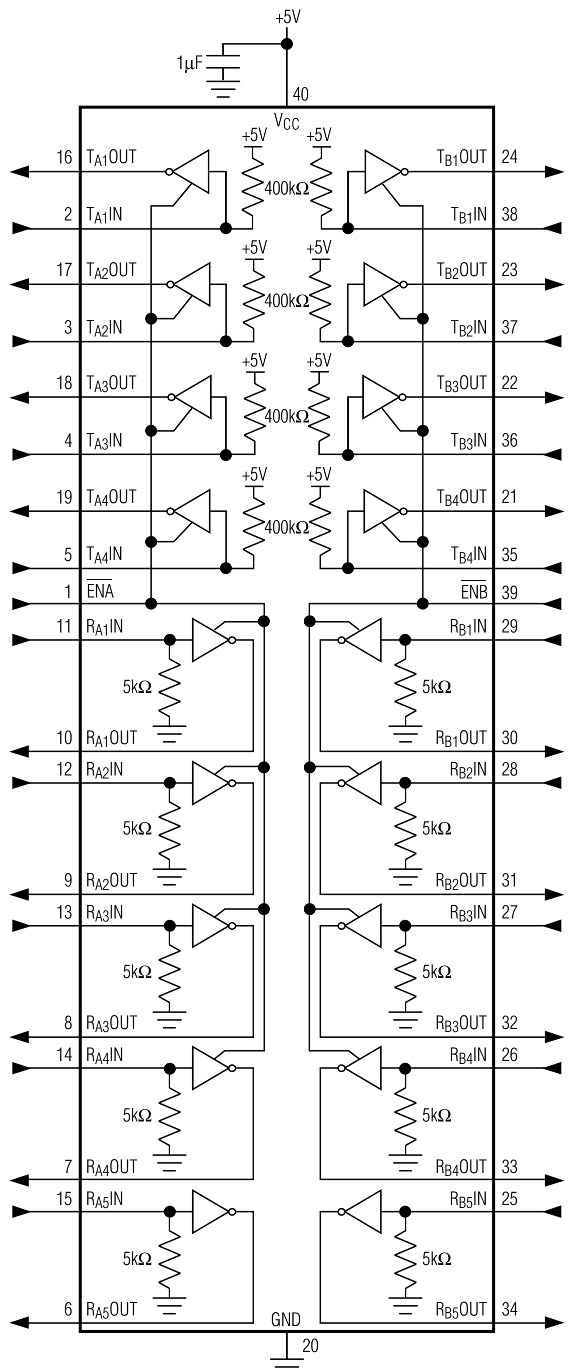
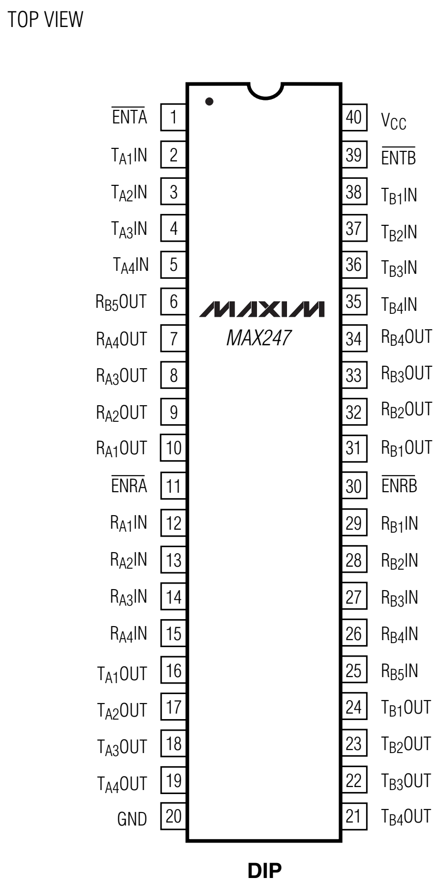


Figure 22. MAX246 Pin Configuration and Typical Operating Circuit



MAX247 FUNCTIONAL DESCRIPTION

9 RECEIVERS
- 4 A-SIDE RECEIVERS
- 5 B-SIDE RECEIVERS (R_{B5} ALWAYS ACTIVE)

8 TRANSMITTERS
- 4 A-SIDE TRANSMITTERS
- 4 B-SIDE TRANSMITTERS

4 CONTROL PINS
- ENABLE RECEIVER A-SIDE ($\overline{ENRA}$)
- ENABLE RECEIVER B-SIDE ($\overline{ENRB}$)
- ENABLE RECEIVER A-SIDE ($\overline{ENTA}$)
- ENABLE RECEIVERr B-SIDE ($\overline{ENTB}$)

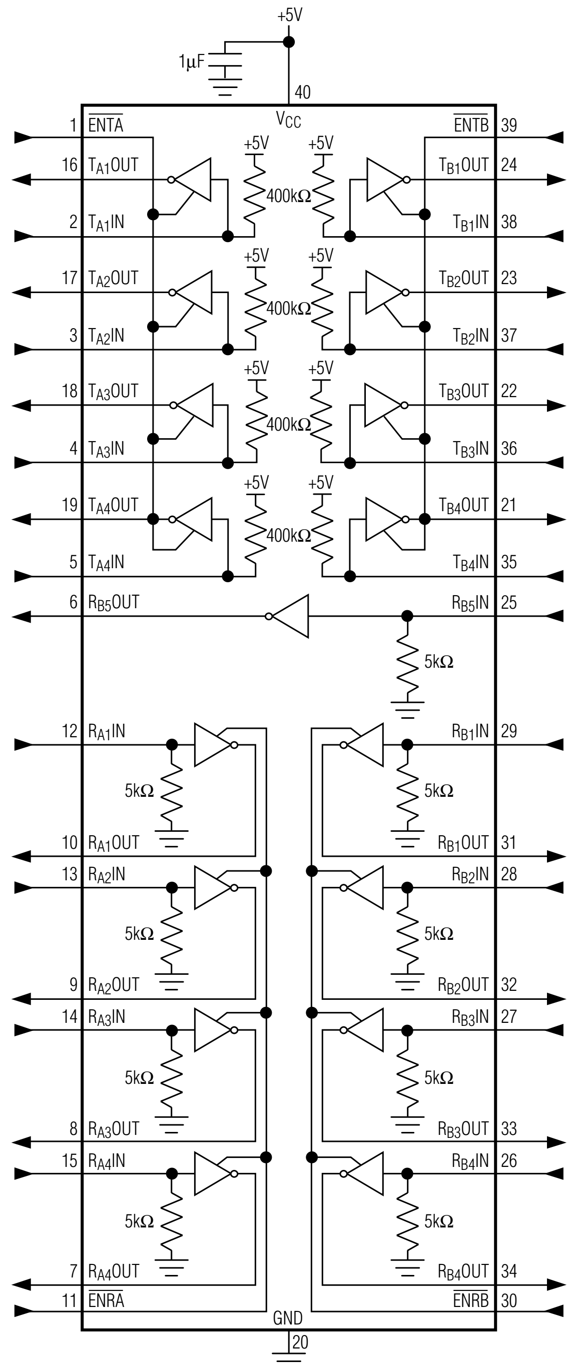
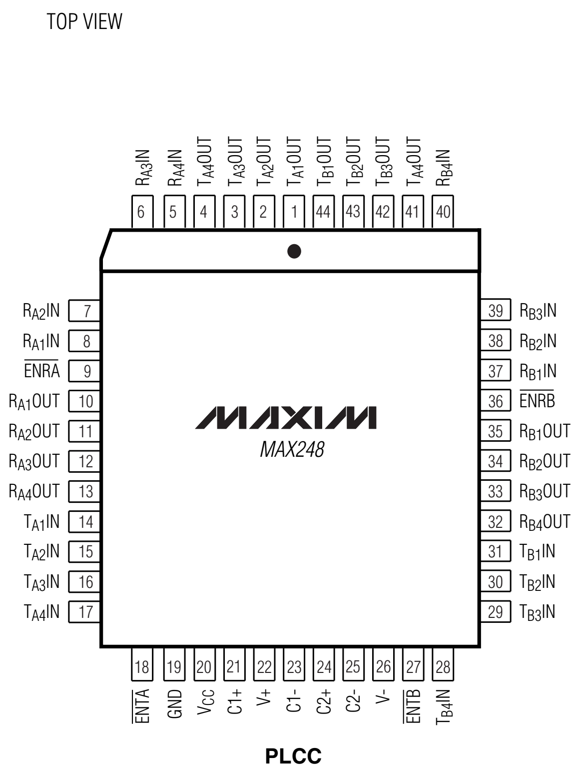


Figure 23. MAX247 Pin Configuration and Typical Operating Circuit



MAX248 FUNCTIONAL DESCRIPTION

8 RECEIVERS
- 4 A-SIDE RECEIVERS
- 4 B-SIDE RECEIVERS

8 TRANSMITTERS
- 4 A-SIDE TRANSMITTERS
- 4 B-SIDE TRANSMITTERS

4 CONTROL PINS
- ENABLE RECEIVER A-SIDE (ENRA)
- ENABLE RECEIVER B-SIDE (ENRB)
- ENABLE RECEIVER A-SIDE (ENTA)
- ENABLE RECEIVER B-SIDE (ENTB)

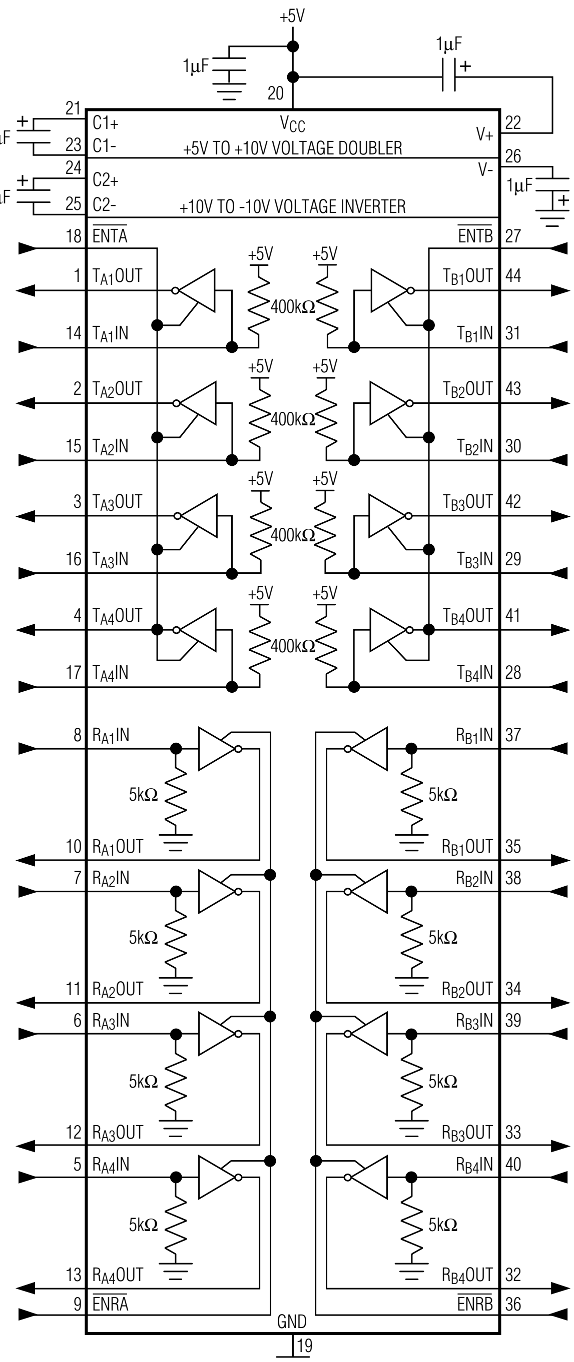
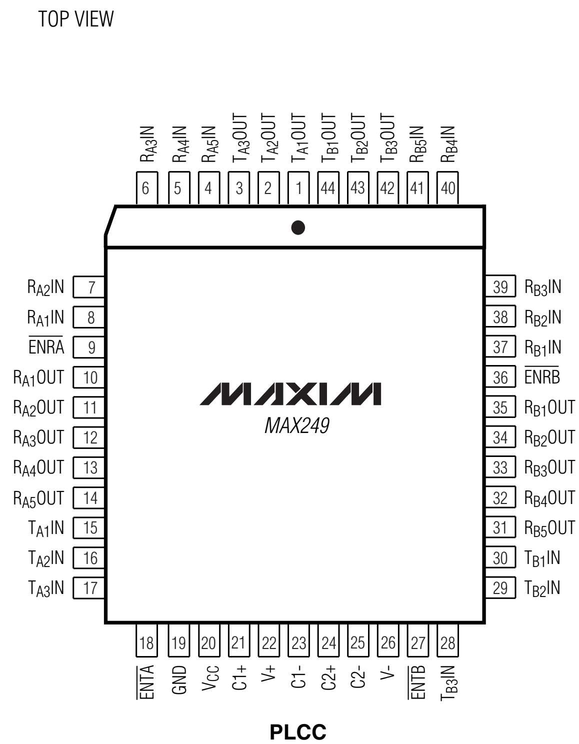


Figure 24. MAX248 Pin Configuration and Typical Operating Circuit



MAX249 FUNCTIONAL DESCRIPTION

10 RECEIVERS
- 5 A-SIDE RECEIVERS
- 5 B-SIDE RECEIVERS

6 TRANSMITTERS
- 3 A-SIDE TRANSMITTERS
- 3 B-SIDE TRANSMITTERS

4 CONTROL PINS
- ENABLE RECEIVER A-SIDE (ENRA)
- ENABLE RECEIVER B-SIDE (ENRB)
- ENABLE RECEIVER A-SIDE (ENTA)
- ENABLE RECEIVER B-SIDE (ENTB)

