November 14, 2010

School of Engineering Science

Simon Fraser University
8888 University Drive
Burnaby, BC
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Re: *ENSC 440 Design Specifications for Clean Marine's Shoreline Oil Detection System*

To Whom It May Concern;

The following documentation outlines Clean Marine Systems ENSC 440 project design specification for a shoreline oil detection system. The project has been chosen to combat one of the world's most horrific man-made disasters, ocean oil spills, aimed at detecting the extent of oil spill coverage, providing real time alerts to designated authorities describing the effected zones.

This design specification will detail Clean Marine Systems complete project parameters, breaking discussions into each component of design. The project is currently in the development stage of production, where we are putting the respected components together to begin extensive product testing.

The young and dedicated team of engineers at Clean Marine Systems will be each taking responsibility for their own area of expertise in the development cycle of this project, but due to the complexity of the project, many crossovers will occur, allowing full team participation.

Sincerely,

James Kennedy

Chief Executive Officer
Clean Marine Systems

Enclosure: *Clean Marine Systems Shoreline Oil Detection System Project Proposal*

CLEAN MARINE

Design Specification

Shoreline Oil Detection System

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Fall 2010

Executive Summary

Ocean oil exploration continues forward into the future, drilling holes in new geological regions around the world, which ensures the need for proper and effective monitoring of such oil exploration projects. Given the extremities of oil exploration in the ocean, Clean Marine is developing a Shoreline Oil Detection System that will be strategically placed along the shoreline, and other such delicate marine ecosystems, continuously monitoring the oceans water to detect any contamination from oil. In the event that oil is detected, the Shoreline Oil Detection System will alert the concerned parties, ensuring that the most effective disaster recovery is implemented, saving marine life, time, and money.

The development stage of this project will flow into two stages of development.

The first stage will be designing the detailed specifications described in this document, so that they are independently fully working prototypes. This will be the most creative and important stage of the development cycle for each of the functional specifications will be taken into consideration.

When this stage is completed, full system integration will involve combining all the separate 'parts' of the project into a single Shoreline Oil Detection System that can be displayed for presentation and taken to the ocean for prototype testing and system debugging.

This document outlines the design specifications of Clean Marine's Shoreline Oil Detection System.

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Introduction

Clean Marine Systems' Shoreline Oil Detection System is an oil detection unit that sits floating on the surface of the ocean, surrounding ocean habitats that require special care and attention to guard against disastrous ecological contamination. The Shoreline Oil Detection System will detect the content of oil in the oceans water with two electrodes that will be strategically placed along the water surface. A microprocessor will then decode the analog reading from the two electrodes and based on a comparison algorithm implemented in the microprocessor it will determine whether the level of contamination is above or below the 'critical level'. Upon critical level detection, the microprocessor will transmit an alert via cellular network to an operator.

Scope

This document will outline the design specification for Clean Marine's Shoreline Oil Detection System. It will outline each respected area of development, stating specifications for the system that will be incorporated at this time in the lifecycle.

It also feels relevant to mention that at the current stage of development, unseen complications can, and most likely will, occur. In the unfortunate event that this should occur, certain design specification changes may be made in order to better suit the needs of the project.

Intended Audience

This document is intended to be used as a guide for the team of engineers at Clean Marine. It will be referenced for exact specifications of the products and components being used, which will aid the team when incorporating the product into one unit. It is also intended to provide potential funders or donators the opportunity to see the exact detail of the project they will be potentially funding.

System Specification

Overview

The Shoreline Oil Detection System consists of a microprocessor which we are using to read/sense signals from an analog sensing circuit, interprets them, and then transmits necessary information based on that interpretation via a cellular wireless modem. It also will monitor the battery charge level, ensuring over charging doesn't occur. The system's physical user interface includes a reset button that allows the microprocessor to recalibrate itself based on the water that the device has been placed in. The electronics are enclosed in a waterproof container which, along with a solar array, is mounted to a floating frame.

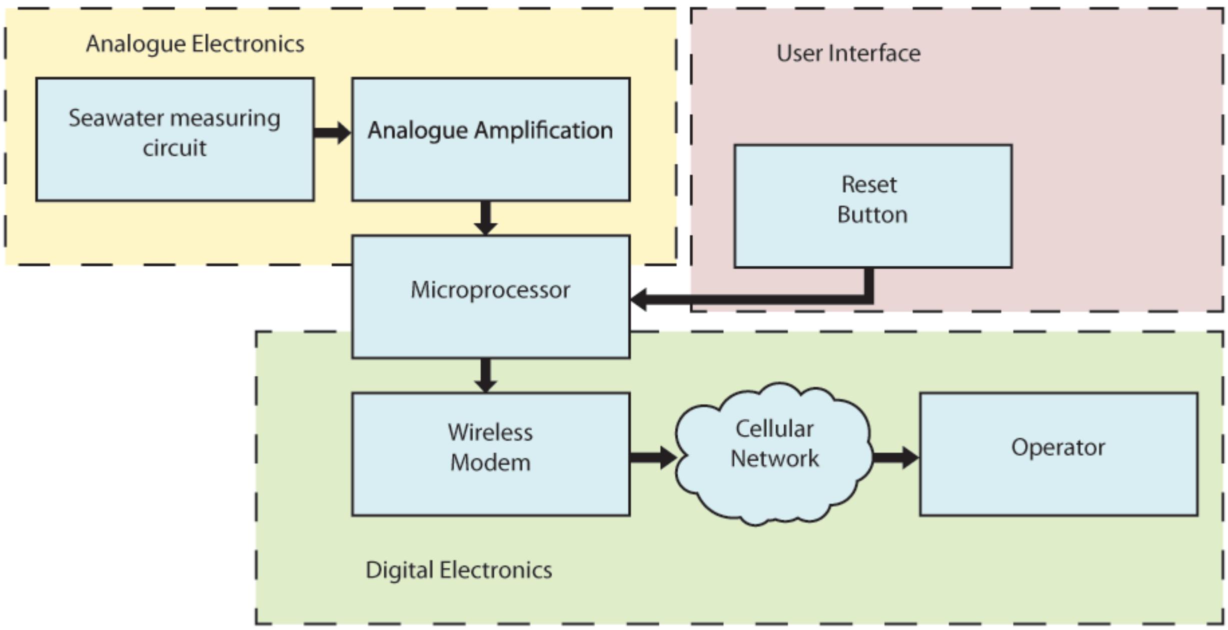


Figure 1 Electronics Block Diagram

Physical Design

Frame

The unit's frame shall be held together by PVC tubing, with 4 elbow, waterproof joints. Due to the nature of the joints, being watertight, the Shoreline Oil Detection System will float on the surface of the water.

The casing will sit upon a solid steel crosshatching to enable the water pass directly through without a the possibility of a puddle forming, and also allow for easy attach points for various parts to connect to.

The solar panels shall be placed just inside of the case, so no extra framing will be required here.

Figure 2 PVC Tubing Frame

Anchor

In the event that the unit will not be attached to an already existing buoy, the unit shall be anchored to a standard Navy Anchor, no special weight shall be needed since the device will be very light itself. See image below of a Navy Anchor.

Figure 3 Navy Anchor (Navy Anchor)[4]

Anchor Rope (mooring line)

The frame shall be either anchored to an existing buoy, or a buoy that will be available for purchase with the product. This shall be accomplished with standard marine rope, held on to both ends with the popular Gallows Knot [1], in combination with the Blood Bight Dropper[2]. Both knots are shown below.

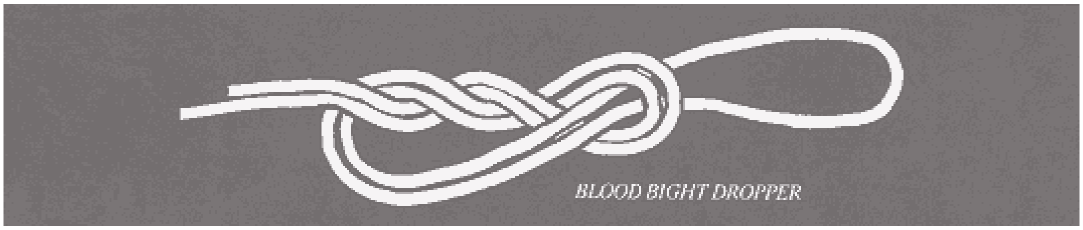


Figure 4 Blood Bight Dropper [2]

Figure 5 Gallows Knot [3]

These knots, one as the main holding support cable, the other as the backup, will provide a double support system for making sure they hold in place the valuable equipment, preventing a loss from a bad anchor.

Buoy

The buoy will be a standard marine buoy, we have chosen the standard 13" buoy with an AnchorLift to be used, which is big enough to allow the Shoreline Oil Detection System to be easily seen from a distance, shown below.

Figure 6 AnchorLift Buoy [5]

Casing

The unit will be enclosed in a water tight Pelican Case (see figure below) to ensure that the electronics stay dry and not affected by the harsh ocean environment. Since the unit does require two leads (wires) that attach to the electrodes, a small hole will be drilled in the bottom of the case to allow the wires to get out of the unit. This small hole will be closed with rubber cement to ensure that the unit stays watertight through all conditions.

Figure 7 Pelican Case [6]

Electrical Design

The electrical system consists of four subsystems: Conductivity Sensing Circuit, Power Supply, Data Processing Unit, and Data Transmission Unit, which will each be discussed separately.

Conductivity Sensing Circuit

To monitor the continuous changes in the conductivity of seawater, we have designed a constant current source to provide a test current to our sensing electrodes. The circuit used to achieve this is a Howland current pump that yields a constant output current equal to 150 μA for an input DC voltage equal to 1.5 V. The output current is applied to the load, which in our case is the seawater. The equations below show the relationship between the resistor values and the value for the output current I_o. The expression for the output impedance is:

$$R_0 = \frac{R_2}{\frac{R_2}{R_1} - \frac{R_4}{R_3}}$$

For an output impedance Ro to be equal to infinity, the denominator needs to be zero, which requires R1=R3 and R2=R4, which means the four resistors will form a *balanced bridge*:

$$\frac{R_4}{R_3} = \frac{R_2}{R_1}$$

The value of R2 was selected to be sufficiently smaller than R1 [9].With Ro = infinity, the output current becomes independent of Voltage across the load:

$$i_o = \frac{v_{in}}{R_1}$$

The voltage compliance becomes:

$$|v_l| = \frac{R_1}{R_1 + R_2} v_{sat}$$

Which both solve to give the spefications:

I_o	**150 μA**
V_{in}	**1.5 V**
R_1	**10 KΩ**
$V_{x(max)}$	**4.56V**
V_{sat}	**5V**
$V_{L(oil)}$	**4.56V**

Table 1 Supplied and Measured Values for Howland Circuit

V_x will be recorded when oil is detected on the sea surface. The measured resistance of the crude oil is infinity resulting in $V_{L(oil)}$ shown above.