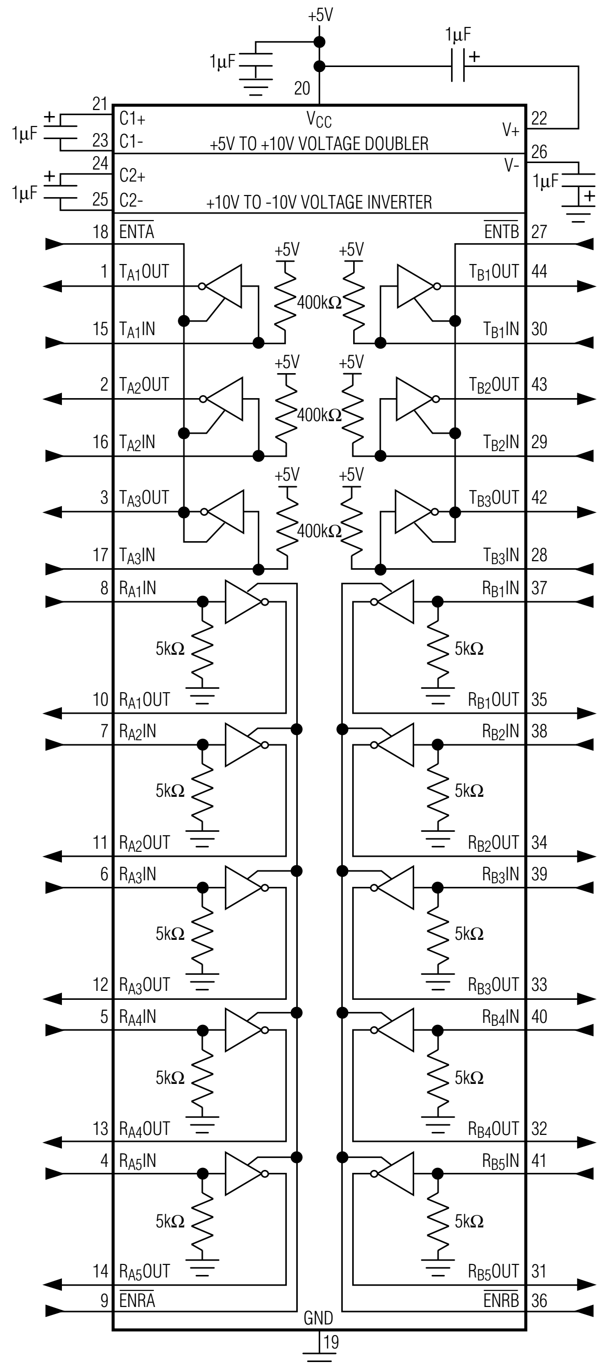


Figure 25. MAX249 Pin Configuration and Typical Operating Circuit

Ordering Information (continued)

PART	TEMP RANGE	PIN-PACKAGE
MAX222CPN	0°C to +70°C	18 Plastic DIP
MAX222CWN	0°C to +70°C	18 Wide SO
MAX222C/D	0°C to +70°C	Dice*
MAX222EPN	-40°C to +85°C	18 Plastic DIP
MAX222EWN	-40°C to +85°C	18 Wide SO
MAX222EJN	-40°C to +85°C	18 CERDIP
MAX222MJN	-55°C to +125°C	18 CERDIP
MAX223CAI	0°C to +70°C	28 SSOP
MAX223CWI	0°C to +70°C	28 Wide SO
MAX223C/D	0°C to +70°C	Dice*
MAX223EAI	-40°C to +85°C	28 SSOP
MAX223EWI	-40°C to +85°C	28 Wide SO
MAX225CWI	0°C to +70°C	28 Wide SO
MAX225EWI	-40°C to +85°C	28 Wide SO
MAX230CPP	0°C to +70°C	20 Plastic DIP
MAX230CWP	0°C to +70°C	20 Wide SO
MAX230C/D	0°C to +70°C	Dice*
MAX230EPP	-40°C to +85°C	20 Plastic DIP
MAX230EWP	-40°C to +85°C	20 Wide SO
MAX230EJP	-40°C to +85°C	20 CERDIP
MAX230MJP	-55°C to +125°C	20 CERDIP
MAX231CPD	0°C to +70°C	14 Plastic DIP
MAX231CWE	0°C to +70°C	16 Wide SO
MAX231CJD	0°C to +70°C	14 CERDIP
MAX231C/D	0°C to +70°C	Dice*
MAX231EPD	-40°C to +85°C	14 Plastic DIP
MAX231EWE	-40°C to +85°C	16 Wide SO
MAX231EJD	-40°C to +85°C	14 CERDIP
MAX231MJD	-55°C to +125°C	14 CERDIP
MAX232CPE	0°C to +70°C	16 Plastic DIP
MAX232CSE	0°C to +70°C	16 Narrow SO
MAX232CWE	0°C to +70°C	16 Wide SO
MAX232C/D	0°C to +70°C	Dice*
MAX232EPE	-40°C to +85°C	16 Plastic DIP
MAX232ESE	-40°C to +85°C	16 Narrow SO
MAX232EWE	-40°C to +85°C	16 Wide SO
MAX232EJE	-40°C to +85°C	16 CERDIP
MAX232MJE	-55°C to +125°C	16 CERDIP
MAX232MLP	-55°C to +125°C	20 LCC
MAX232ACPE	0°C to +70°C	16 Plastic DIP
MAX232ACSE	0°C to +70°C	16 Narrow SO
MAX232ACWE	0°C to +70°C	16 Wide SO

PART	TEMP RANGE	PIN-PACKAGE
MAX232AC/D	0°C to +70°C	Dice*
MAX232AEPE	-40°C to +85°C	16 Plastic DIP
MAX232AESE	-40°C to +85°C	16 Narrow SO
MAX232AEWE	-40°C to +85°C	16 Wide SO
MAX232AEJE	-40°C to +85°C	16 CERDIP
MAX232AMJE	-55°C to +125°C	16 CERDIP
MAX232AMLP	-55°C to +125°C	20 LCC
MAX233CPP	0°C to +70°C	20 Plastic DIP
MAX233EPP	-40°C to +85°C	20 Plastic DIP
MAX233ACPP	0°C to +70°C	20 Plastic DIP
MAX233ACWP	0°C to +70°C	20 Wide SO
MAX233AEPP	-40°C to +85°C	20 Plastic DIP
MAX233AEWP	-40°C to +85°C	20 Wide SO
MAX234CPE	0°C to +70°C	16 Plastic DIP
MAX234CWE	0°C to +70°C	16 Wide SO
MAX234C/D	0°C to +70°C	Dice*
MAX234EPE	-40°C to +85°C	16 Plastic DIP
MAX234EWE	-40°C to +85°C	16 Wide SO
MAX234EJE	-40°C to +85°C	16 CERDIP
MAX234MJE	-55°C to +125°C	16 CERDIP
MAX235CPG	0°C to +70°C	24 Wide Plastic DIP
MAX235EPG	-40°C to +85°C	24 Wide Plastic DIP
MAX235EDG	-40°C to +85°C	24 Ceramic SB
MAX235MDG	-55°C to +125°C	24 Ceramic SB
MAX236CNG	0°C to +70°C	24 Narrow Plastic DIP
MAX236CWG	0°C to +70°C	24 Wide SO
MAX236C/D	0°C to +70°C	Dice*
MAX236ENG	-40°C to +85°C	24 Narrow Plastic DIP
MAX236EWG	-40°C to +85°C	24 Wide SO
MAX236ERG	-40°C to +85°C	24 Narrow CERDIP
MAX236MRG	-55°C to +125°C	24 Narrow CERDIP
MAX237CNG	0°C to +70°C	24 Narrow Plastic DIP
MAX237CWG	0°C to +70°C	24 Wide SO
MAX237C/D	0°C to +70°C	Dice*
MAX237ENG	-40°C to +85°C	24 Narrow Plastic DIP
MAX237EWG	-40°C to +85°C	24 Wide SO
MAX237ERG	-40°C to +85°C	24 Narrow CERDIP
MAX237MRG	-55°C to +125°C	24 Narrow CERDIP
MAX238CNG	0°C to +70°C	24 Narrow Plastic DIP
MAX238CWG	0°C to +70°C	24 Wide SO
MAX238C/D	0°C to +70°C	Dice*
MAX238ENG	-40°C to +85°C	24 Narrow Plastic DIP

** Contact factory for dice specifications.*

Ordering Information (continued)

PART	TEMP RANGE	PIN-PACKAGE
MAX238EWG	-40°C to +85°C	24 Wide SO
MAX238ERG	-40°C to +85°C	24 Narrow CERDIP
MAX238MRG	-55°C to +125°C	24 Narrow CERDIP
MAX239CNG	0°C to +70°C	24 Narrow Plastic DIP
MAX239CWG	0°C to +70°C	24 Wide SO
MAX239C/D	0°C to +70°C	Dice*
MAX239ENG	-40°C to +85°C	24 Narrow Plastic DIP
MAX239EWG	-40°C to +85°C	24 Wide SO
MAX239ERG	-40°C to +85°C	24 Narrow CERDIP
MAX239MRG	-55°C to +125°C	24 Narrow CERDIP
MAX240CMH	0°C to +70°C	44 Plastic FP
MAX240C/D	0°C to +70°C	Dice*
MAX241CAI	0°C to +70°C	28 SSOP
MAX241CWI	0°C to +70°C	28 Wide SO
MAX241C/D	0°C to +70°C	Dice*
MAX241EAI	-40°C to +85°C	28 SSOP
MAX241EWI	-40°C to +85°C	28 Wide SO
MAX242CAP	0°C to +70°C	20 SSOP
MAX242CPN	0°C to +70°C	18 Plastic DIP
MAX242CWN	0°C to +70°C	18 Wide SO
MAX242C/D	0°C to +70°C	Dice*
MAX242EPN	-40°C to +85°C	18 Plastic DIP
MAX242EWN	-40°C to +85°C	18 Wide SO
MAX242EJN	-40°C to +85°C	18 CERDIP
MAX242MJN	-55°C to +125°C	18 CERDIP

PART	TEMP RANGE	PIN-PACKAGE
MAX243CPE	0°C to +70°C	16 Plastic DIP
MAX243CSE	0°C to +70°C	16 Narrow SO
MAX243CWE	0°C to +70°C	16 Wide SO
MAX243C/D	0°C to +70°C	Dice*
MAX243EPE	-40°C to +85°C	16 Plastic DIP
MAX243ESE	-40°C to +85°C	16 Narrow SO
MAX243EWE	-40°C to +85°C	16 Wide SO
MAX243EJE	-40°C to +85°C	16 CERDIP
MAX243MJE	-55°C to +125°C	16 CERDIP
MAX244CQH	0°C to +70°C	44 PLCC
MAX244C/D	0°C to +70°C	Dice*
MAX244EQH	-40°C to +85°C	44 PLCC
MAX245CPL	0°C to +70°C	40 Plastic DIP
MAX245C/D	0°C to +70°C	Dice*
MAX245EPL	-40°C to +85°C	40 Plastic DIP
MAX246CPL	0°C to +70°C	40 Plastic DIP
MAX246C/D	0°C to +70°C	Dice*
MAX246EPL	-40°C to +85°C	40 Plastic DIP
MAX247CPL	0°C to +70°C	40 Plastic DIP
MAX247C/D	0°C to +70°C	Dice*
MAX247EPL	-40°C to +85°C	40 Plastic DIP
MAX248CQH	0°C to +70°C	44 PLCC
MAX248C/D	0°C to +70°C	Dice*
MAX248EQH	-40°C to +85°C	44 PLCC
MAX249CQH	0°C to +70°C	44 PLCC
MAX249EQH	-40°C to +85°C	44 PLCC

** Contact factory for dice specifications.*

Package Information

For the latest package outline information, go to **www.maxim-ic.com/packages**.

National Semiconductor

November 2000

LM35
Precision Centigrade Temperature Sensors

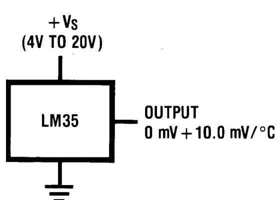
General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ˚ Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼˚C at room temperature and ±¾˚C over a full −55 to +150˚C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1˚C in still air. The LM35 is rated to operate over a −55˚ to +150˚C temperature range, while the LM35C is rated for a −40˚ to +110˚C range (−10˚ with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

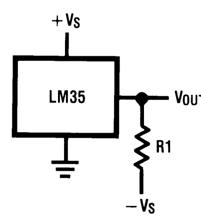
- Calibrated directly in ˚ Celsius (Centigrade)
- Linear + 10.0 mV/˚C scale factor
- 0.5˚C accuracy guaranteeable (at +25˚C)
- Rated for full −55˚ to +150˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08˚C in still air
- Nonlinearity only ±¼˚C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications



DS005516-3

FIGURE 1. Basic Centigrade Temperature Sensor (+2˚C to +150˚C)



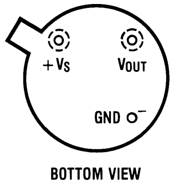
DS005516-4

Choose $R_1 = -V_S/50\ \mu A$
V_{OUT}=+1,500 mV at +150˚C
= +250 mV at +25˚C
= −550 mV at −55˚C

FIGURE 2. Full-Range Centigrade Temperature Sensor

Connection Diagrams

TO-46
Metal Can Package*

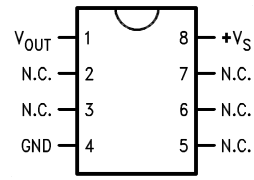


DS005516-1

*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

SO-8
Small Outline Molded Package

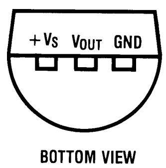


DS005516-21

N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

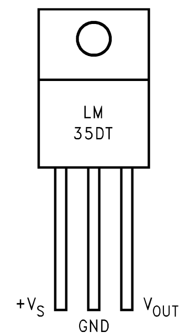
TO-92
Plastic Package



DS005516-2

Order Number LM35CZ,
LM35CAZ or LM35DZ
See NS Package Number Z03A

TO-220
Plastic Package*



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*Tab is connected to the negative pin (GND).

Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings (Note 10)

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

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60˚C to +180˚C
TO-92 Package,	−60˚C to +150˚C
SO-8 Package,	−65˚C to +150˚C
TO-220 Package,	−65˚C to +150˚C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300˚C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260˚C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55˚C to +150˚C
LM35C, LM35CA	−40˚C to +110˚C
LM35D	0˚C to +100˚C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy (Note 7)	T_A=+25˚C	±0.2	±0.5		±0.2	±0.5		˚C
	T_A=−10˚C	±0.3			±0.3		±1.0	˚C
	T_A=T_{MAX}	±0.4	±1.0		±0.4	±1.0		˚C
	T_A=T_{MIN}	±0.4	±1.0		±0.4		±1.5	˚C
Nonlinearity (Note 8)	T_{MIN}≤T_A≤T_{MAX}	**±0.18**		**±0.35**	**±0.15**		**±0.3**	˚C
Sensor Gain (Average Slope)	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/˚C
Load Regulation (Note 3) 0≤I_L≤1 mA	T_A=+25˚C	±0.4	±1.0		±0.4	±1.0		mV/mA
	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	T_A=+25˚C	±0.01	±0.05		±0.01	±0.05		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25˚C	56	67		56	67		µA
	V_S=+5V	**105**		**131**	**91**		**114**	µA
	V_S=+30V, +25˚C	56.2	68		56.2	68		µA
	V_S=+30V	**105.5**		**133**	**91.5**		**116**	µA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25˚C	0.2	1.0		0.2	1.0		µA
	4V≤V_S≤30V	**0.5**		**2.0**	**0.5**		**2.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	µA/˚C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	˚C
Long Term Stability	T_J=T_{MAX}, for 1000 hours	±0.08			±0.08			˚C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35			LM35C, LM35D			Units
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	(Max.)
Accuracy, LM35, LM35C (Note 7)	T_A=+25˚C	±0.4	±1.0		±0.4	±1.0		˚C
	T_A=−10˚C	±0.5			±0.5		±1.5	˚C
	$T_A=T_{MAX}$	±0.8	±1.5		±0.8		±1.5	˚C
	$T_A=T_{MIN}$	±0.8		±1.5	±0.8		±2.0	˚C
Accuracy, LM35D (Note 7)	T_A=+25˚C				±0.6	±1.5		˚C
	$T_A=T_{MAX}$				±0.9		±2.0	˚C
	$T_A=T_{MIN}$				±0.9		±2.0	˚C
Nonlinearity (Note 8)	$T_{MIN} \le T_A \le T_{MAX}$	**±0.3**		**±0.5**	**±0.2**		**±0.5**	˚C
Sensor Gain (Average Slope)	$T_{MIN} \le T_A \le T_{MAX}$	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/˚C
Load Regulation (Note 3) $0 \le I_L \le 1$ mA	T_A=+25˚C	±0.4	±2.0		±0.4	±2.0		mV/mA
	$T_{MIN} \le T_A \le T_{MAX}$	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation (Note 3)	T_A=+25˚C	±0.01	±0.1		±0.01	±0.1		mV/V
	$4V \le V_S \le 30V$	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25˚C	56	80		56	80		μA
	V_S=+5V	**105**		**158**	**91**		**138**	μA
	V_S=+30V, +25˚C	56.2	82		56.2	82		μA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	μA
Change of Quiescent Current (Note 3)	$4V \le V_S \le 30V$, +25˚C	0.2	2.0		0.2	2.0		μA
	$4V \le V_S \le 30V$	**0.5**		**3.0**	**0.5**		**3.0**	μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	μA/˚C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	˚C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			˚C

Note 1: Unless otherwise noted, these specifications apply: $-55˚C \le T_J \le +150˚C$ for the LM35 and LM35A; $-40˚ \le T_J \le +110˚C$ for the LM35C and LM35CA; and $0˚ \le T_J \le +100˚C$ for the LM35D. V_S=+5Vdc and I_{LOAD}=50 μA, in the circuit of *Figure 2*. These specifications also apply from +2˚C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400˚C/W, junction to ambient, and 24˚C/W junction to case. Thermal resistance of the TO-92 package is 180˚C/W junction to ambient. Thermal resistance of the small outline molded package is 220˚C/W junction to ambient. Thermal resistance of the TO-220 package is 90˚C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/˚C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in ˚C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

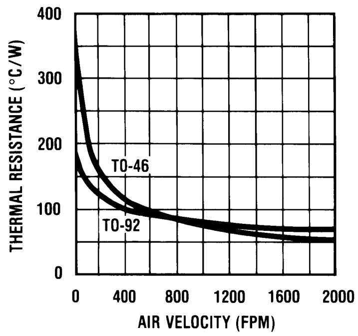
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

Typical Performance Characteristics

Thermal Resistance Junction to Air



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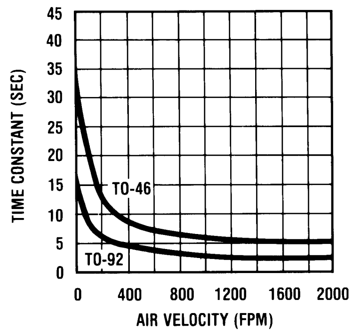
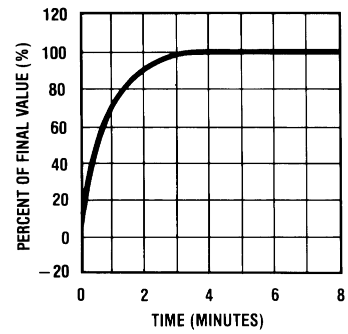
Thermal Time Constant



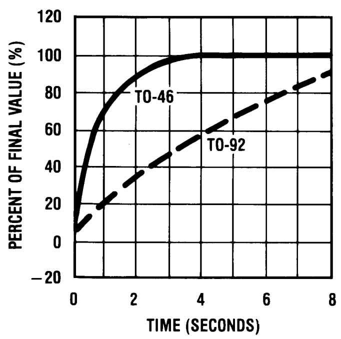
DS005516-26

Thermal Response in Still Air



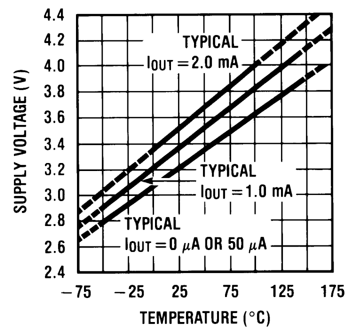
DS005516-27

Thermal Response in Stirred Oil Bath



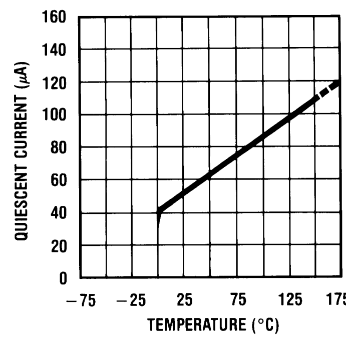
DS005516-28

Minimum Supply Voltage vs. Temperature



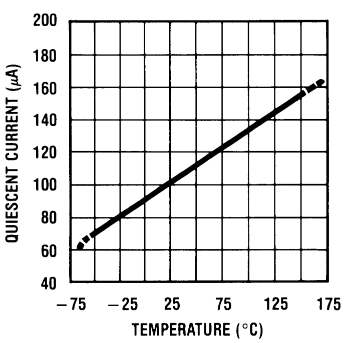
DS005516-29

Quiescent Current vs. Temperature (In Circuit of *Figure 1*.)



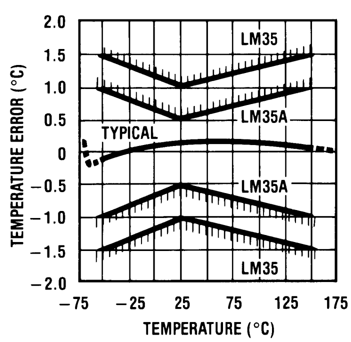
DS005516-30

Quiescent Current vs. Temperature (In Circuit of *Figure 2*.)



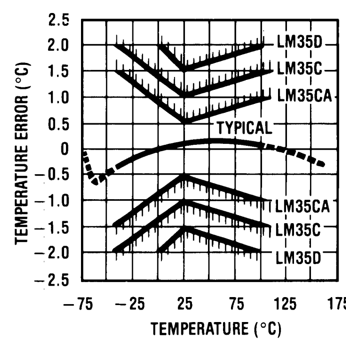
DS005516-31

Accuracy vs. Temperature (Guaranteed)



DS005516-32

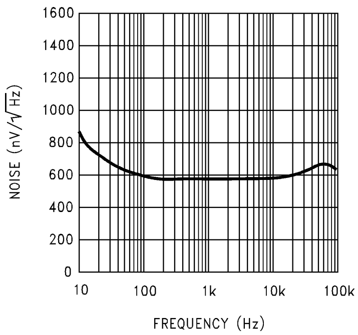
Accuracy vs. Temperature (Guaranteed)



DS005516-33

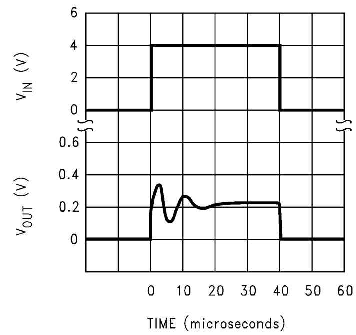
Typical Performance Characteristics (Continued)

Noise Voltage



DS005516-34

Start-Up Response



DS005516-35

Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01˚C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as the surface, and that the LM35 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, the LM35 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM35 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 or its connections.

These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance, θ_{JA})

	TO-46, no heat sink	**TO-46*, small heat fin**	**TO-92, no heat sink**	**TO-92**, small heat fin**	**SO-8 no heat sink**	**SO-8** small heat fin**	**TO-220 no heat sink**
Still air	400˚C/W	100˚C/W	180˚C/W	140˚C/W	220˚C/W	110˚C/W	90˚C/W
Moving air	100˚C/W	40˚C/W	90˚C/W	70˚C/W	105˚C/W	90˚C/W	26˚C/W
Still oil	100˚C/W	40˚C/W	90˚C/W	70˚C/W			
Stirred oil	50˚C/W	30˚C/W	45˚C/W	40˚C/W			
(Clamped to metal, Infinite heat sink)	(24˚C/W)					(55˚C/W)	

*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.
**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

Typical Applications

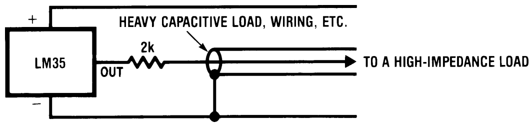


FIGURE 3. LM35 with Decoupling from Capacitive Load

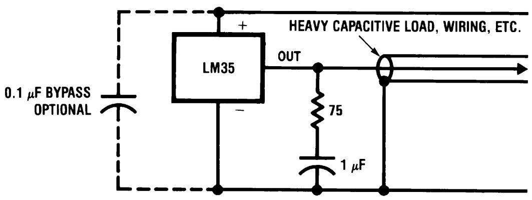


FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pf without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*.

When the LM35 is applied with a 200Ω load resistor as shown in *Figure 5*, *Figure 6* or *Figure 8* it is relatively immune to wiring capacitance because the capacitance forms a by-pass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 µF from output to ground are often useful. These are shown in *Figure 13*, *Figure 14*, and *Figure 16*.

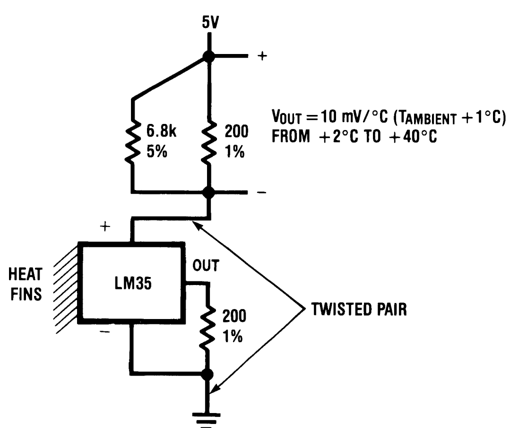


FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

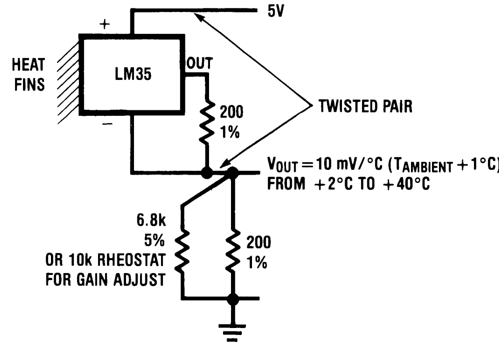


FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

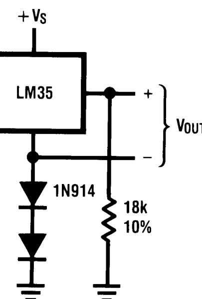


FIGURE 7. Temperature Sensor, Single Supply, −55˚ to +150˚C

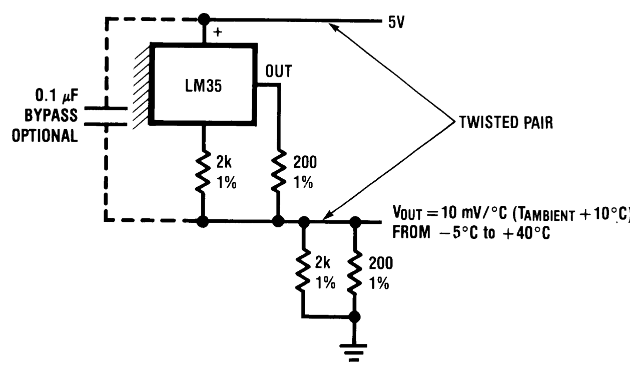


FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

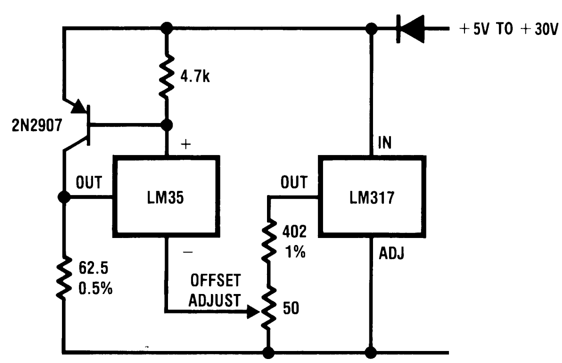
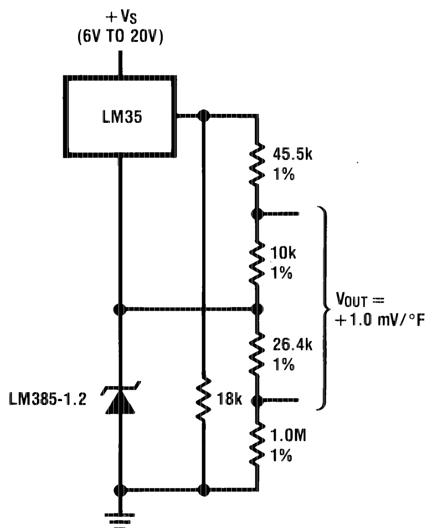


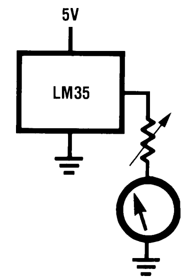
FIGURE 9. 4-To-20 mA Current Source (0˚C to +100˚C)

Typical Applications (Continued)



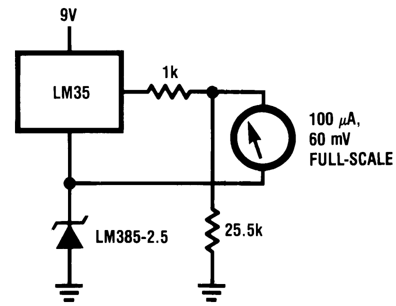
DS005516-10

FIGURE 10. Fahrenheit Thermometer



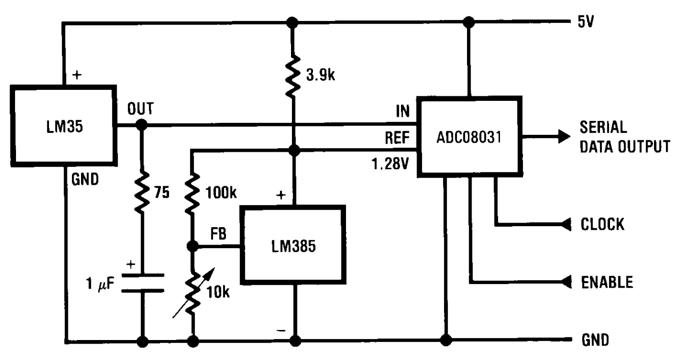
DS005516-11

FIGURE 11. Centigrade Thermometer (Analog Meter)