Below is a schematic of our Howland constant current source used in the system:

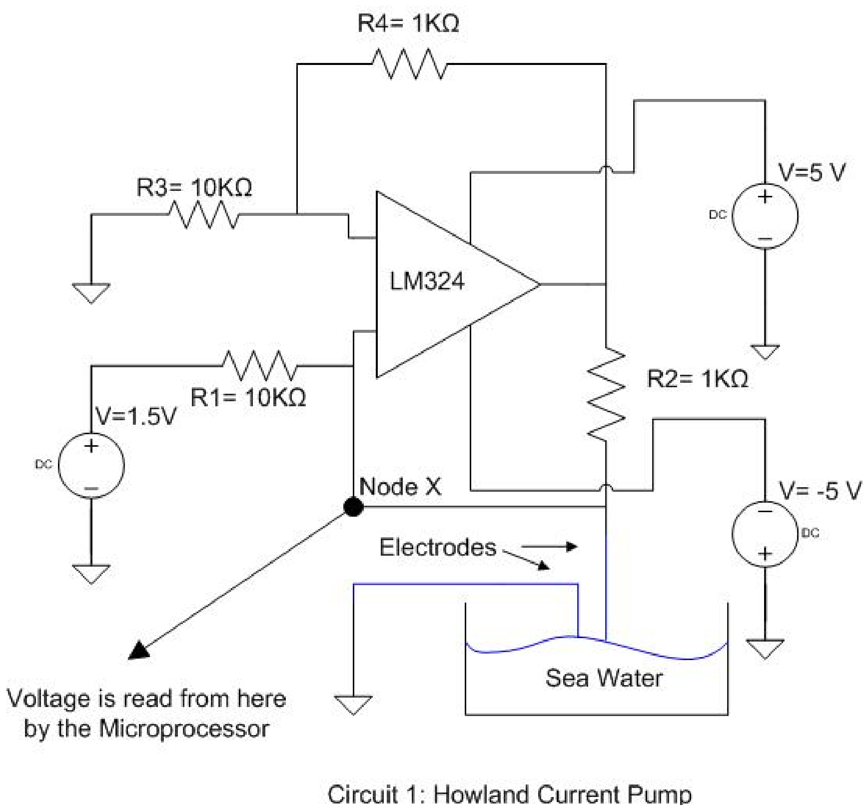


Figure 8 Howland Current Pump

Below are some of the measurements found in the lab during the testing of clean water and seawater:

State	Measured Resistance (KΩ)	Vin (V)	Vx (V)	Vcc+/- (V)
Pure water	1.4	1.2	1.7	5
Diluted w/ oil	2.5	1.2	2.978	5
while mixing previous step level	4.1	1.2	4.32	5
More Oil	5.3	1.2	4.41	5
while mixing previous step level	15.3	1.2	4.48	5

Table 2 Test Electrode Measurements

The above table proves the theoretical calculations predicted. I_{output} calculated was 120 μA, which agrees with the $V_{X(measured)}$. For example using $I_{out} = \frac{V_{in}}{R_1}$, measuring R_1 = 14 KΩ and I_{out}

= 120 μA, provides a V_x=1.68V, which falls within a 1.1% error tolerance. It can also be seen that with mixed water and oil, resistance approaches infinity, resulting in $V_X \sim V_{cc+}$, which is shown to be V_X = 4.48 V, an error of 1.7%.

Another note is that in order for the electrodes to produce accurate measurements in a sample of polluted water, they need to be placed barely touching the water surface, which is where the oil sits above in a thin layer. If they dip further into the water, V_X measured will be equal to that of clean salty water due to the new path for the current to follow, which is misleading.

Electrodes in the Circuit

For the detection circuit to work properly and yield reliable data, we selected good quality electrodes that can endure the harsh marine environment, including corrosion. We wanted them to be able to resist corrosion for a sufficient period of time before any major maintenance is required, that period has been selected for 3 months. After some research, discussions and consultations with other faculty professors, we decided to use zinc coated electrodes. Few of the alternatives we considered at first were gold, carbon, and platinum, but after considering the costs and reliability of each material, we agreed to go for zinc electrodes. These electrodes will be approximately 1 cm apart from each other, which will allow the current to transfer between them. After few testes in the lab, a very intuitive result was obtained: we found that the further the distance between the two electrodes, the higher the measured resistance becomes.

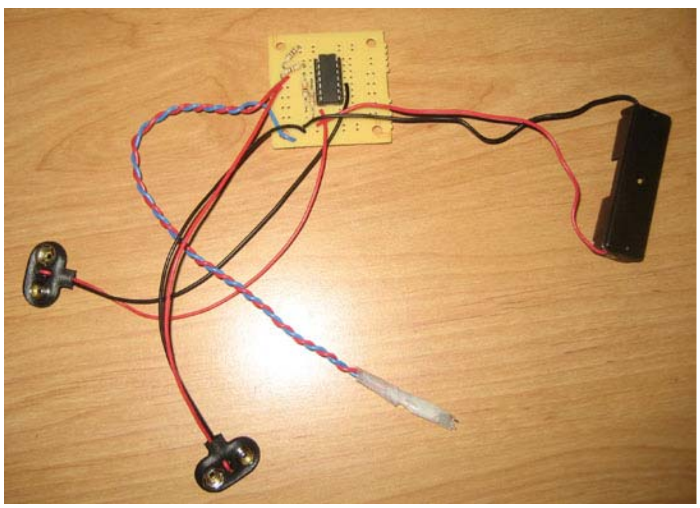


Figure 9 Electrode Circuit

During testing in the lab, we found that in order to properly detect the existence of oil on the surface of seawater, the electrodes cannot be merged very far at all into the water. Oil floats on the surface and the electrodes should not go in further than the thickness of the oil slick. It was noticed that as soon as the electrodes touches the sea water surface below the oil surface, a totally different load voltage is measured, indicating water is clean even though water was indeed contaminated.

In order to solve this problem, we have decided to permanently attach the electrodes to a separate floating device that will be able to track the water level very effectively.

Microcontroller

The microprocessor for the Shoreline Oil Detection System is an Arduino Mega 2560 [11]. The following are some of the specifications:

- Required V_{supply} = 7 - 12 V.
- Built in regulator for output voltage connections (which will also be used to power the cellular modem).

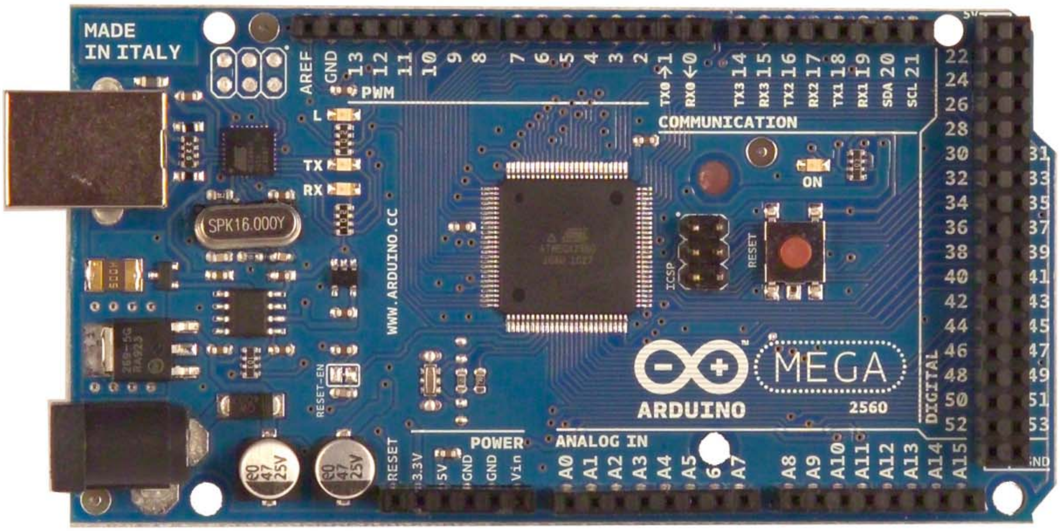


Figure 10 Arduino Uno Mega Microcontroller

Cellular Modem

To transmit the SMS signals the SM5100B Cellular Shield [12] will be used. It has a SIM card socket, and a voltage regulator so that the Arduino's voltage rail of 3.8V can be used. The following lists its characteristics:

$V_{operating}$	3.6V
I_{off}	50uA
$I_{on\ (max)}$	2A

Table 3 Cellular Modem Characteristics

Figure 11 SM5100B Cellular Shield

To transmit the data we will be using the SFE Quad-Band Cellular Duck Antenna SMA, specifically designed to fit on the SM5100B.

Figure 12 Quad-Band Cellular Duck Antenna

Power Supply

The system will receive its power directly from a Lead Acid rechargeable battery, which will be charged up using two solar panels. Each solar panel is 150x85 mm ,has an output voltage of 7.5 V DC open circuit and a short circuit current of 220 mA, and it is 3000 maH.

The battery voltage will be regulated before it is fed to each device in the subsystem. We will be using a total of 3 Voltage regulators. The microprocessor manages internally the power delivered to the cellular modem.

A voltage regulator LM317T[10] together with a CMOS inverter ICL7662 will be used to power up the operational amplifier LM324, which is used in the current pump circuit. Another LM317 will be used to generate a regulated voltage of 1.5V that is needed as an input voltage for the conductivity sensing circuit.

To have a safe charge up of the circuit, we have to consider two things: battery overcharge, and current leakage from the battery to the solar panel [7]. To avoid current leakage we are using a blocking diode that would prevent current from running from the battery to the solar panels. To prevent battery overcharging we are using a BJT switch that opens when the battery is fully charged up. The processor will be monitoring the voltage output of the battery, and as soon as it senses a voltage equal to 6V, it will send a 1V signal to the base of the BJT turning the solar panel effectively off. As soon as this happens the switch becomes open and no more current flows to the battery until the sensed voltage across the battery drops below 6V, and in this case the processor will make the input voltage at the base of the BJT equal zero.

The schematics below outlines in details how the power supply circuitry of the system works, and the components used.

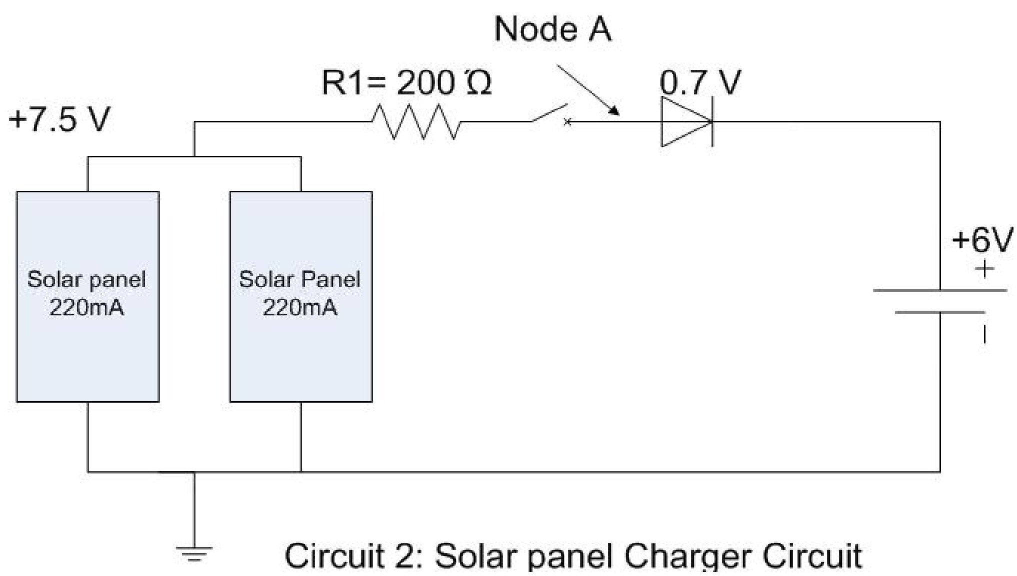


Figure 13 Solar Panel Charger Circuit

The BJT switch is biased according to the equations below:

$$V_{in} = 0.7 + R_b \cdot I_b$$

$$I_c = \beta \cdot I_b \quad (\,where\ \beta = 100)$$

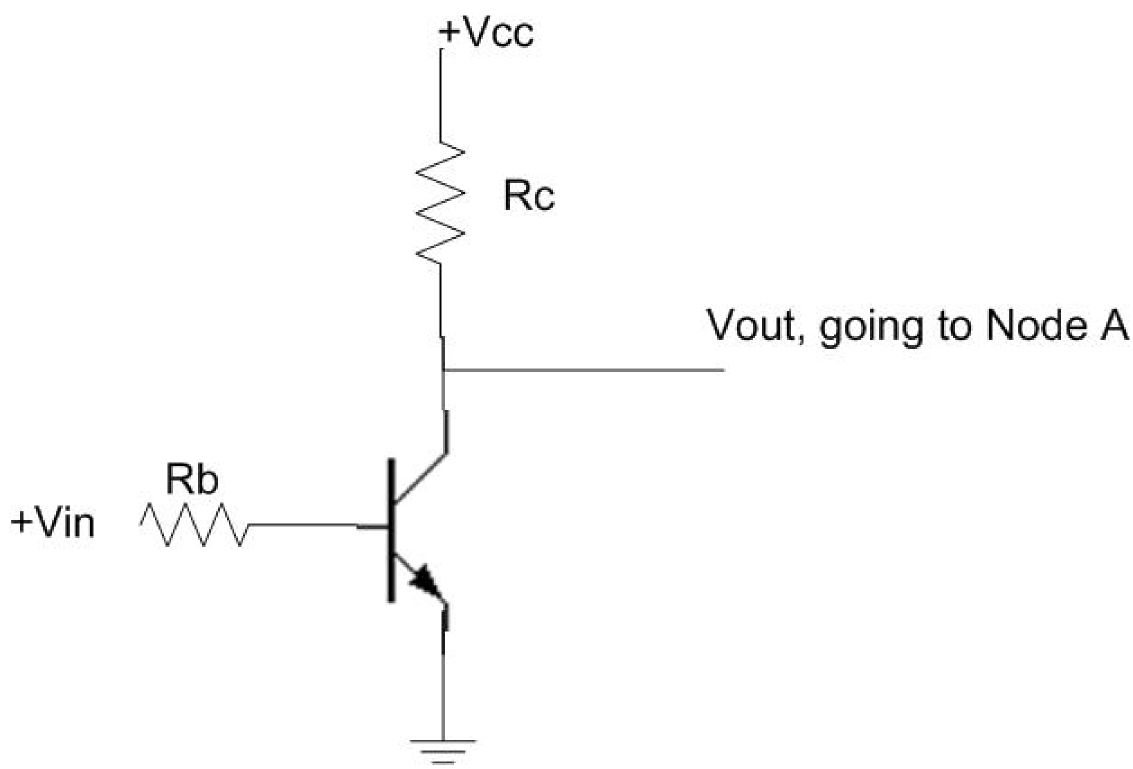
When the switch is open V_A = 6.7 V, and it will close when V_A < 6V.

Given that the diode will use 0.7V, 6.7V will be a fully charged battery.

$$I_c = \frac{V_A}{R_c} = \frac{6.7V}{1000\Omega} = 6.7mA$$

$$I_b = \frac{I_c}{\beta} = 67\mu A$$

$$R_b = \frac{(V_{in} - 0.7)}{I_b} = \frac{(1 - 0.7)}{I_b} = 4.48K\Omega$$



Circuit 3: BJT Switch for Overcharge Protection

Figure 14 BJT Switch for Overcharge Protection

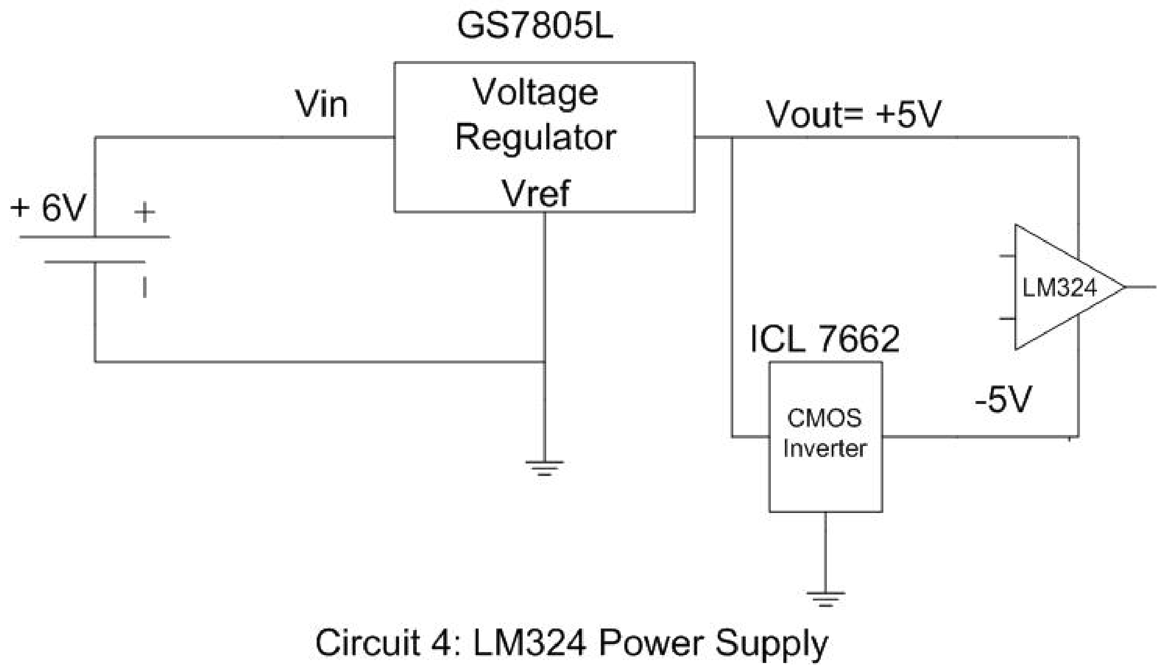


Figure 15 LM324 Regulator Power Supply Circuit

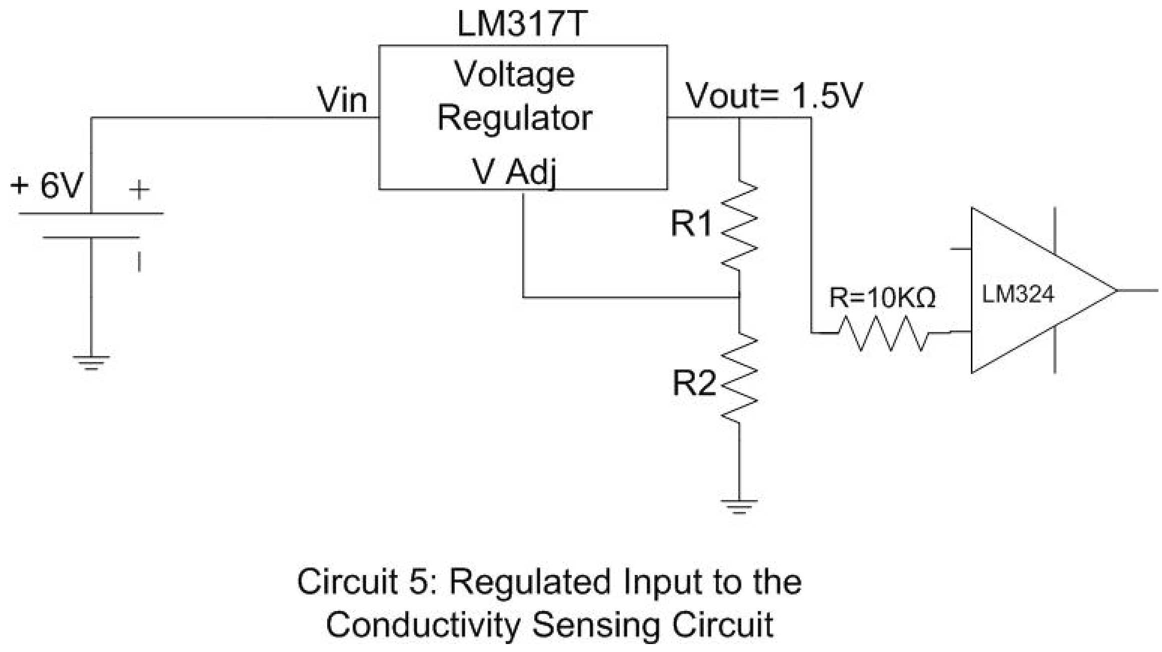


Figure 16 Regulated Input For Conducting Electrode Circuit

The output voltage is determined based on the value of *R1*and *R2* according to the following equation:

$$V_{out} = 1.25 \cdot (1 + \frac{R_2}{R_1})$$

Picking V_{out}= 1.5V means the factor R2/R1 = 0.2. From this we can select R_1= 1KΩ, which gives R_2= 1.2KΩ.