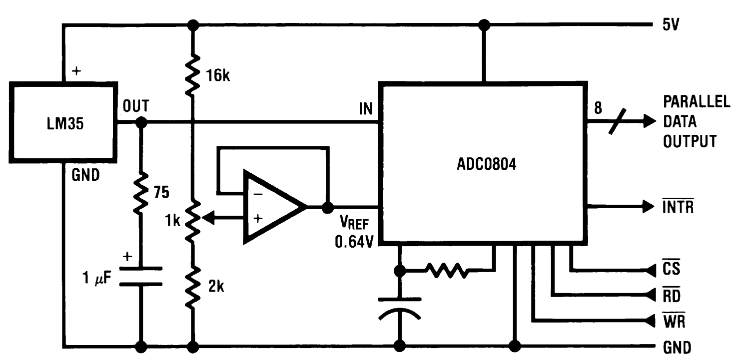
DS005516-12

FIGURE 12. Fahrenheit ThermometerExpanded Scale Thermometer
(50˚ to 80˚ Fahrenheit, for Example Shown)



DS005516-13

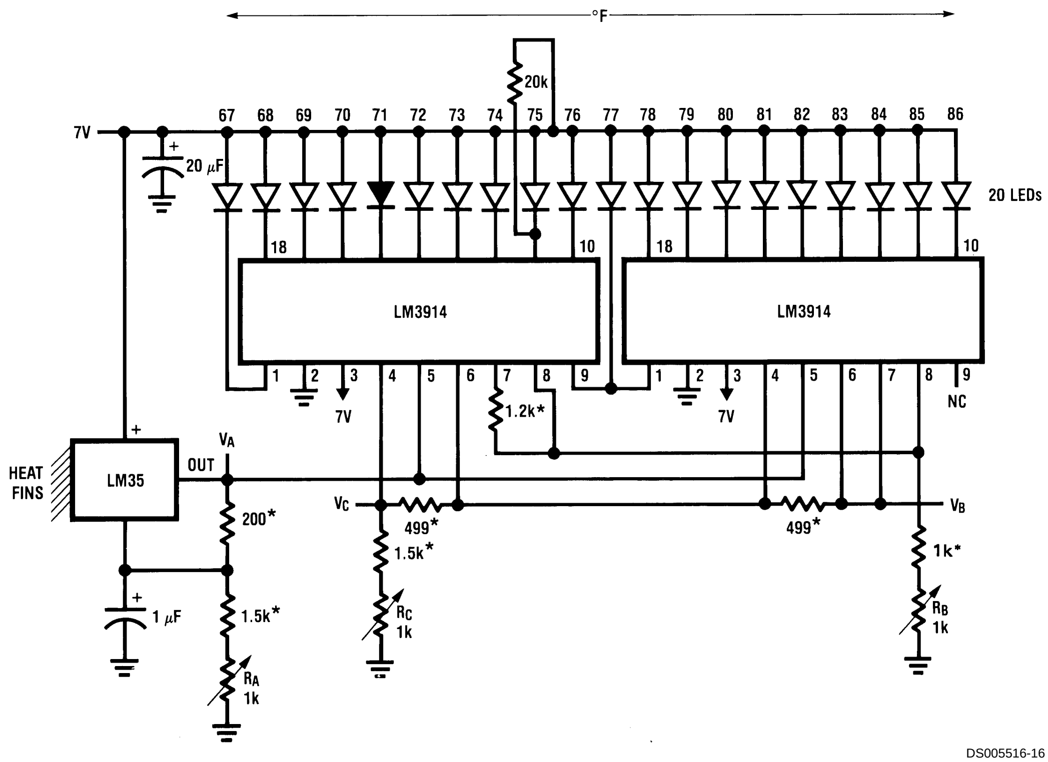
FIGURE 13. Temperature To Digital Converter (Serial Output) (+128˚C Full Scale)



DS005516-14

FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE™ Outputs for Standard Data Bus to μP Interface) (128˚C Full Scale)

Typical Applications (Continued)



*=1% or 2% film resistor
Trim R_B for V_B=3.075V
Trim R_C for V_C=1.955V
Trim R_A for V_A=0.075V + 100mV/˚C x $T_{ambient}$
Example, V_A=2.275V at 22˚C

FIGURE 15. Bar-Graph Temperature Display (Dot Mode)

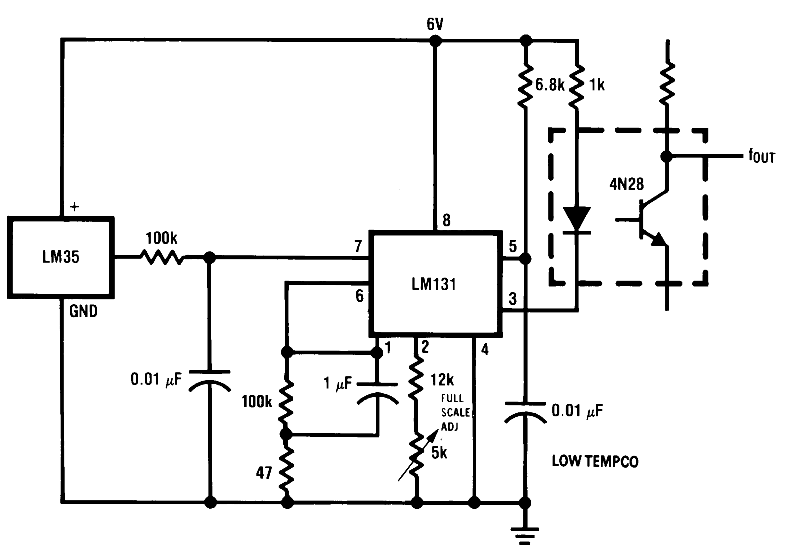
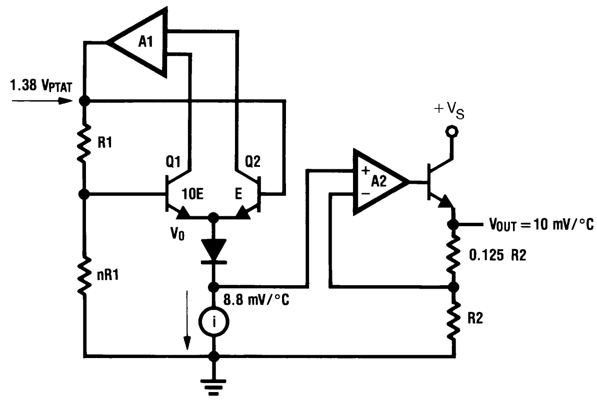


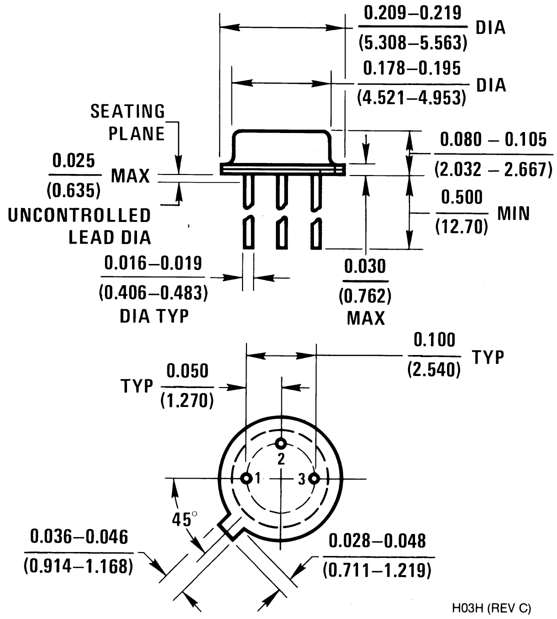
FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output (2˚C to +150˚C; 20 Hz to 1500 Hz)

Block Diagram

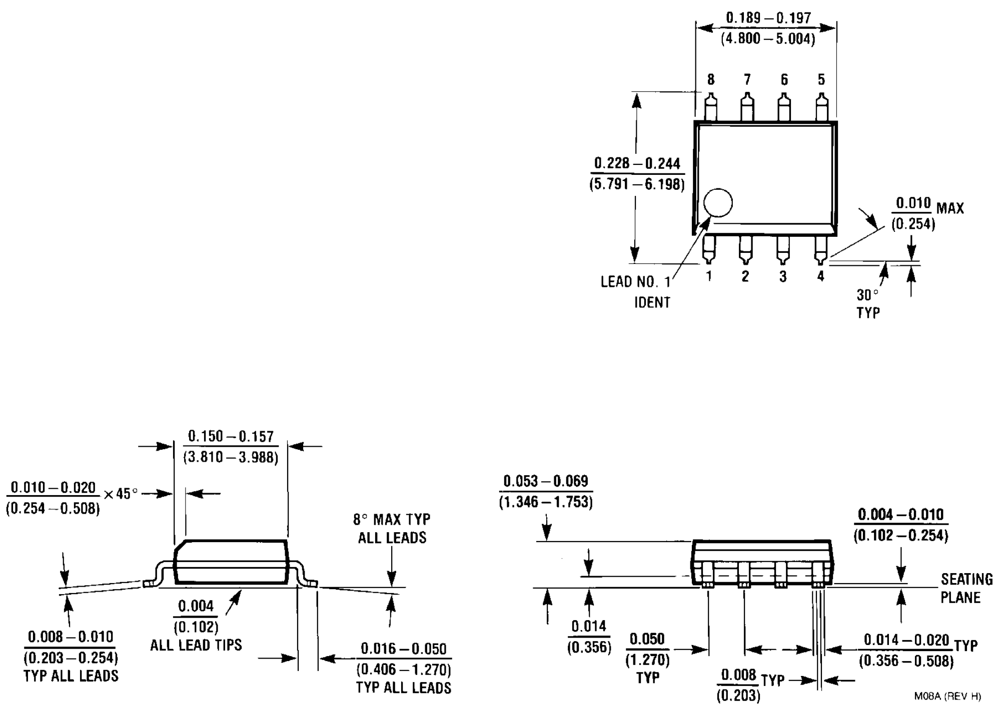


DS005516-23

Physical Dimensions inches (millimeters) unless otherwise noted

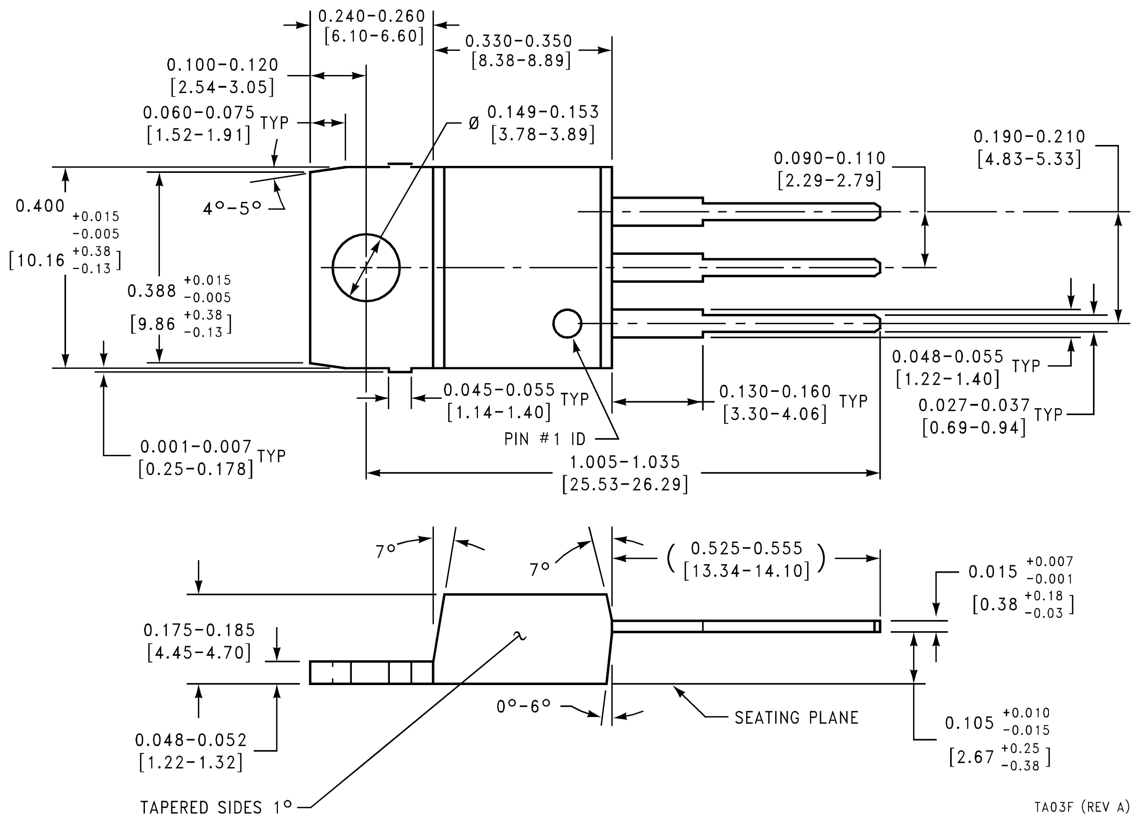


TO-46 Metal Can Package (H)
Order Number LM35H, LM35AH, LM35CH,
LM35CAH, or LM35DH
NS Package Number H03H



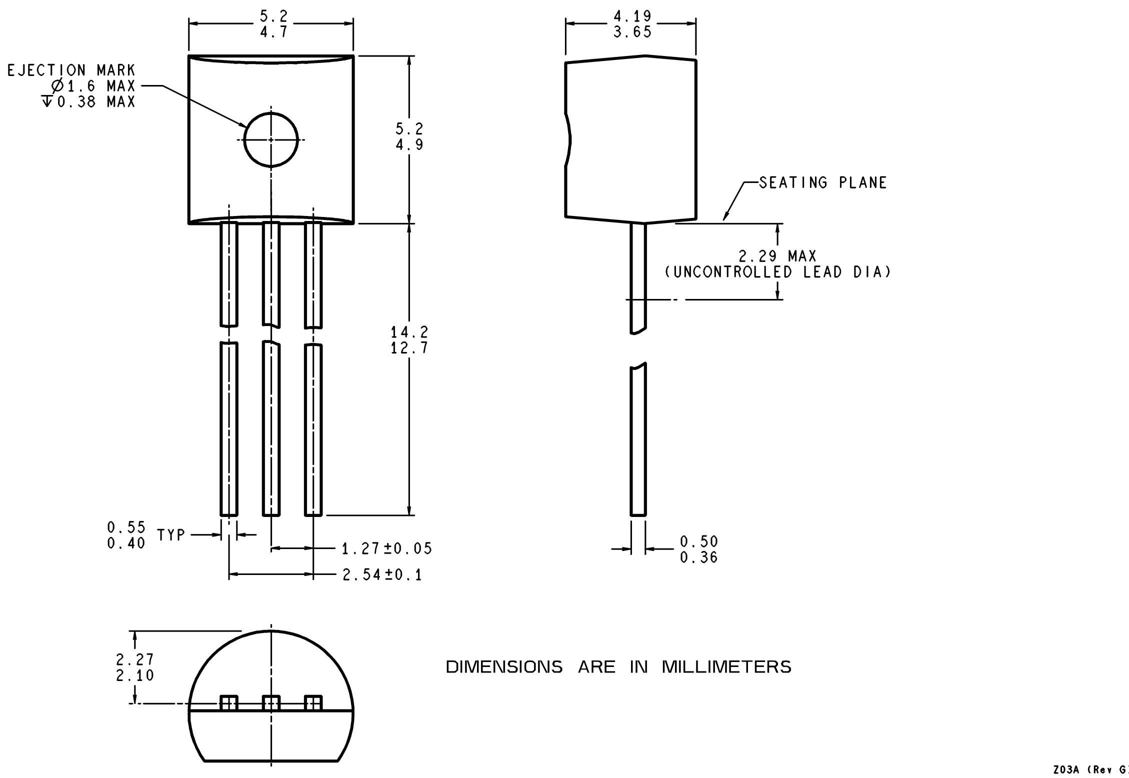
SO-8 Molded Small Outline Package (M)
Order Number LM35DM
NS Package Number M08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Power Package TO-220 (T)
Order Number LM35DT
NS Package Number TA03F

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



TO-92 Plastic Package (Z)
Order Number LM35CZ, LM35CAZ or LM35DZ
NS Package Number Z03A

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- Low forward voltage drop.
- High surge current capability.

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General Purpose Rectifiers (Glass Passivated)

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ T_A = 75°C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

Electrical Characteristics

T_A = 25°C unless otherwise noted

Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

Typical Characteristics

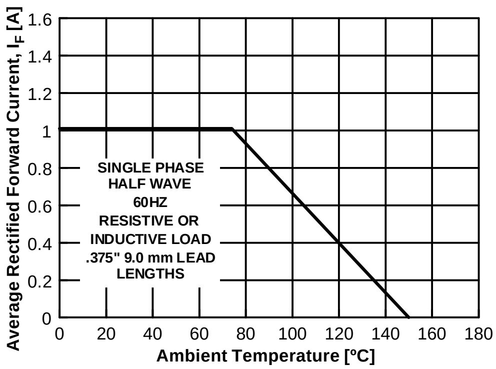

Figure 1. Forward Current Derating Curve

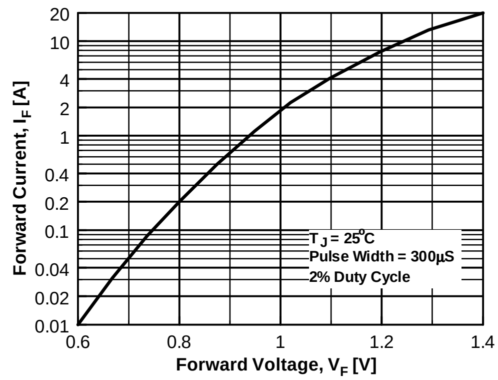

Figure 2. Forward Voltage Characteristics

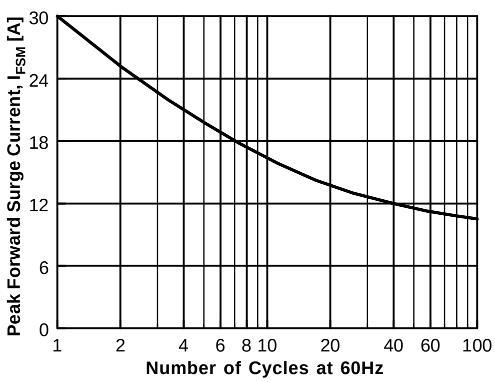

Figure 3. Non-Repetitive Surge Current

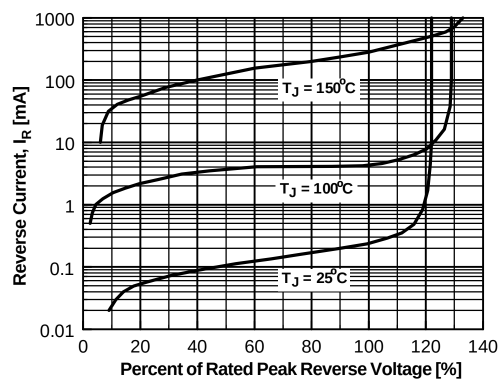

Figure 4. Reverse Current vs Reverse Voltage

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DenseTrench™	GTO™	Power247™	SuperSOT™-6	
DOME™	HiSeC™	PowerTrench®	SuperSOT™-8	
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FACT Quiet Series™	MICROWIRE™	SILENT SWITCHER®	UltraFET®	

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.

Rev. H4

HT12D/HT12F
2^{12} Series of Decoders

Features

- Operating voltage: 2.4V~12V
- Low power and high noise immunity CMOS technology
- Low standby current
- Capable of decoding 12 bits of information
- Binary address setting
- Received codes are checked 3 times
- Address/Data number combination
  - HT12D: 8 address bits and 4 data bits
  - HT12F: 12 address bits only
- Built-in oscillator needs only 5% resistor
- Valid transmission indicator
- Easy interface with an RF or an infrared transmission medium
- Minimal external components
- Pair with Holtek′s 2^{12} series of encoders
- 18-pin DIP, 20-pin SOP package

Applications

- Burglar alarm system
- Smoke and fire alarm system
- Garage door controllers
- Car door controllers
- Car alarm system
- Security system
- Cordless telephones
- Other remote control systems

General Description

The 2^{12} decoders are a series of CMOS LSIs for remote control system applications. They are paired with Holtek′s 2^{12} series of encoders (refer to the encoder/decoder cross reference table). For proper operation, a pair of encoder/decoder with the same number of addresses and data format should be chosen.

The decoders receive serial addresses and data from a programmed 2^{12} series of encoders that are transmitted by a carrier using an RF or an IR transmission medium. They compare the serial input data three times continuously with their local addresses. If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The VT pin also goes high to indicate a valid transmission.

The 2^{12} series of decoders are capable of decoding informations that consist of N bits of address and 12–N bits of data. Of this series, the HT12D is arranged to provide 8 address bits and 4 data bits, and HT12F is used to decode 12 bits of address information.

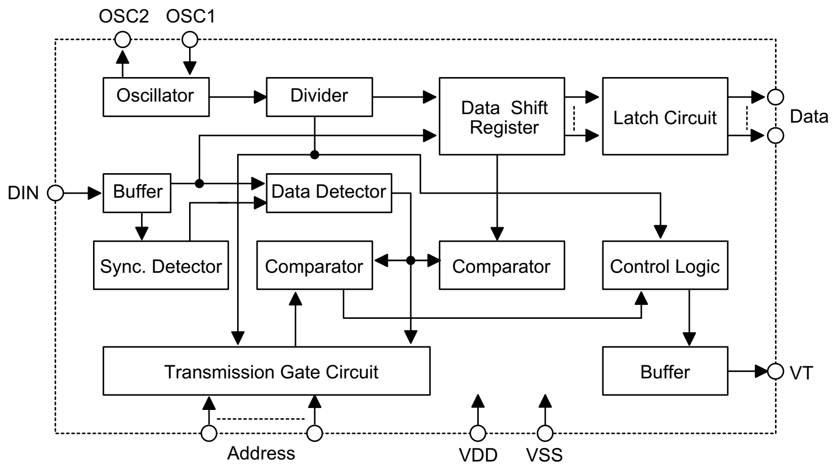
Selection Table

Function / Part No.	Address No.	Data		VT	Oscillator	Trigger	Package
		No.	Type				
HT12D	8	4	L	√	RC oscillator	DIN active ″Hi″	18DIP, 20SOP
HT12F	12	0	—	√	RC oscillator	DIN active ″Hi″	18DIP, 20SOP

Notes: Data type: L stands for latch type data output.

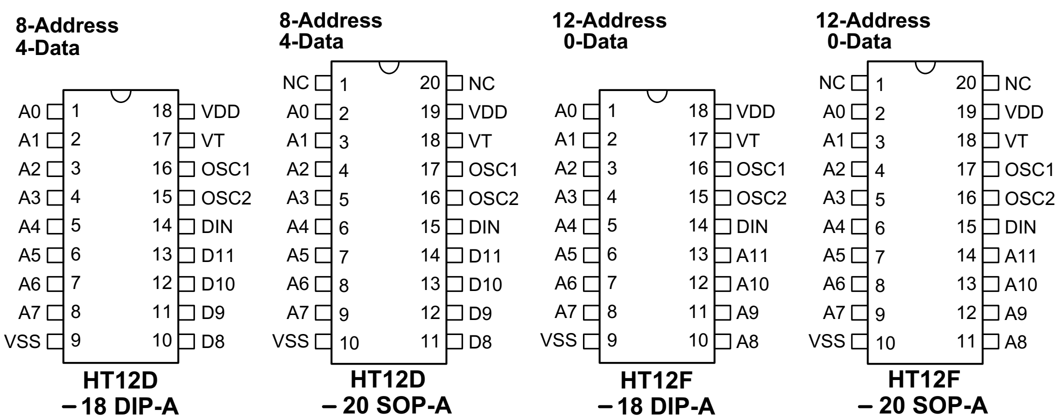
VT can be used as a momentary data output.

Block Diagram



Note: The address/data pins are available in various combinations (see the address/data table).

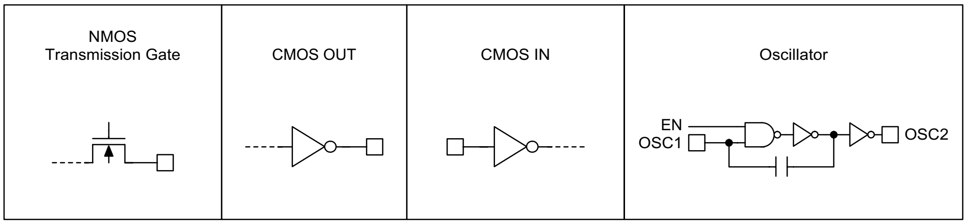
Pin Assignment



Pin Description

Pin Name	I/O	Internal Connection	Description
A0~A11 (HT12F)	I	NMOS Transmission Gate	Input pins for address A0~A11 setting These pins can be externally set to VSS or left open.
A0~A7 (HT12D)			Input pins for address A0~A7 setting These pins can be externally set to VSS or left open.
D8~D11 (HT12D)	O	CMOS OUT	Output data pins, power-on state is low.
DIN	I	CMOS IN	Serial data input pin
VT	O	CMOS OUT	Valid transmission, active high
OSC1	I	Oscillator	Oscillator input pin
OSC2	O	Oscillator	Oscillator output pin
VSS	—	—	Negative power supply, ground
VDD	—	—	Positive power supply

Approximate internal connection circuits



Absolute Maximum Ratings

Supply Voltage ....–0.3V to 13V

Input Voltage ....V_{SS}–0.3 to V_{DD}+0.3V

Storage Temperature ....–50°C to 125°C

Operating Temperature...........................–20°C to 75°C

Note: These are stress ratings only. Stresses exceeding the range specified under ″Absolute Maximum Ratings″ may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

Electrical Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	5	12	V
I_{STB}	Standby Current	5V	Oscillator stops	—	0.1	1	μA
		12V		—	2	4	μA
I_{DD}	Operating Current	5V	No load, f_{OSC}=150kHz	—	200	400	μA
I_O	Data Output Source Current (D8~D11)	5V	V_{OH}=4.5V	–1	–1.6	—	mA
	Data Output Sink Current (D8~D11)	5V	V_{OL}=0.5V	1	1.6	—	mA
I_{VT}	VT Output Source Current	5V	V_{OH}=4.5V	–1	–1.6	—	mA
	VT Output Sink Current		V_{OL}=0.5V	1	1.6	—	mA
V_{IH}	″H″ Input Voltage	5V	—	3.5	—	5	V
V_{IL}	″L″ Input Voltage	5V	—	0	—	1	V
f_{OSC}	Oscillator Frequency	5V	R_{OSC}=51kΩ	—	150	—	kHz

Functional Description

Operation

The 2^{12} series of decoders provides various combinations of addresses and data pins in different packages so as to pair with the 2^{12} series of encoders.

The decoders receive data that are transmitted by an encoder and interpret the first N bits of code period as addresses and the last 12–N bits as data, where N is the address code number. A signal on the DIN pin activates the oscillator which in turn decodes the incoming address and data. The decoders will then check the received address three times continuously. If the received address codes all match the contents of the decoder's local address, the 12–N bits of data are decoded to activate the output pins and the VT pin is set high to indicate a valid transmission. This will last unless the address code is incorrect or no signal is received.

The output of the VT pin is high only when the transmission is valid. Otherwise it is always low.

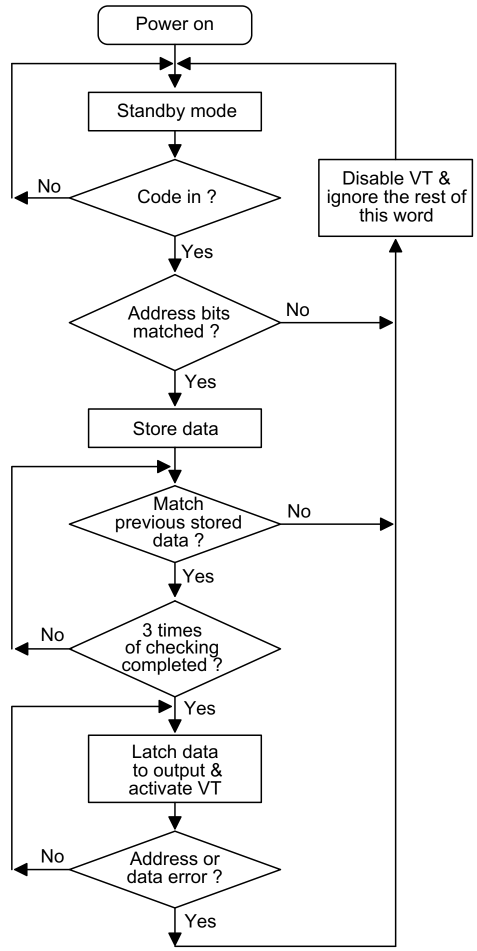
Output type

Of the 2^{12} series of decoders, the HT12F has no data output pin but its VT pin can be used as a momentary data output. The HT12D, on the other hand, provides 4 latch type data pins whose data remain unchanged until new data are received.