Our current design supplies 6V, so in order to meet the required 7-12V for the microcontroller a step up DC to DC voltage converter will be used. The MC34063A will be a used for this purpose. It provides an adjustable output voltage for an input between 3 to 40V and an output current of up to 1.5 A. These parameters make the MC34063A a flexible component essential for providing the required power to our circuit.

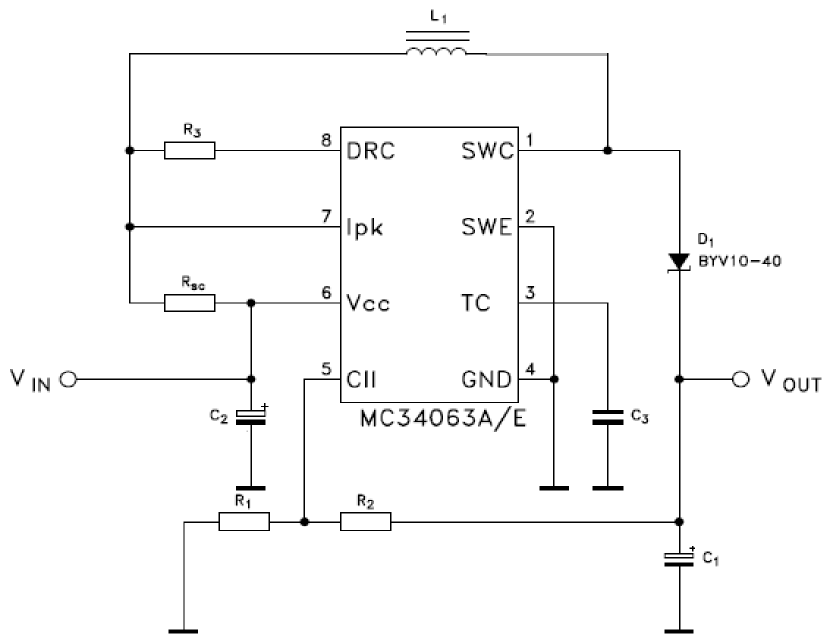


Figure 17 Step Up DC/DC Converter Configuration

User Interface

The device will have a friendly user interface that will allow for easy operation both in the sea and at the control station.

In The Sea

During the boot up process or the main board, the sensing circuit measures the voltage drop seen across the electrodes. This will ideally be performed in the clean salty water to be monitored. At this point the Microcontroller saves this recorded value as the reference voltage which any fluctuation will be compared to. The microprocessor board has a built in reboot button that will initiate this process.

Control Station

The concerned authorities at the control station will receive an alert message through the cellular modem when the device detects the existence of an oil contamination. The warning alert will stays on at the Shoreline Oil Detection System, until the operator acknowledges it. The message is acknowledged when operator resets the board at that physical unit.

Software Design

The software has two states: start-up, and monitoring. Each of these states shall be described in detail below.

Each device out there will be identified by two constants to be stored at the time of programming in the software:

- *Device id* – Unique identifier for each of the units.
- *SMS receiver* – Phone number SMS Alerts will be sent to.

Start-up process

The start-up process cycles the following sequential list of actions when initiated, after which it passes the control on to the monitoring process. It should be noted that an operator can initiate this state by pressing the physical reset button on the microprocessor.

1. Take baseline measurement of the present water conductivity.
2. Boot cellular modem and send test SMS message to the *SMS receiver*.
   Message body: Detector [*device id*] started successfully.
3. Turn off cellular modem.

Monitoring process

After the start-up process has been completed and has handed the control to the monitoring process, this loop continuously runs while the device has power.

1. Test battery charge levels using analog voltage input
   a. <If charge level is low AND charging circuit is off> Turn charging circuit on
   b. <Else if charge level is full AND charging circuit is on> Turn charging circuit off
2. Test water conditions using analog voltage input
   a. <If NOT alert sent AND voltage level is below threshold AND count IS GREATER THAN [an integer constant yet to be defined]>
      i. Boot up cellular modem
      ii. Send alert message to *SMS receiver*
      Message body: *Alert! Detector* [device id] *has identified oil.*
      iii. Turn off cellular modem
      iv. Change alert sent to TRUE.
   b. <If NOT alert sent AND voltage level is below threshold AND count IS LESS THAN OR EQUAL TO [the same integer constant in a.]> Increment count
   c. <If NOT alert sent AND voltage level is above threshold AND count IS GREATER THAN 0> Decrement count

Wireless System Design

The Shoreline Oil Detection System will be able to wirelessly transmit alerts to an operator by using a cellular module, the Spectrum SM5100B. This board was picked because its direct compatibility with our microprocessor with direct serial communications. Using this functionality, alerts will be transmitted over a GSM cellular network as an SMS message. These messages can then be received by an operator's cellular phone, or any other type of special-purpose email account compatible with current SMS message standards.

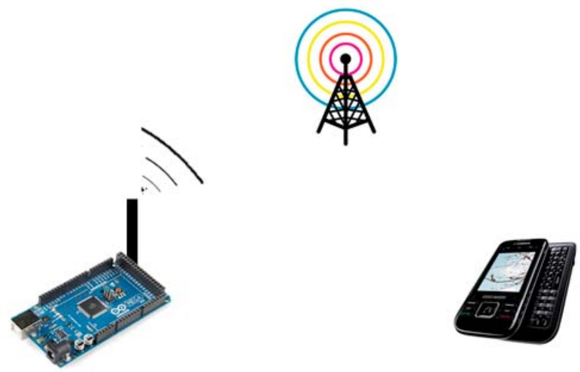


Figure 18 Wireless Communication Diagram

Reliability Design

Reliability will be an obstacle for the Shoreline Oil Detection System, since it will be floating in the ocean, one of the harshest environments known to humans. We must keep in mind it is not feasible to continuously maintain it. Initially our biggest concern was the electrodes and how fast they corrode. Our solution to this problem is to use zinc coated electrodes, since zinc coatings prevents oxidation. This process is known as plating [13]. More discussion on this can be found in the Electrical Design specifications. The process of corrosion on the zinc electrodes is slower when compared to other metals, and therefore won't need to be changed often as compared with alternative materials, our prediction is every 3 months, which will be confirmed during extensive product testing later in the life cycle.

Clean Marine must also be aware that the system cannot detect oil if the electrodes are below the thin layer of oil on the surface of water, which is approximately 5mm deep on the surface of the water, since most of the oil floats on the surface of the water. So instead of using long thin electrodes we are going to use 2 thin pins that float on the surface of the water, this way, both oil and the pin will be on the surface enabling effective detection.

Safety Design

Our primary issue is the lead acid battery that we will be using as our power supply. Lead is extremely toxic, so we have incorporated a voltage detection circuit which will prevent overcharging and current leakage, and also connecting the solar panels to charge again. This has two parts to it, one is the analog circuit, which is described in the Power Supply section of the Electrical Design section. In the event the worst case scenario occurs, that is if the lead acid battery does overcharge and leak, it will be enclosed in the water tight pelican case to prevent contamination of the water.

There are other safety issues that need to be considered since our device will be exposed to all aspects of the environment it will be placed in, such as: visibility, environment, and animals. In order to avoid ships and boats hitting the Shoreline Oil Detection System, it will either be attached to an existing buoy, or attached to its own bright buoy that will ensure any marine traffic will see it. To aid in visibility, a low powered bright LED will be attached on top of the finished product, which will blink periodically, similar to a lighthouse.

We have chosen our particular design to reduce the impact on the environment but also to reduce the amount of damage that any curious animal might have in the system. With this in mind, we have enclosed all the components aside from the solar panels and the LED in a water tight Pelican Case.

System Test Plan

A series of testing needs to be done in order to insure the Shoreline Oil Detection System is working as planned. In phase one, every subsystem will be tested separately under different conditions. Once all subsystems are confirmed behaving properly, an integration test will be done. At the point all subsystems making the product will be assembled into one unit including the microcontroller and tested. This will be implemented in phase two of the lifecycle.

Sensing Circuit

The seawater conductivity changes very fast depending on a variety of factors such as temperature, time, location, season, and weather. It is important to note that the two stages will be tested in two different environments: the lab, and the sea.

The Howland current pump circuit that acts as our conductivity sensing circuit will be tested to see if the conductivity of oil contaminated samples and clean seawater is measured properly. At first we will start testing the circuit in the lab on different samples of seawater, drinking water, and water contaminated with oil. The purpose here is to see how much conductivity seawater exhibits and how much it differs from both drinking water and contaminated water. We also want to track the sensitivity of the electrodes used with regards to changes in voltage.

In stage two the circuit will be deployed in the open sea during different times of the day which will allow us to gather real time measurements. The goal is to simulate as closely as possible field deployment.

Solar Panels and Batteries

Since the circuit will be powered through a solar panel, we will also test the power supply delivering power to each subsystem. This will have to be accomplished in real day light, since the panels require solar energy to work.

The solar panels will require testing when connected in our charging circuit. We will determine fully charged time, based on varying light levels.

We will also determine how long the Lead-Acid rechargeable battery takes to fully charge, under the various conditions as well. In addition, the overcharge protection circuit, the transistor switch, will also be monitored at this time, to ensure proper functionality.

Since the battery charge switch is controlled by the microprocessor, we will also be testing the microprocessor detection algorithm for proper functionality.

One concern we have is our cellular modem draws a current of 1.2 A. Upon generation of an oil spill warning, how much draw on the battery will this be, and will our solar panels be able to handle charging after the event occurs. In reality, there is only need for one alert, either there is oil there or not, but some instances where it was a false reading of the electrodes will need to be taken into consideration.

Cellular Modem

The cellular modem will issue a warning signal as soon as an oil spill is detected. Testing needs to be done to determine how long it will take for the signal to be sent and received. We will investigate this in both the lab and in the sea.

Our aim is to see if the microcontroller and the cellular modem communicate properly. In this fashion we ensure that the software is free of any bugs and also tests the power supply for the modem; that its delivering enough power so a signal can be transmitted successfully.