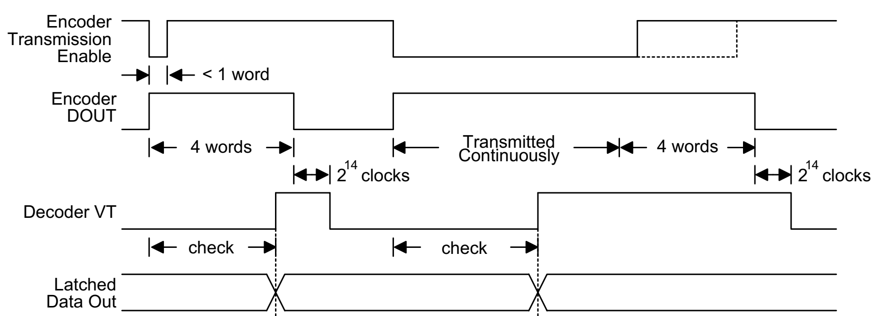
Part No.	Data Pins	Address Pins	Output Type	Operating Voltage
HT12D	4	8	Latch	2.4V~12V
HT12F	0	12	—	2.4V~12V

Flowchart

The oscillator is disabled in the standby state and activated when a logic "high" signal applies to the DIN pin. That is to say, the DIN should be kept low if there is no signal input.



Decoder timing



Encoder/Decoder cross reference table

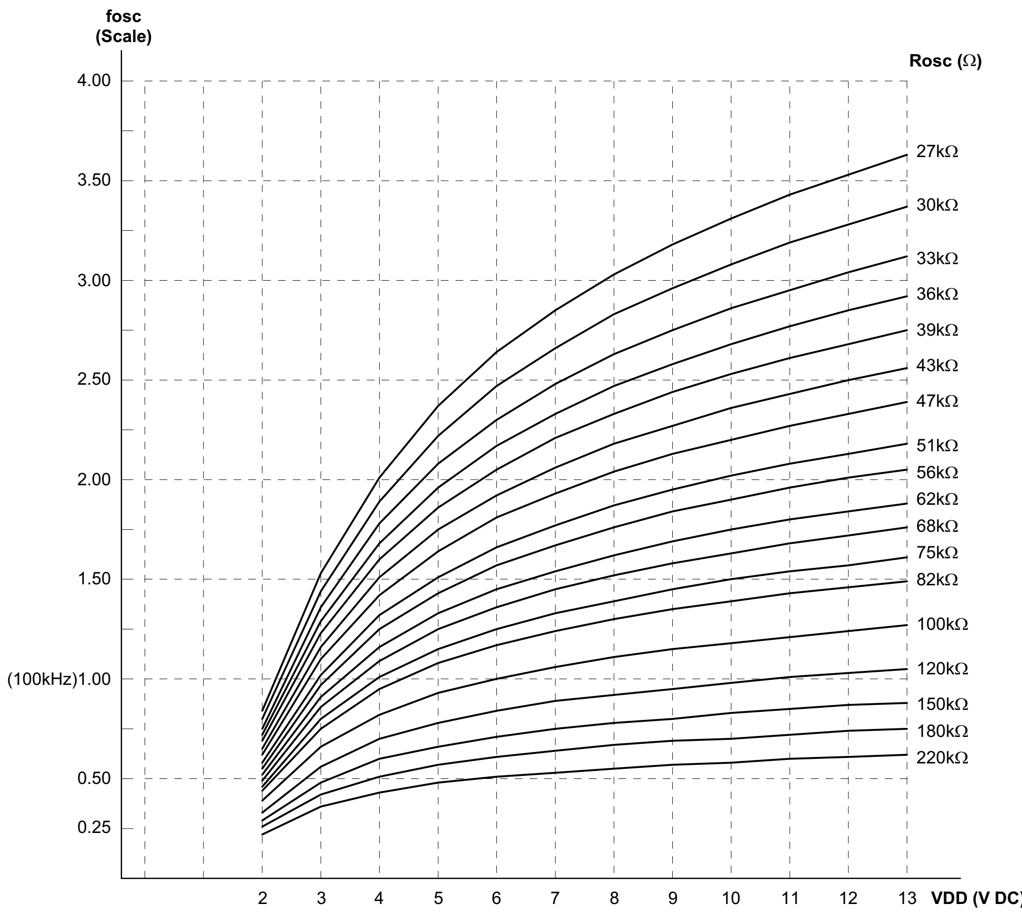
Decoders Part No.	Data Pins	Address Pins	VT	Pair Encoder	Package			
					Encoder		Decoder	
					DIP	SOP	DIP	SOP
HT12D	4	8	√	HT12A HT12E	18	20	18	20
HT12F	0	12	√	HT12A HT12E	18	20	18	20

Address/Data sequence

The following table provides address/data sequence for various models of the 2^{12} series of decoders.

Part No.	Address/Data Bits											
	0	1	2	3	4	5	6	7	8	9	10	11
HT12D	A0	A1	A2	A3	A4	A5	A6	A7	D8	D9	D10	D11
HT12F	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11

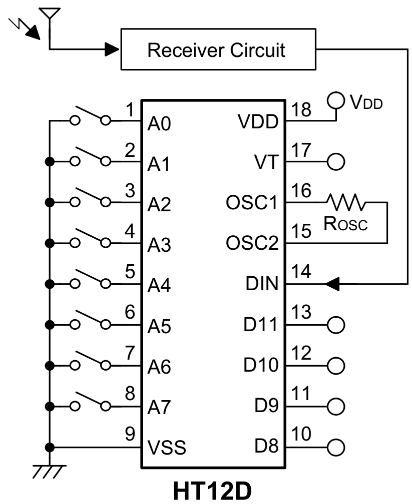
Oscillator frequency vs supply voltage

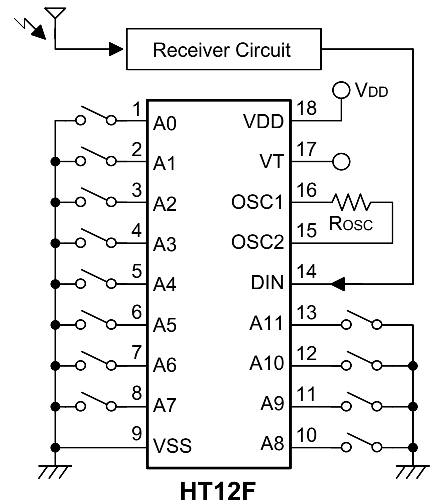


Note: The recommended oscillator frequency is f_{OSCD} (decoder) $\cong$ 50 f_{OSCE} (HT12E encoder)

$\cong \frac{1}{3} f_{OSCE}$ (HT12A encoder).

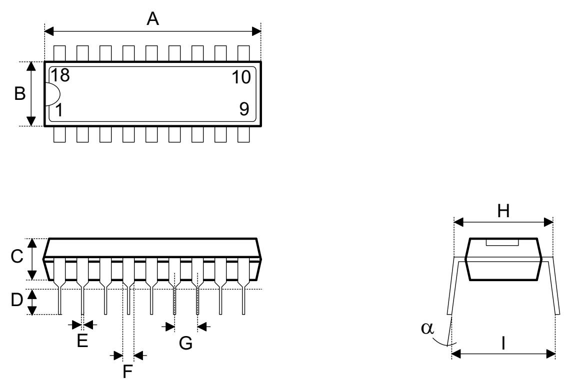
Application Circuits





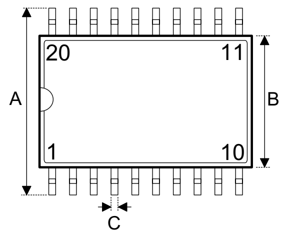
Package Information

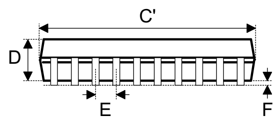
18-pin DIP (300mil) outline dimensions

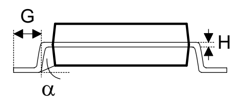


Symbol	Dimensions in mil		
	Min.	Nom.	Max.
A	895	—	915
B	240	—	260
C	125	—	135
D	125	—	145
E	16	—	20
F	50	—	70
G	—	100	—
H	295	—	315
I	335	—	375
α	0°	—	15°

20-pin SOP (300mil) outline dimensions



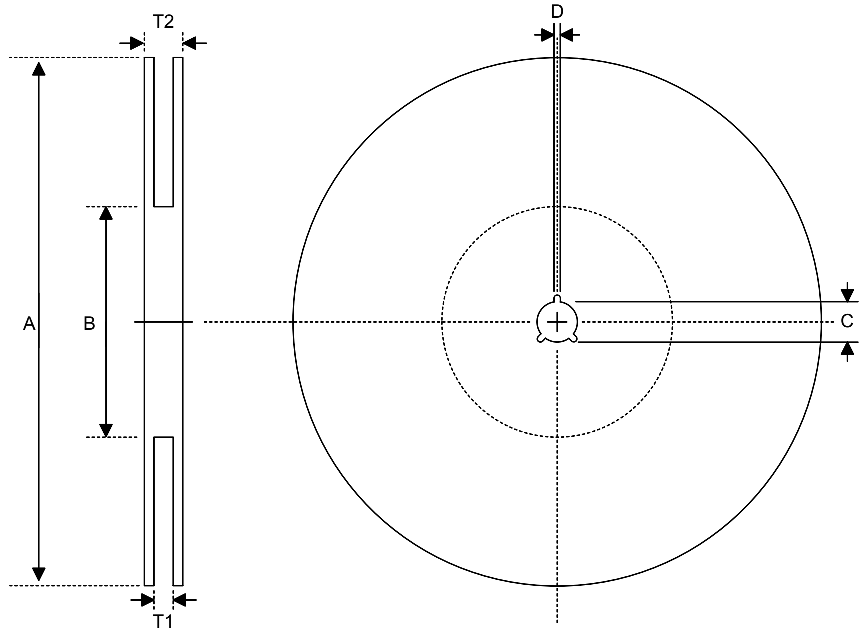




Symbol	Dimensions in mil		
	Min.	Nom.	Max.
A	394	—	419
B	290	—	300
C	14	—	20
C′	490	—	510
D	92	—	104
E	—	50	—
F	4	—	—
G	32	—	38
H	4	—	12
α	0°	—	10°

Product Tape and Reel Specifications

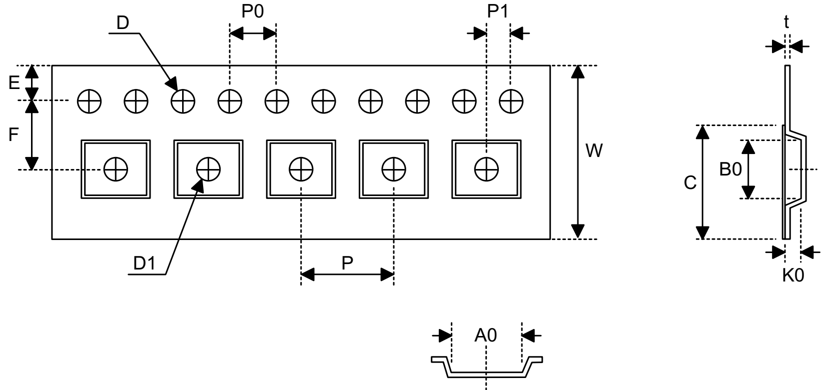
Reel dimensions



SOP 20W

Symbol	Description	Dimensions in mm
A	Reel Outer Diameter	330±1.0
B	Reel Inner Diameter	62±1.5
C	Spindle Hole Diameter	13.0+0.5 −0.2
D	Key Slit Width	2.0±0.5
T1	Space Between Flange	24.8+0.3 −0.2
T2	Reel Thickness	30.2±0.2

Carrier tape dimensions



SOP 20W

Symbol	Description	Dimensions in mm
W	Carrier Tape Width	24.0+0.3 −0.1
P	Cavity Pitch	12.0±0.1
E	Perforation Position	1.75±0.1
F	Cavity to Perforation (Width Direction)	11.5±0.1
D	Perforation Diameter	1.5+0.1
D1	Cavity Hole Diameter	1.5+0.25
P0	Perforation Pitch	4.0±0.1
P1	Cavity to Perforation (Length Direction)	2.0±0.1
A0	Cavity Length	10.8±0.1
B0	Cavity Width	13.3±0.1
K0	Cavity Depth	3.2±0.1
t	Carrier Tape Thickness	0.3±0.05
C	Cover Tape Width	21.3

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HT12A/HT12E
2^{12} Series of Encoders

Features

- Operating voltage
  - 2.4V~5V for the HT12A
  - 2.4V~12V for the HT12E
- Low power and high noise immunity CMOS technology
- Low standby current: 0.1μA (typ.) at V_{DD}=5V
- HT12A with a 38kHz carrier for infrared transmission medium
- Minimum transmission word
  - Four words for the HT12E
  - One word for the HT12A
- Built-in oscillator needs only 5% resistor
- Data code has positive polarity
- Minimal external components
- HT12A/E: 18-pin DIP/20-pin SOP package

Applications

- Burglar alarm system
- Smoke and fire alarm system
- Garage door controllers
- Car door controllers
- Car alarm system
- Security system
- Cordless telephones
- Other remote control systems

General Description

The 2^{12} encoders are a series of CMOS LSIs for remote control system applications. They are capable of encoding information which consists of N address bits and 12–N data bits. Each address/data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF or an infrared transmission medium upon receipt of a trigger signal. The capability to select a $\overline{TE}$ trigger on the HT12E or a DATA trigger on the HT12A further enhances the application flexibility of the 2^{12} series of encoders. The HT12A additionally provides a 38kHz carrier for infrared systems.

Selection Table

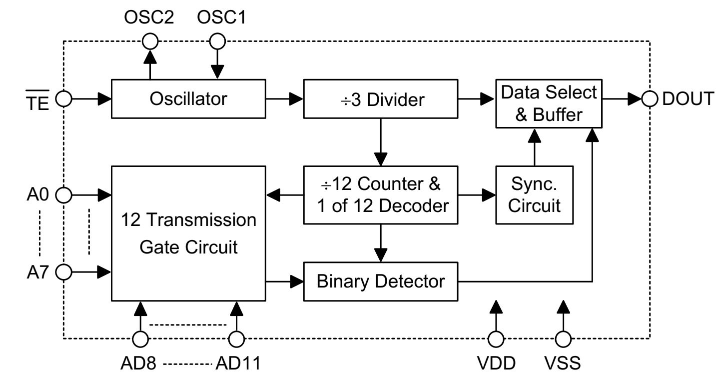
Function / Part No.	Address No.	Address/ Data No.	Data No.	Oscillator	Trigger	Package	Carrier Output	Negative Polarity
HT12A	8	0	4	455kHz resonator	D8~D11	18 DIP 20 SOP	38kHz	No
HT12E	8	4	0	RC oscillator	$\overline{TE}$	18 DIP 20 SOP	No	No

Note: Address/Data represents pins that can be address or data according to the decoder requirement.