Microcontroller

The Microcontroller is the core of our unit and therefore it needs to go through a thorough testing before it can be integrated with other subsystems of the circuit. The microprocessor regulates the power delivered to the modem, issues warning signals to the cellular modem after the detection of oil, and it also controls the charging mechanism of the battery. Therefore any failure or errors in operation of the microcontroller certainly means a bad performance of the device.

Software stress testing will be performed for any bugs that it may have. We will see if the microcontroller does repeatedly and successfully its assigned tasks as listed. This will be performed one by one, adding more components to the circuit at a time when the previous bugs have been eliminated.

Power Supply

Each subsystem in the unit gets its power delivered through independent voltage regulators. To ensure the unit will operate properly, we will have to test the output voltage under loads to make sure it will be adequate for our system.

Testing will also be performed when the system is integrated and put together with the microcontroller.

The goal here is to see that the output voltage is truly regulated and meets the power requirements for the unit to operate properly.

Conclusion

Clean Marine Systems is dedicated to saving the environment with technology that is aimed at helping eliminate human involvement in the detection of the environmental disaster.

We have gone into specific details of how we plan on implementing our Shoreline Oil Detection System in this document, which has broken each component of the project into specific, piecewise description.

With our competent team of engineers, we are confident that we will be able to complete stage 2 of our development cycle, where we have a working prototype ready for extensive testing.

James Kennedy
CEO

Ahmed Saleh
COO

Ned Tobin
CFO

Farid Mabrouk
CTO

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19-1292; Rev 2; 7/96

MAXIM

CMOS Voltage Converters

General Description

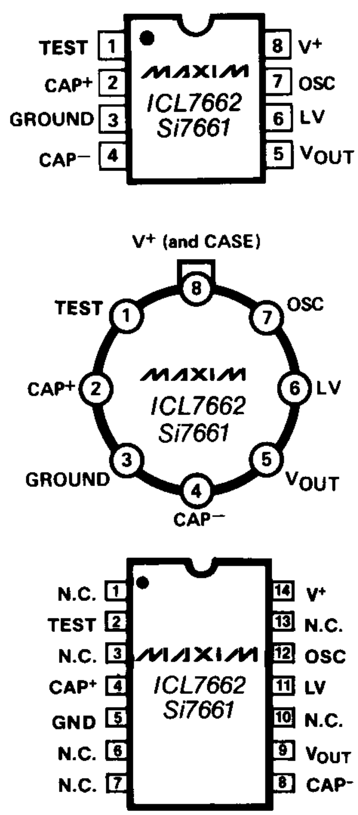
The ICL7662/Si7661 is a monolithic charge pump voltage inverter that will convert a positive voltage in the range of +4.5V to +20V to the corresponding negative voltage of -4.5V to -20V. The ICL7662/Si7661 provides performance far superior to previous implementations of charge pump voltage inverters by combining low quiescent current with high efficiency. The ICL7662/Si7661 has an oscillator, control circuitry, and 4 power MOS switches on-chip, with the only required external components being two low cost capacitors.

Applications

- Inexpensive Negative Supplies
- Data Acquisition Systems
- Up to -20V for Op Amps, and Other Linear Circuits
- Supply Splitter, V_{OUT} = Vs/2
- RS-232 Power Supplies

Pin Configurations

Top View



Features

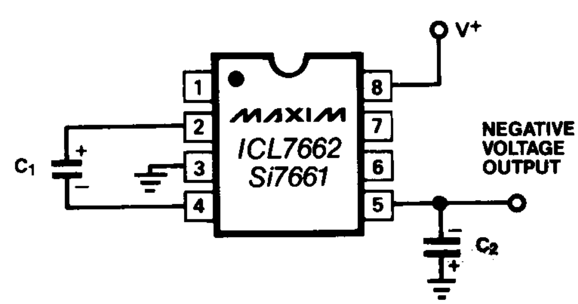
- ◆ **+4.5V to +20V Supply to -4.5V to -20V Output**
- ◆ **Cascaded Voltage Multiplication (V_{OUT} = -n × V+)**
- ◆ **99.7% Typical Open Circuit Conversion Efficiency**
- ◆ **Requires Only 2 External Capacitors**
- ◆ **Pin Compatible with the ICL7660**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
ICL7662CPA	0°C to +70°C	8 Plastic DIP
ICL7662CBD	0°C to +70°C	14 SO
ICL7662CBA	0°C to +70°C	8 SO
ICL7662C/D	0°C to +70°C	Dice
ICL7662EPA	-40°C to +85°C	8 Plastic DIP
ICL7662EBD	-40°C to +85°C	14 SO
ICL7662EBA	-40°C to +85°C	8 SO
ICL7662MTV-4	-55°C to +125°C	8 TO-99
ICL7662MJA	-55°C to +125°C	8 CERDIP

Ordering Information continued at end of data sheet.

Typical Operating Circuit



Negative Voltage Converter

ABSOLUTE MAXIMUM RATINGS

V+ TO GND ....-0.3V, +22V
Oscillator Input to GND (Note 1)
(V- < 12V)..-0.3V, V+ + 0.3V
(V+ > 12V)...V+ - 12.3V, V+ + 0.3V
Power Dissipation (Note 2)
Plastic DIP...300mW
SO 500mW
TO-99 ....500mW
CERDIP 500mW

Operating Temperature Ranges
Commercial (ICL7662C_, Si7661C_).................0°C to +70°C
Extended (ICL7662E__, Si7661D_ or ESA) .....-40°C to +85°C
Military (ICL7662MTV/MJA,
Si7661AA/AK) ....-55°C to +125°C
Storage Temperature.......................................-65°C to +160°C
Lead Temperature (soldering, 10sec) ....+300°C

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: ICL7662

($V_+ = +15V$, $T_A = +25°C$, $C_{OSC} = 0$, unless otherwise noted. See Test Cuircuit Figure 1.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage Range-Lo	V+ L	R_L = 10kΩ, LV = GND	-55°C < T_A < +125°C	4.5		11	V
Supply Voltage Range-Hi	V+ H	R_L = 10kΩ, LV = Open	-40°C < T_A <+85°C	9		20	
			-55°C < T_A < +125°C	9		16.5	
Supply Current	I+	R_L = ∞, LV = Open	T_A = +25°C		0.25	0.60	mA
			0°C < T_A <+70°C		0.30	0.85	
			-55°C < T_A < +125°C		0.40	1.0	
Output Source Resistance	R_O	I_O = 20mA, LV = Open	T_A = +25°C		60	100	Ω
			0°C < T_A <+70°C		70	120	
			-55°C < T_A < +125°C		90	150	
Supply Current	I+	V+ = 5V, R_L = ∞, LV = GND	T_A = +25°C		20	150	µA
			0°C < T_A <+70°C		25	200	
			-55°C < T_A < +125°C		30	250	
Output Source Resistance	R_O	V+ = 5V, I_O = 3mA, LV = GND	T_A = +25°C		125	200	Ω
			0°C < T_A <+70°C		150	250	
			-55°C < T_A < +125°C		200	350	
Oscillator Frequency	f_{OSC}				10		kHz
Power Efficiency	P_{eff}	R_L = 2kΩ	T_A = +25°C	93	96		%
			Min < T_A < Max	90	95		
Voltage Conversion Efficiency	V_{OEf}	R_L = ∞	Min < T_A < Max	97	99.9		%
Oscillator Sink or Source Current	I_{OSC}	V+ = 5V (V_{OSC} = 0V to +5V)			0.5		µA
		V+ = 15V (V_{OSC} = +5V to +15V)			4.0		

Note 1: Connecting any terminal to voltages greater than V+ or less than ground may cause destructive latchup. It is recommended that no input from sources operating from external supplies be applied prior to power-up of the ICL7662.
Note 2: Derate linearly above +50°C by 5.5mW/°C.
Note 3: Pin 1 is a test pin and is not connected in normal use.

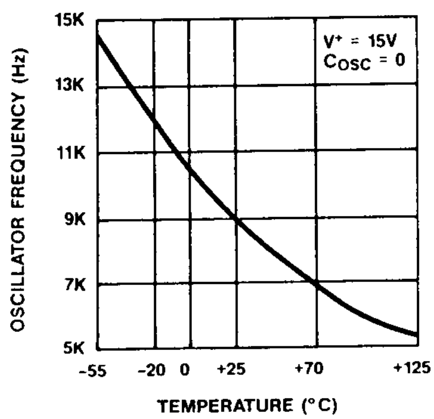
ELECTRICAL CHARACTERISTICS: Si7661

(V_+ = +15V, T_A = +25°C, C_{OSC} = 0, unless otherwise noted. See Test Cuircuit Figure 1.)

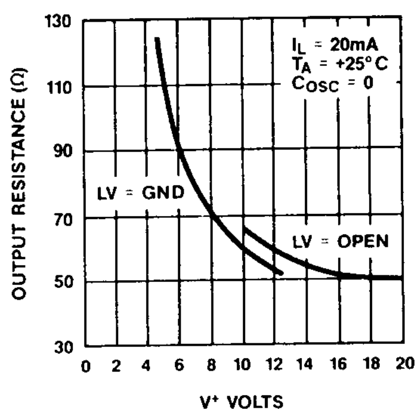
PARAMETER	SYMBOL	TEST CONDITIONS UNLESS OTHERWISE SPECIFIED: C_{OSC} = 0		LIMITS: TEMP (1 = 25°C, 2 = 125, 85, 70°C, 3 = -55, -25, 0°C)	LIMITS: TYP	A, B, C, D, E SUFFIX: MIN	A, B, C, D, E SUFFIX: MAX	UNITS
INPUT								
Supply Voltage Range (LV)	$V+_{LV}$	R_L = 10kΩ, LV = 0V		1, 2, 3		4.5	9	V
Supply Voltage Range	V+	R_L = 10kΩ, LV = Open	Si7661B, C, D, E	1, 2, 3		8	20	V
			Si7661A	1, 2, 3		8	16.5	V
Supply Current	I+	V+ = 4.5V, R_L = ∞, LV = 0V		1			500	µA
		V+ = 4.5V, R_L = ∞, LV = Open		1			2	mA
OUTPUT								
Output Source Resistance	R_{OUT}	V+ = 4.5V, LV = 0V, I_O = 3mA		1	100			Ω
		V+ = 15V, LV = Open, I_O = 20mA		1, 3	55		100	Ω
				2			120	Ω
Power Conversion Efficiency	PE	V+ = 15V, R_L = 2kΩ		1	92			%
Voltage Conversion Efficiency	$V_{OUT}E$	V+ = 15V, R_L = ∞		1	99.7	97		%
DYNAMIC								
Oscillator Frequency	f_{OSC}	V+ = 15V		1	10			kHz
Oscillator Impedance	Z_{OSC}	V+ = 4.5V, LV = 0V		1	1			MΩ
		V+ = 15V		1	100			kΩ

Typical Operating Characteristics

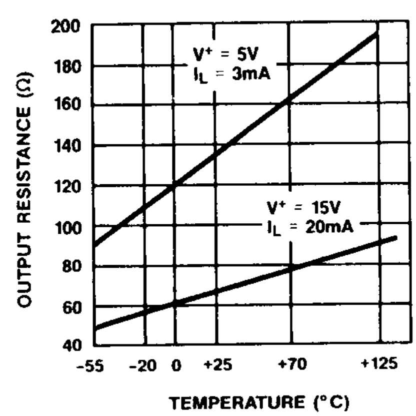
UNLOADED OSCILLATOR FREQUENCY vs. TEMPERATURE



OUTPUT SOURCE RESISTANCE vs. SUPPLY VOLTAGE

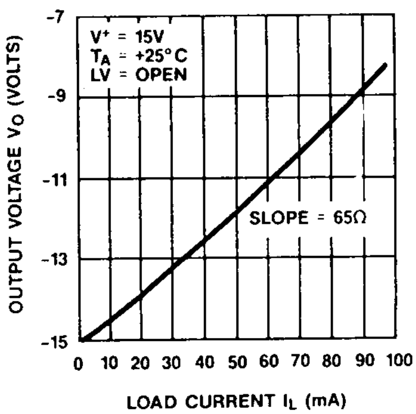


OUTPUT SOURCE RESISTANCE vs. TEMPERATURE

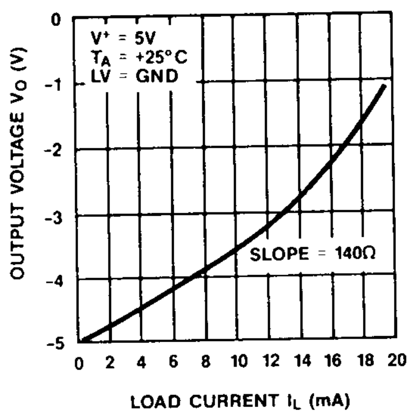


Typical Operating Characteristics (continued)

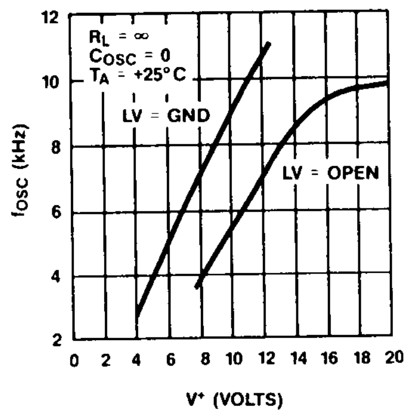
OUTPUT VOLTAGE vs. LOAD CURRENT



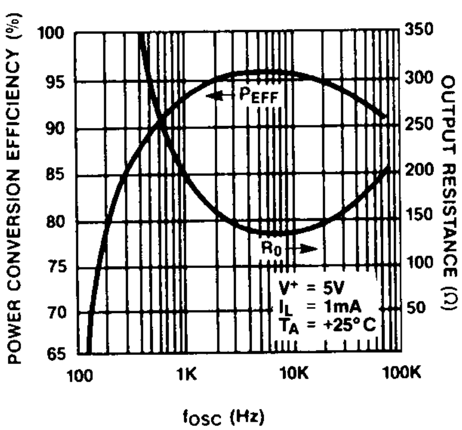
OUTPUT VOLTAGE vs. LOAD CURRENT



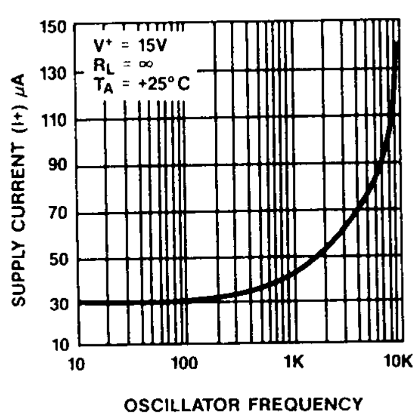
OSCILLATION FREQUENCY vs. SUPPLY VOLTAGE



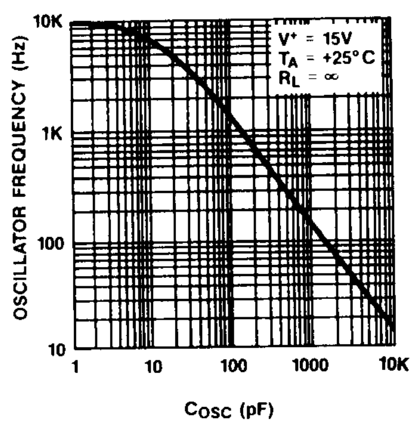
POWER CONVERSION FREQUENCY AND OUTPUT RESISTANCE vs. OSCILLATOR FREQUENCY



SUPPLY CURRENT vs. OSCILLATOR FREQUENCY



OSCILLATION FREQUENCY vs. EXTERNAL OSCILLATOR CAPACITANCE



Detailed Description

All the circuitry necessary to complete a voltage inverter is contained on the ICL7662 (Si7661). Only 2 external capacitors are needed. These may be inexpensive 10µF polarized electrolytic capacitors. Figure 2, an idealized voltage inverter, illustrates the ICL7662 (Si7661) operation. During the first half of the cycle, switches S2 and S4 are open; switches S1 and S3 are closed, and the capacitor C1 is charged to a voltage V_{IN}. During the second half cycle, switches S1 and S3 are opened, and switches S2 and S4 are closed. The capacitor C1 undergoes a negative shift equal to V_{IN}. Assuming ideal switches (R_{ON} = 0) and no load on C2, charge is then transferred from C1 to C2 such that the voltage on C2 is exactly $-V_{IN}$.

The four switches in Figure 2 are MOS power switches. Switch S1 is a P channel switch and switches S2, S3 and S4 are N channel devices.

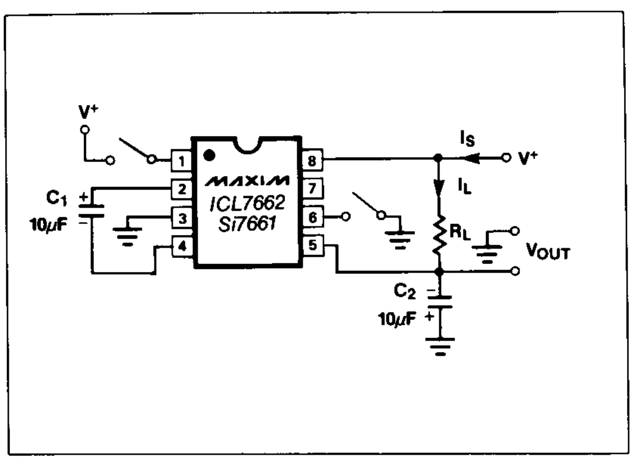


Figure 1. ICL7662/Si7661 Test Circuit

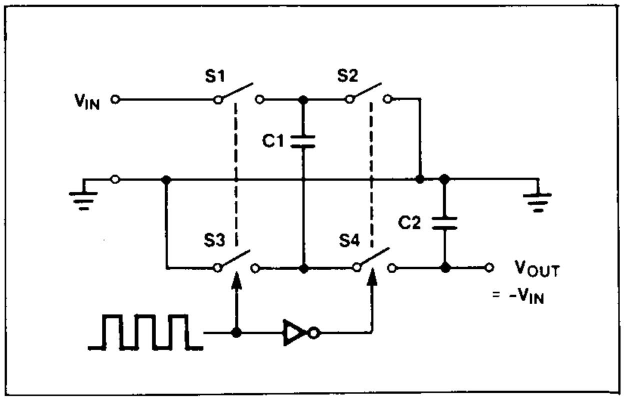


Figure 2. Idealized Negative Voltage Converter

Efficiency Considerations

Theoretically, a voltage multiplier can approach 100% efficiency if certain conditions are met. The ICL7662 (Si7661) approaches the conditions listed below for negative voltage multiplication if large values of C1 and C2 are used.

- The output switches have virtually no offset and extremely low ON resistance.
- Minimal power is consumed by the drive circuitry.
- The impedances of the reservoir and pump capacitors are negligible.

The energy loss per charge pump cycle is:

$$E = \frac{1}{2} \times C1 \times (V_{IN}^2 - V_{OUT}^2)$$

There will be a substantial voltage difference between V_{IN} and V_{OUT} if the impedances of C1 and C2 (at the pump frequency) are high compared to output load R1. To reduce output ripple, make C2 as large in value as is practical. Increasing the value of both C1 and C2 will improve the efficiency.

General Precautions

- The positive terminal of C1 must be connected to Pin 2 of the ICL7662 (Si7661), and the positive terminal of C2 must be connected to Ground.
- Never exceed maximum supply voltages.
- For higher efficiency, connect LV to Ground for supply voltages less than 8 volts.
- V_{OUT} should not be shorted to V^+ for extended periods of time. Transient conditions (including startup) are acceptable.

Applications

Changing Oscillator Frequency

Normally the OSC pin of the ICL7662 (Si7661) is left open, and the 10kHz nominal frequency (5kHz charge pump frequency) is used. The oscillator can be lowered by connecting an external capacitor between OSC and V^+ (see Figure 3). A graph in the Typical Operating Characteristics section shows the nominal frequency versus capacitor value. Lowering the oscillator frequency will improve the conversion efficiency with very low output current values. An undesirable effect of lowering the oscillator frequency is that the impedance level of the pump capacitor will increase. Increasing the value of C1 and C2 will compensate for this effect.