Block Diagram

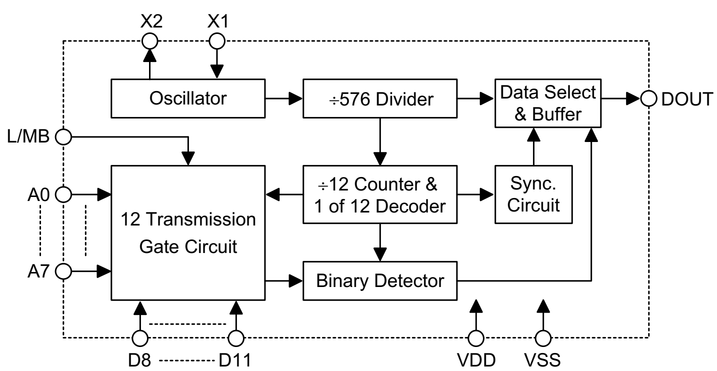
$\overline{TE}$ trigger

HT12E



DATA trigger

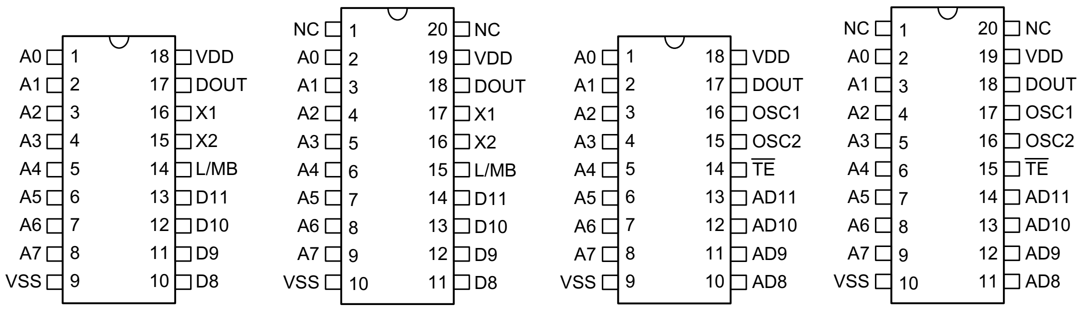
HT12A



Note: The address data pins are available in various combinations (refer to the address/data table).

Pin Assignment

8-Address 4-Data | 8-Address 4-Data | 8-Address 4-Address/Data | 8-Address 4-Address/Data



HT12A – 18 DIP | HT12A – 20 SOP | HT12E – 18 DIP | HT12E – 20 SOP

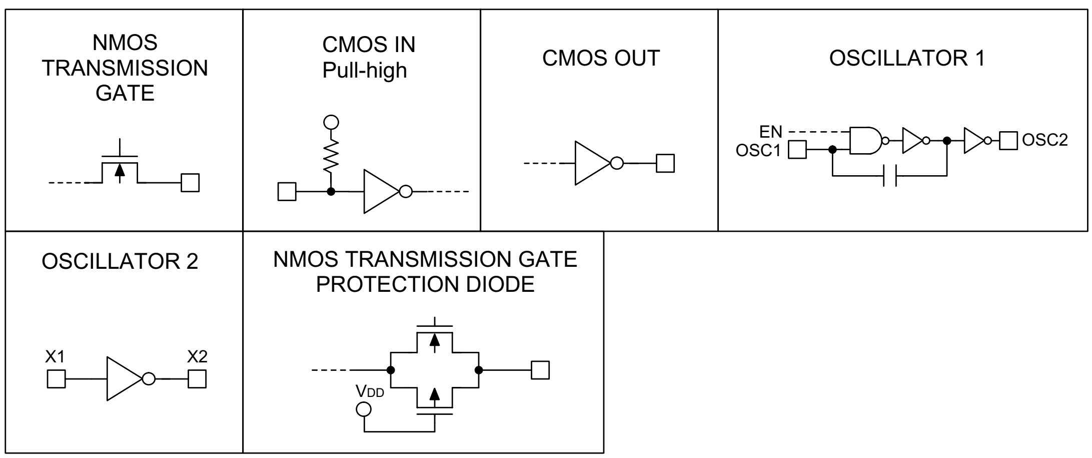
Pin Description

Pin Name	I/O	Internal Connection	Description
A0~A7	I	CMOS IN Pull-high (HT12A) / NMOS TRANSMISSION GATE PROTECTION DIODE (HT12E)	Input pins for address A0~A7 setting These pins can be externally set to VSS or left open
AD8~AD11	I	NMOS TRANSMISSION GATE PROTECTION DIODE (HT12E)	Input pins for address/data AD8~AD11 setting These pins can be externally set to VSS or left open
D8~D11	I	CMOS IN Pull-high	Input pins for data D8~D11 setting and transmission enable, active low These pins should be externally set to VSS or left open (see Note)
DOUT	O	CMOS OUT	Encoder data serial transmission output
L/MB	I	CMOS IN Pull-high	Latch/Momentary transmission format selection pin: Latch: Floating or VDD Momentary: VSS

Pin Name	I/O	Internal Connection	Description
$\overline{TE}$	I	CMOS IN Pull-high	Transmission enable, active low (see Note)
OSC1	I	OSCILLATOR 1	Oscillator input pin
OSC2	O	OSCILLATOR 1	Oscillator output pin
X1	I	OSCILLATOR 2	455kHz resonator oscillator input
X2	O	OSCILLATOR 2	455kHz resonator oscillator output
VSS	I	—	Negative power supply, grounds
VDD	I	—	Positive power supply

Note: D8~D11 are all data input and transmission enable pins of the HT12A.
$\overline{TE}$ is a transmission enable pin of the HT12E.

Approximate internal connections



Absolute Maximum Ratings

Supply Voltage (HT12A) ....–0.3V to 5.5V

Input Voltage....................V_{SS}–0.3 to V_{DD}+0.3V

Operating Temperature...............–20°C to 75°C

Supply Voltage (HT12E) ....–0.3V to 13V

Storage Temperature.................–50°C to 125°C

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

Electrical Characteristics

HT12A

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	3	5	V
I_{STB}	Standby Current	3V	Oscillator stops	—	0.1	1	μA
		5V		—	0.1	1	μA
I_{DD}	Operating Current	3V	No load f_{OSC}=455kHz	—	200	400	μA
		5V		—	400	800	μA
I_{DOUT}	Output Drive Current	5V	$V_{OH}=0.9V_{DD}$ (Source)	–1	–1.6	—	mA
			$V_{OL}=0.1V_{DD}$ (Sink)	2	3.2	—	mA
V_{IH}	"H" Input Voltage	—	—	$0.8V_{DD}$	—	V_{DD}	V
V_{IL}	"L" Input Voltage	—	—	0	—	$0.2V_{DD}$	V
R_{DATA}	D8~D11 Pull-high Resistance	5V	V_{DATA}=0V	—	150	300	kΩ

HT12E

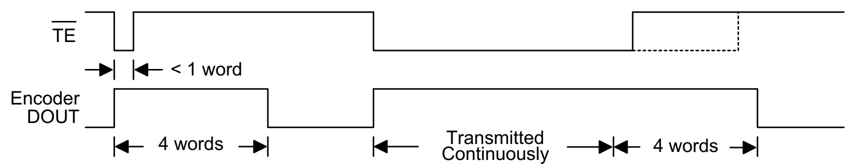
Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	2.4	5	12	V
I_{STB}	Standby Current	3V	Oscillator stops	—	0.1	1	μA
		12V		—	2	4	μA
I_{DD}	Operating Current	3V	No load f_{OSC}=3kHz	—	40	80	μA
		12V		—	150	300	μA
I_{DOUT}	Output Drive Current	5V	$V_{OH}=0.9V_{DD}$ (Source)	–1	–1.6	—	mA
			$V_{OL}=0.1V_{DD}$ (Sink)	1	1.6	—	mA
V_{IH}	"H" Input Voltage	—	—	$0.8V_{DD}$	—	V_{DD}	V
V_{IL}	"L" Input Voltage	—	—	0	—	$0.2V_{DD}$	V
f_{OSC}	Oscillator Frequency	5V	R_{OSC}=1.1MΩ	—	3	—	kHz
$R_{\overline{TE}}$	$\overline{TE}$ Pull-high Resistance	5V	$V_{\overline{TE}}$=0V	—	1.5	3	MΩ

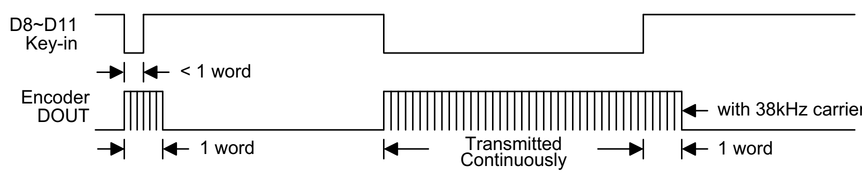
Functional Description

Operation

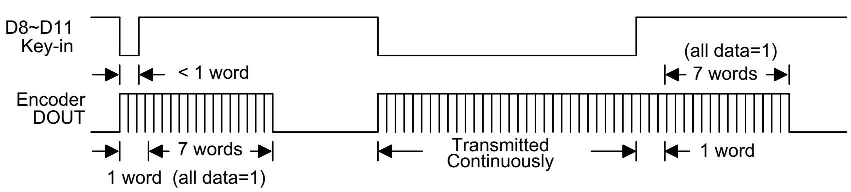
The 2^{12} series of encoders begin a 4-word transmission cycle upon receipt of a transmission enable ($\overline{TE}$ for the HT12E or D8~D11 for the HT12A, active low). This cycle will repeat itself as long as the transmission enable ($\overline{TE}$ or D8~D11) is held low. Once the transmission enable returns high the encoder output completes its final cycle and then stops as shown below.



Transmission timing for the HT12E



Transmission timing for the HT12A (L/MB=Floating or VDD)

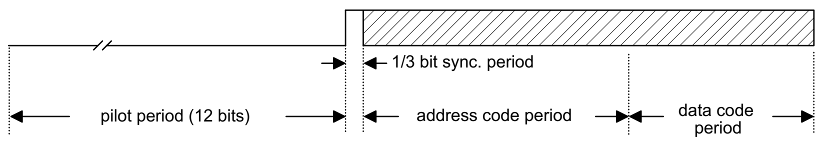


Transmission timing for the HT12A (L/MB=VSS)

Information word

If L/MB=1 the device is in the latch mode (for use with the latch type of data decoders). When the transmission enable is removed during a transmission, the DOUT pin outputs a complete word and then stops. On the other hand, if L/MB=0 the device is in the momentary mode (for use with the momentary type of data decoders). When the transmission enable is removed during a transmission, the DOUT outputs a complete word and then adds 7 words all with the "1" data code.

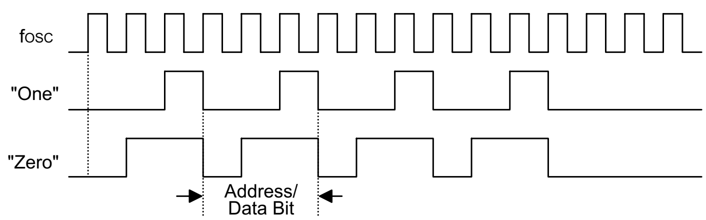
An information word consists of 4 periods as illustrated below.



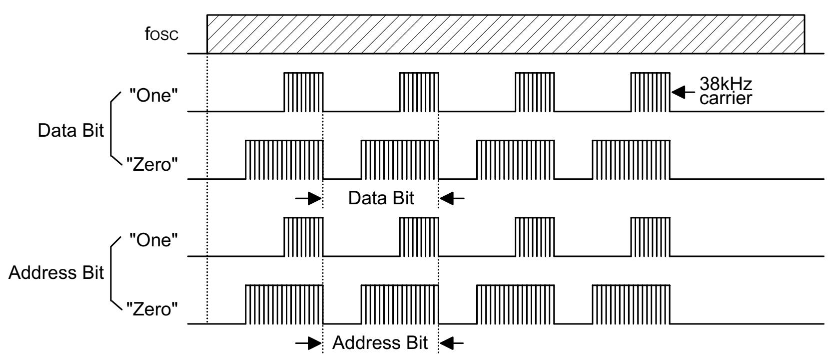
Composition of information

Address/data waveform

Each programmable address/data pin can be externally set to one of the following two logic states as shown below.



Address/Data bit waveform for the HT12E



Address/Data bit waveform for the HT12A

The address/data bits of the HT12A are transmitted with a 38kHz carrier for infrared remote controller flexibility.

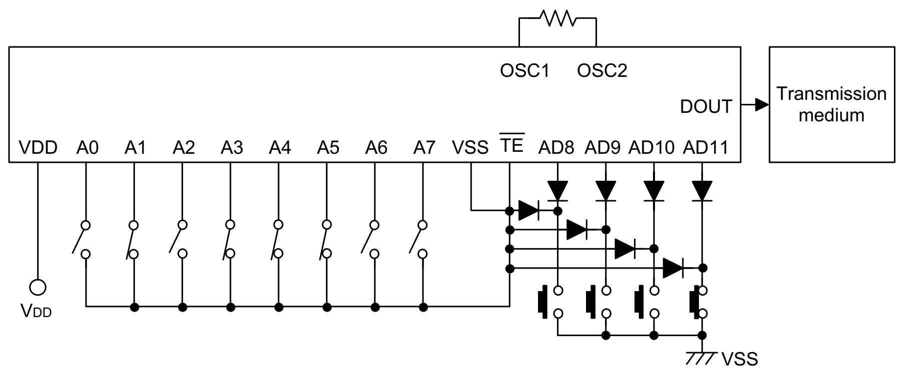
Address/data programming (preset)

The status of each address/data pin can be individually pre-set to logic "high" or "low". If a transmission-enable signal is applied, the encoder scans and transmits the status of the 12 bits of address/data serially in the order A0 to AD11 for the HT12E encoder and A0 to D11 for the HT12A encoder.

During information transmission these bits are transmitted with a preceding synchronization bit. If the trigger signal is not applied, the chip enters the standby mode and consumes a reduced current of less than 1μA for a supply voltage of 5V.

Usual applications preset the address pins with individual security codes using DIP switches or PCB wiring, while the data is selected by push buttons or electronic switches.

The following figure shows an application using the HT12E:



The transmitted information is as shown:

Pilot & Sync.	A0	A1	A2	A3	A4	A5	A6	A7	AD8	AD9	AD10	AD11
	1	0	1	0	0	0	1	1	1	1	1	0

Address/Data sequence

The following provides the address/data sequence table for various models of the 2^{12} series of encoders. The correct device should be selected according to the individual address and data requirements.