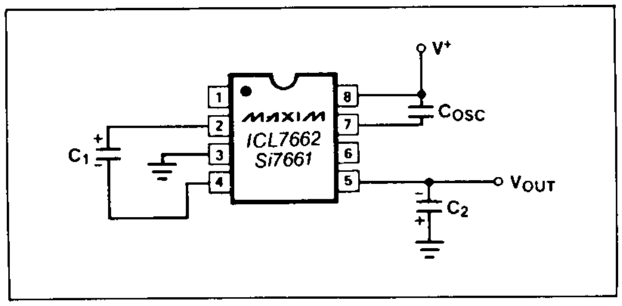


Figure 3. Lowering Oscillator Frequency

In some applications, particularly audio amplifiers, the 5kHz output ripple frequency is objectionable. The oscillator frequency may be increased by one of two methods. The first method is to overdrive the OSC pin with an external oscillator. To eliminate the possibility of latchup, insert a 1kΩ resistor in series with the OSC input (see Figure 4). If the external clock source does not pullup close to V^+, then a 10kΩ pullup resistor is suggested. The pump frequency, and, therefore, the output ripple will be one-half of the external clock frequency. Driving the ICL7662 (Si7661) with a higher frequency clock will slightly increase the supply current, but allows the use of smaller external capacitors and increases the ripple frequency.

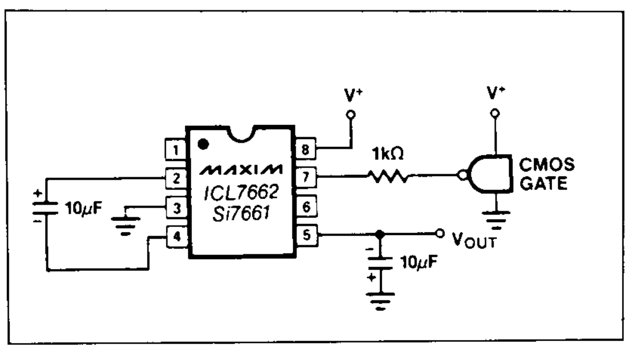
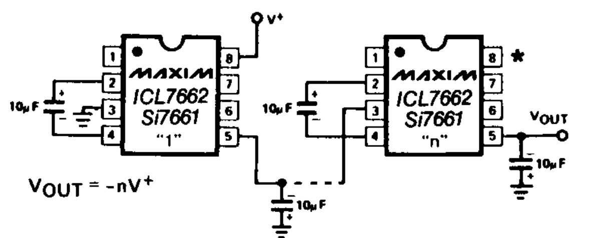


Figure 4. External Clocking

The second method is to tie pin 1 (TEST) to V^+.This disconnects the internal oscillator from the OSC pin. Since there is always a small amount of parasitic capacitance from the OSC pin, tying the TEST pin to V^+ will allow the capacitor to oscillate faster (depending on how much parasitic capacitance there is from the OSC pin).

Cascading Devices

To produce larger negative voltage multiplication of the initial supply voltage, the ICL7662 (Si7661) may be cascaded as shown in Figure 5. The resulting output resistance is approximately equal to the weighted sum of the individual ICL7662 (Si7661) R_{OUT} values. For light loads, the practical limit is 10 devices. The output voltage is defined by $V_{OUT} = -n \times V^+$ (where n is an integer representing the number of cascaded devices).



*Pin 8 tied to Pin 3 of device n-1.

Figure 5. Cascading ICL7662s for Increased Output Voltage

Negative Voltage Converter

The most common application of the ICL7662 (Si7661) is as a charge pump voltage inverter, converting a positive voltage to the corresponding negative equivalent. The simple circuit of Figure 6 shows that only two external components (C1 and C2) are needed. In most applications C1 and C2 are low cost 10µF electrolytic capacitors. The ICL7662 (Si7661) is NOT a voltage regulator, and the output source resistance is approximately 60Ω with a +15V supply. This means that with an input voltage of +15V, the output voltage will be -15V, under light loads (less than 1mA load current), but will decrease to -14.4V with a 10mA load current. The output source impedance of the complete circuit is the sum of the ICL7662 (Si7661) output resistance and the impedance of the pump capacitor at the pump frequency.

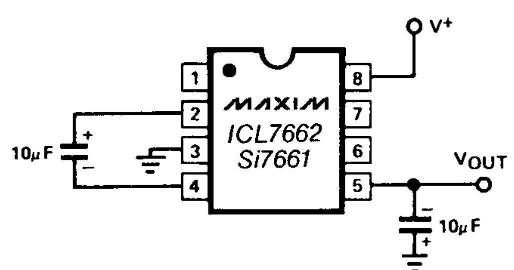


Figure 6. Negative Voltage Converter

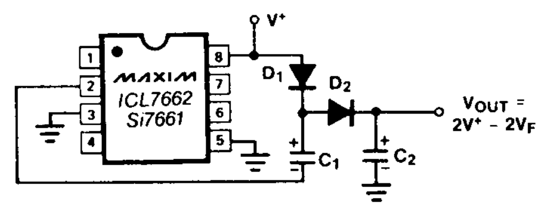
The output ripple of the voltage inverter can be calculated by noting that the output current is supplied solely by the reservoir capacitor during one-half of the charge pump cycle. This introduces an output ripple of:

$$V_{RIPPLE} = \frac{1}{2} \times I_{OUT} \times (1/F_{PUMP}) \times (1/C2)$$

For the nominal F_{PUMP} of 5kHz (one-half of the nominal 10kHz oscillator frequency) and a 10µF C2, the output ripple will be approximately 10mV with a load current of 10mA.

Positive Voltage Doubler

The ICL7662 (Si7661) can double a positive voltage as shown in Figure 7. It basically uses the ICL7662 (Si7661) as a power inverter. The only drawback from this circuit is the inevitable voltage drop across the two diodes.



NOTE: D_1 and D_2 can be any suitable diode.

Figure 7. Positive Voltage Doubler

Paralleling Devices

Paralleling ICL7662s (or Si7661s) reduces the output resistance. As illustrated in Figure 8, each device requires its own pump capacitor C1; however, the reservoir capacitor C2 serves all devices. The equation for calculating output resistance is also shown in Figure 8.

$$R_{OUT} = \frac{R_{OUT} \text{ (of ICL7662 or Si7661)}}{n \text{ (number of devices)}}$$

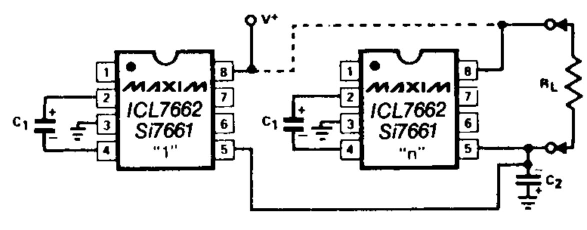


Figure 8. Paralleling ICL7662s to Reduce Output Resistance

Combining Positive Supply Multiplication and Negative Voltage Conversion

This dual function is illustrated in Figure 9. In this circuit, capacitors C1 and C3 perform the pump and reservoir functions respectively for the generation of the negative voltage. Capacitors C2 (pump capacitor) and C4 (reservoir capacitor) are used for the positive voltage converter. The circuit configuration, however, does lead to a higher source impedance of the generated supplies. This is due to the finite impedance of the common charge pump driver.

Voltage Splitting

The ICL7662 (Si7661) can also be used to split a power supply or battery. In Figure 10 the ICL7662 (Si7661) has the positive terminal of the power supply connected to V^+ and the negative terminal connected to V_{OUT}. The midpoint of the power supply is found on Pin 3. The output resistance is much lower than in other applications, and higher currents can be drawn from this configuration.

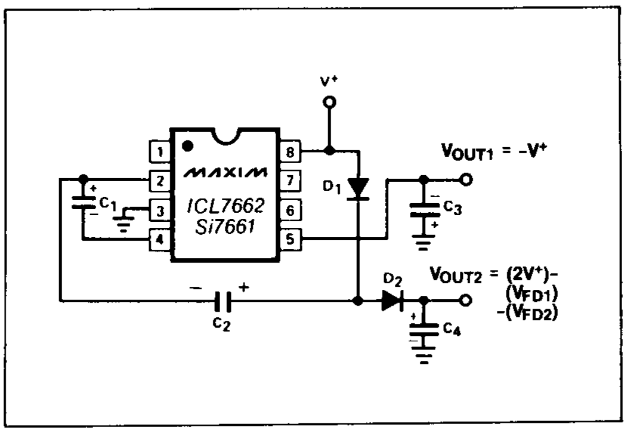


Figure 9. Combined Positive Multiplier and Negative Converter

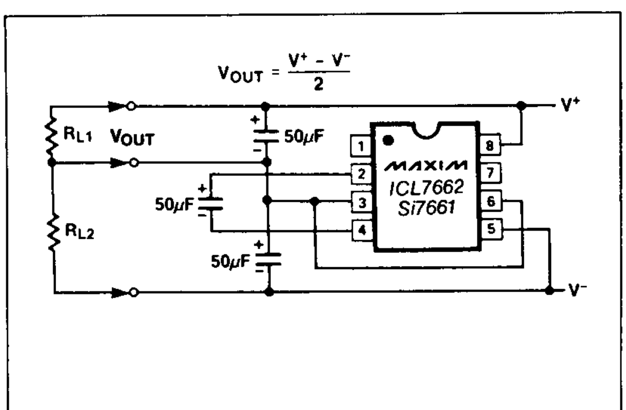
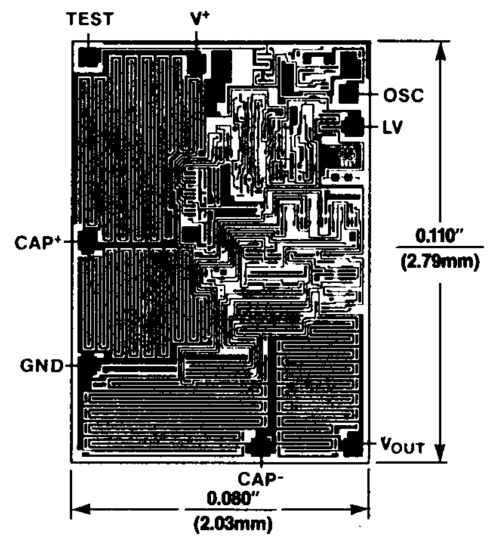