Part No.	Address/Data Bits											
	0	1	2	3	4	5	6	7	8	9	10	11
HT12A	A0	A1	A2	A3	A4	A5	A6	A7	D8	D9	D10	D11
HT12E	A0	A1	A2	A3	A4	A5	A6	A7	AD8	AD9	AD10	AD11

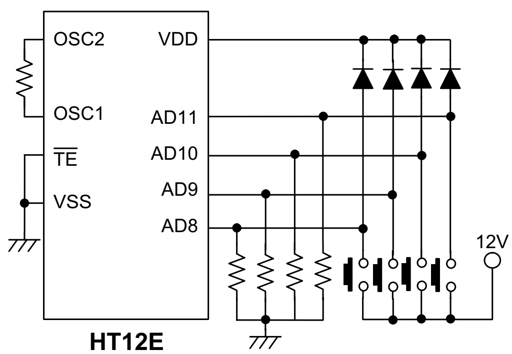
Transmission enable

For the HT12E encoders, transmission is enabled by applying a low signal to the $\overline{TE}$ pin. For the HT12A encoders, transmission is enabled by applying a low signal to one of the data pins D8~D11.

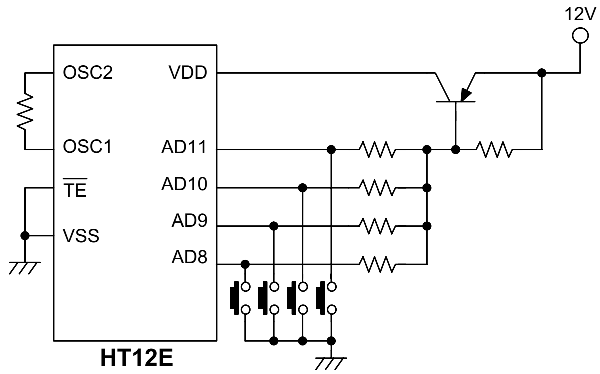
Two erroneous HT12E application circuits

The HT12E must follow closely the application circuits provided by Holtek (see the "Application circuits").

- Error: AD8~AD11 pins input voltage > V_{DD}+0.3V

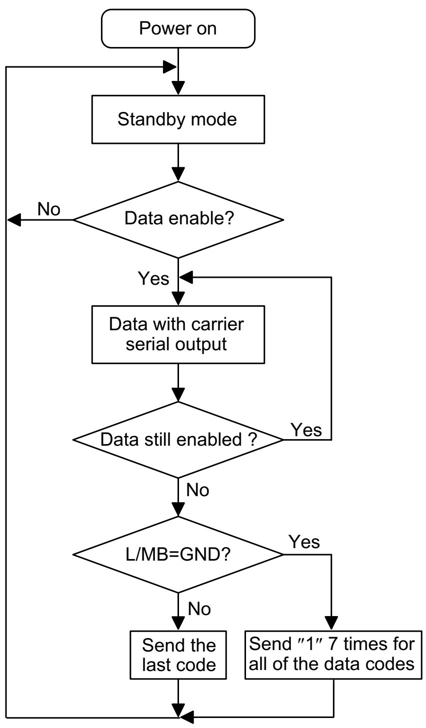


• Error: The IC's power source is activated by pins AD8~AD11

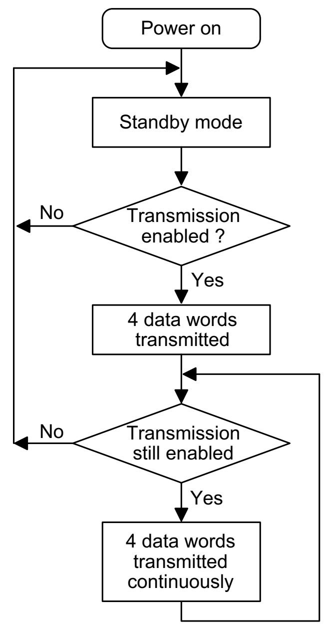


Flowchart

• HT12A

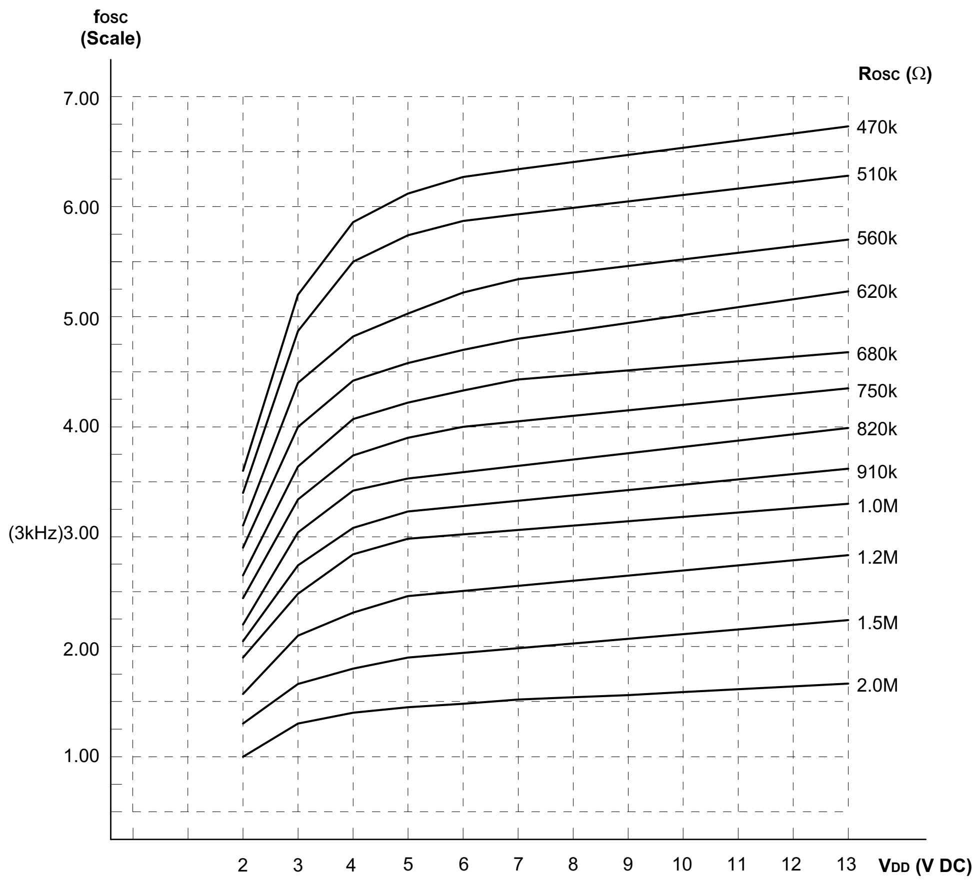


• HT12E



Note: D8~D11 are transmission enables of the HT12A.
$\overline{\text{TE}}$ is the transmission enable of the HT12E.

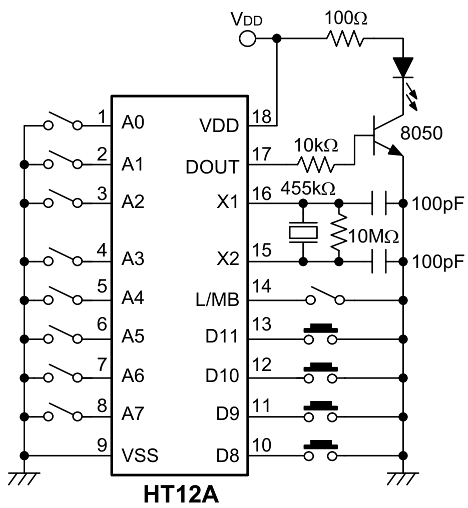
Oscillator frequency vs supply voltage

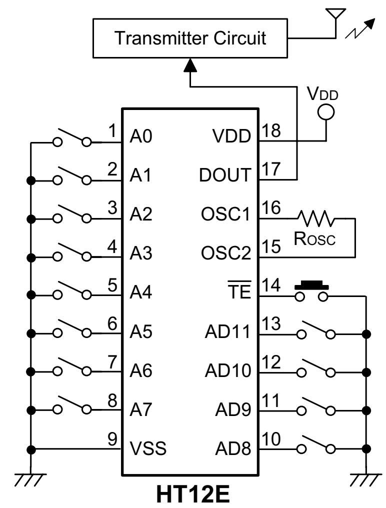


The recommended oscillator frequency is f_{OSCD} (decoder) $\cong 50\ f_{OSCE}$ (HT12E encoder)

$\cong \frac{1}{3}\ f_{OSCE}$ (HT12A encoder)

Application Circuits





Note: Typical infrared diode: EL-1L2 (KODENSHI CORP.)

Typical RF transmitter: JR-220 (JUWA CORP.)

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DATA SHEET

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2N2221A
2N2222A

NPN SILICON TRANSISTOR

JEDEC TO-18 CASE

DESCRIPTION:

The CENTRAL SEMICONDUCTOR 2N2221A, 2N2222A types are Silicon NPN Planar Epitaxial Transistors designed for small signal general purpose and switching applications.

MAXIMUM RATINGS: (T_A=25°C)

	SYMBOL		UNITS
Collector-Base Voltage	V_{CBO}	75	V
Collector-Emitter Voltage	V_{CEO}	40	V
Emitter-Base Voltage	V_{EBO}	6.0	V
Collector Current	I_C	800	mA
Power Dissipation	P_D	400	mW
Power Dissipation (T_C=25°C)	P_D	1.2	W
Operating and Storage Junction Temperature	T_J,T_{stg}	-65 to +200	°C
Thermal Resistance	Θ_{JA}	438	°C/W
Thermal Resistance	Θ_{JC}	146	°C/W

ELECTRICAL CHARACTERISTICS: (T_A=25°C unless otherwise noted)

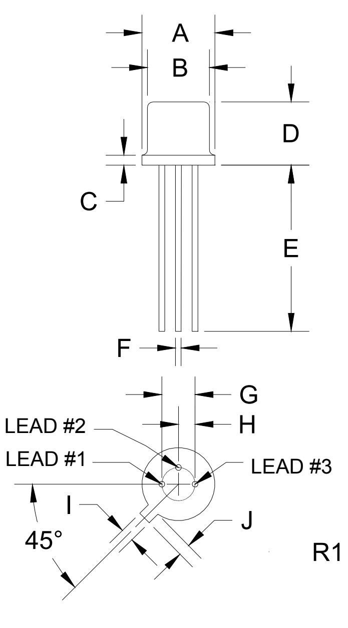
		2N2221A		2N2222A		
SYMBOL	TEST CONDITIONS	MIN	MAX	MIN	MAX	UNITS
I_{CBO}	V_{CB}=60V		10		10	nA
I_{CBO}	V_{CB}=60V, T_A=150°C		10		10	μA
I_{EBO}	V_{EB}=3.0V		10		10	nA
I_{CEV}	V_{CE}=60V, V_{EB}=3.0V		10		10	nA
BV_{CBO}	I_C=10μA	75		75		V
BV_{CEO}	I_C=10mA	40		40		V
BV_{EBO}	I_E=10μA	6.0		6.0		V
$V_{CE(SAT)}$	I_C=150mA, I_B=15mA		0.3		0.3	V
$V_{CE(SAT)}$	I_C=500mA, I_B=50mA		1.0		1.0	V
$V_{BE(SAT)}$	I_C=150mA, I_B=15mA	0.6	1.2	0.6	1.2	V
$V_{BE(SAT)}$	I_C=500mA, I_B=50mA		2.0		2.0	V
h_{FE}	V_{CE}=10V, I_C=0.1mA	20		35		
h_{FE}	V_{CE}=10V, I_C=1.0mA	25		50		
h_{FE}	V_{CE}=10V, I_C=10mA	35		75		
h_{FE}	V_{CE}=10V, I_C=10mA, T_A=-55°C	15		35		
h_{FE}	V_{CE}=10V, I_C=150mA	40	120	100	300	
h_{FE}	V_{CE}=1.0V, I_C=150mA	20		50		
h_{FE}	V_{CE}=10V, I_C=500mA	25		40		

(Continued)

ELECTRICAL CHARACTERISTICS: Continued

SYMBOL	TEST CONDITIONS	2N2221A MIN	2N2221A MAX	2N2222A MIN	2N2222A MAX	UNITS
f_T	V_{CE}=20V, I_C=20mA, f=100MHz	250		300		MHz
C_{ob}	V_{CB}=10V, I_E=0, f=100kHz		8.0		8.0	pF
C_{ib}	V_{EB}=0.5V, I_C=0, f=100kHz		25		25	pF
h_{ie}	V_{CE}=10V, I_C=1.0mA, f=1.0kHz	1.0	3.5	2.0	8.0	kΩ
h_{ie}	V_{CE}=10V, I_C=10mA, f=1.0kHz	0.2	1.0	0.25	1.25	kΩ
h_{re}	V_{CE}=10V, I_C=1.0mA, f=1.0kHz		5.0		8.0	$x10^{-4}$
h_{re}	V_{CE}=10V, I_C=10mA, f=1.0kHz		2.5		4.0	$x10^{-4}$
h_{fe}	V_{CE}=10V, I_C=1.0mA, f=1.0kHz	30	150	50	300	
h_{fe}	V_{CE}=10V, I_C=10mA, f=1.0kHz	50	300	75	375	
h_{oe}	V_{CE}=10V, I_C=1.0mA, f=1.0kHz	3.0	15	5.0	35	μmhos
h_{oe}	V_{CE}=10V, I_C=10mA, f=1.0kHz	10	100	25	200	μmhos
$rb'C_c$	V_{CB}=10V, I_E=20mA, f=31.8MHz		150		150	ps
NF	V_{CE}=10V, I_C=100μA, R_S=1.0kΩ, f=1.0kHz				4.0	dB
t_d	V_{CC}=30V, V_{BE}=0.5, I_C=150mA, I_{B1}=15mA		10		10	ns
t_r	V_{CC}=30V, V_{BE}=0.5, I_C=150mA, I_{B1}=15mA		25		25	ns
t_s	V_{CC}=30V, I_C=150mA, I_{B1}=I_{B2}=15mA		225		225	ns
t_f	V_{CC}=30V, I_C=150mA, I_{B1}=I_{B2}=15mA		60		60	ns

TO-18 PACKAGE - MECHANICAL OUTLINE



DIMENSIONS				
	INCHES		MILLIMETERS	
SYMBOL	MIN	MAX	MIN	MAX
A (DIA)	0.209	0.230	5.31	5.84
B (DIA)	0.178	0.195	4.52	4.95
C	-	0.030	-	0.76
D	0.170	0.210	4.32	5.33
E	0.500	-	12.70	-
F (DIA)	0.016	0.019	0.41	0.48
G (DIA)	0.100		2.54	
H	0.050		1.27	
I	0.036	0.046	0.91	1.17
J	0.028	0.048	0.71	1.22

TO-18 (REV: R1)

LEAD CODE:

1) Emitter
2) Base
3) Collector

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