Figure 10. Splitting a Supply in Half

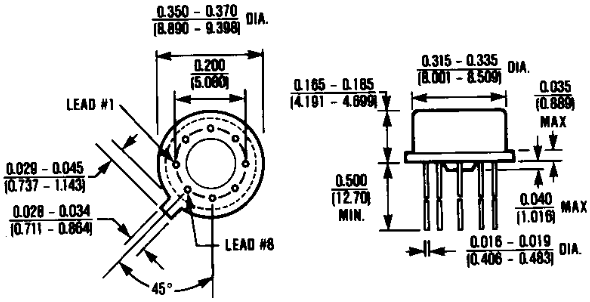
Chip Topography



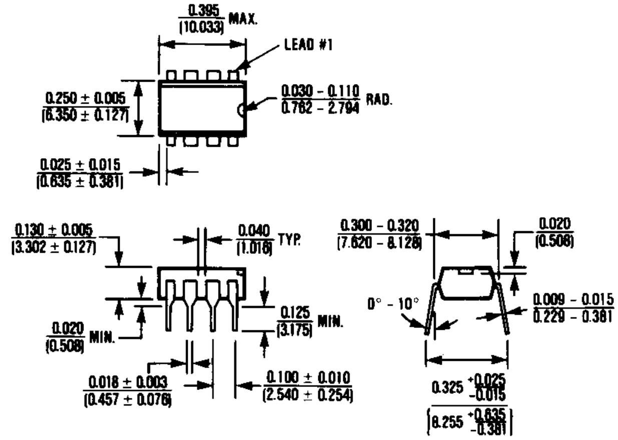
Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE
Si7661CJ	0°C to +70°C	8 Plastic DIP
Si7661CY	0°C to +70°C	14 SO
Si7661CSA	0°C to +70°C	8 SO
Si7661C/D	0°C to +70°C	Dice
Si7661DJ	-40°C to +85°C	8 Plastic DIP
Si7661DY	-40°C to +85°C	14 SO
Si7661ESA	-40°C to +85°C	8 SO
Si7661AA-4	-55°C to +125°C	8 TO-99
Si7661AK	-55°C to +125°C	8 CERDIP

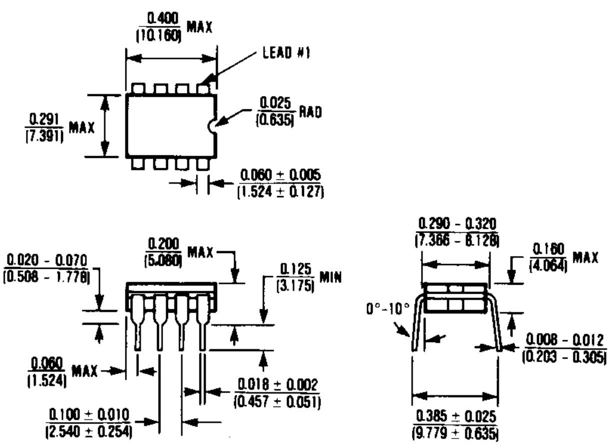
Package Information



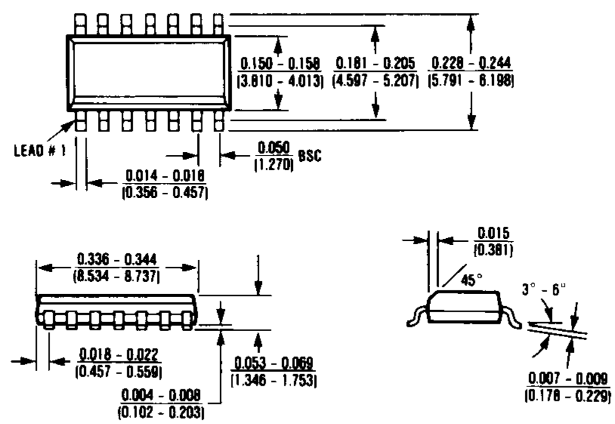
8 Lead TO-99 (TV)
θ_{JA} = 150°C/W
θ_{JC} = 45°C/W



8 Lead Plastic DIP (PA)
θ_{JA} = 160°C/W
θ_{JC} = 75°C/W



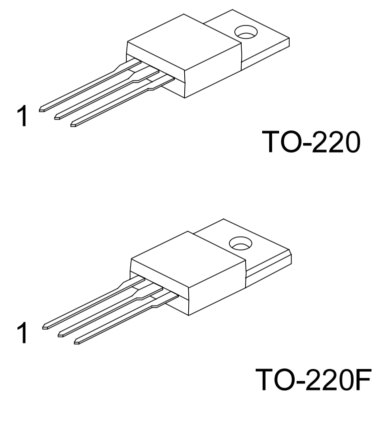
8 Lead CERDIP (JA)
θ_{JA} = 125°C/W
θ_{JC} = 55°C/W



14 Lead Small Outline (SD)
θ_{JA} = 115°C/W
θ_{JC} = 60°C/W

LM78XX

3-TERMINAL 1A POSITIVE VOLTAGE REGULATOR



*Pb-free plating product number: LM78XXL

■ DESCRIPTION

The UTC **LM78XX** family is monolithic fixed voltage regulator integrated circuit. They are suitable for applications that required supply current up to 1 A.

■ FEATURES

* Output current up to 1A
* Fixed output voltage of 3.3V,4.7V,5V, 6V, 7V, 8V, 9V, 10V, 12V, 15V, 18V and 24V available
* Thermal overload shutdown protection
* Short circuit current limiting
* Output transistor SOA protection

■ ORDERING INFORMATION

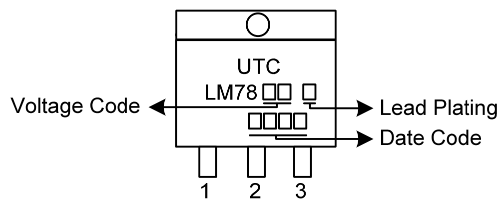
Order Number		Pin Assignment			Package	Packing
Normal	Lead Free Plating	1	2	3		
LM78xx-TA3-D-T	LM78xxL-TA3-D-T	I	G	O	TO-220	Tube
LM78xx-TF3-D-T	LM78xxL-TF3-D-T	I	G	O	TO-220F	Tube

Note: O: Output G: GND I: Input

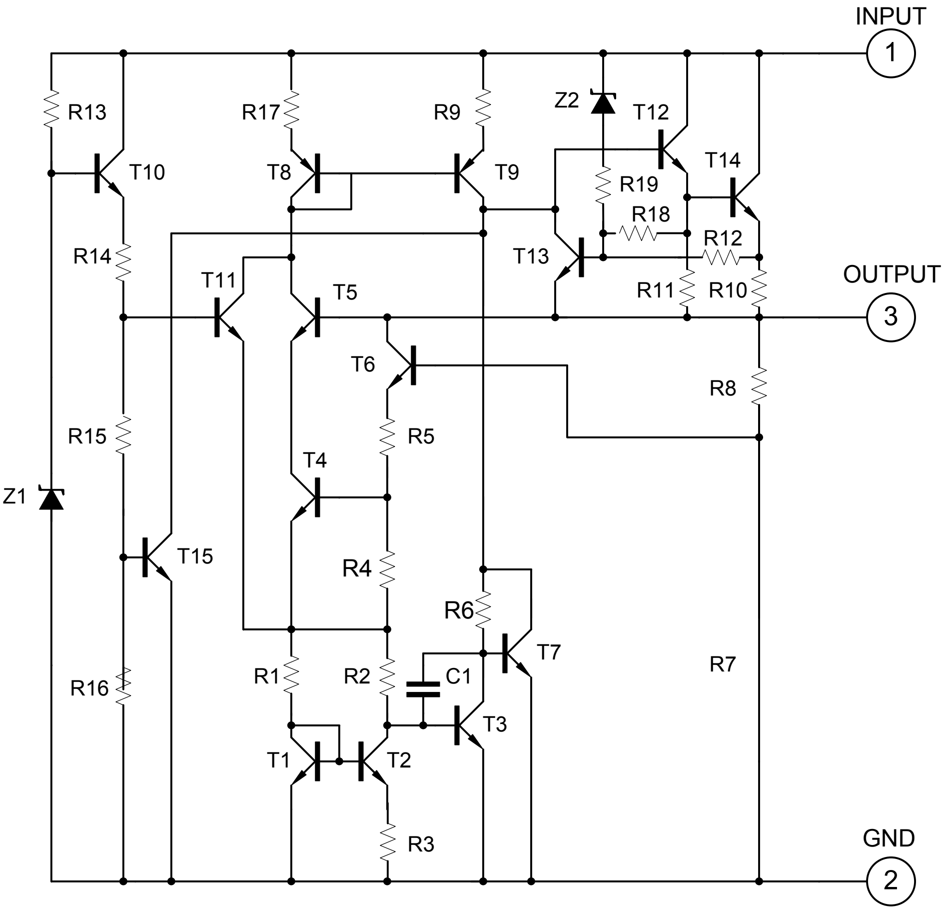
LM78xxL-TA3-D-T

(1)Packing Type	(1) T: Tube
(2)Pin Assignment	(2) refer to Pin Assignment
(3)Package Type	(3) TA3: TO-220, TF3: TO-220F
(4)Lead Plating	(4) L: Lead Free Plating, Blank: Pb/Sn
(5)Output Voltage Code	(5) xx: refer to Marking Information

■ MARKING INFORMATION

PACKAGE	VOLTAGE CODE	VOLTAGE CODE	MARKING
TO-220 TO-220F	33:3.3V 47:4.7V 05:5.0V 06:6.0V 07:7.0V 08:8.0V 09:9.0V	10:10V 12:12V 15:15V 18:18V 24:24V	

■ TEST CIRCUIT



■ ABSOLUTE MAXIMUM RATINGS

(Operating temperature range applies unless otherwise specified)

PARAMETER		SYMBOL	RATING	UNIT
Input voltage	V_{OUT}=3.3~18V	V_{IN}	35	V
	V_{OUT}=24V		40	V
Output Current		I_{OUT}	1	A
Power Dissipation		P_D	Internally Limited	W
Operating Junction Temperature		T_{OPR}	-20 ~ +150	°C
Storage Temperature		T_{STG}	-55 ~ +150	°C

Note Absolute maximum ratings are those values beyond which the device could be permanently damaged.
Absolute maximum ratings are stress ratings only and functional device operation is not implied.

■ THERMAL DATA

PARAMETER	SYMBOL	RATING	UNIT
Thermal Resistance	θ_{JA}	65	°C/W
	θ_{JC}	5	°C/W

■ ELECTRICAL CHARACTERISTICS

(I_{OUT}=0.5A, T_J= 0°C - 125°C, C1=0.33uF, Co=0.1uF, unless otherwise specified)(Note 1)

For UTC LM7833 (V_{IN}=5.8V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	3.168	3.30	3.432	V
		V_{IN} =5.8V ~ 18.3V, I_{OUT}=5mA - 1.0A, P_D≦15W	3.135		3.465	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C,I_{OUT}=5mA - 1.0A			33	mV
		T_J =25°C,I_{OUT}=0.25A - 0.75A			17	mV
Line regulation	ΔV_{OUT}	V_{IN} =5.8V ~ 18.3V, T_J =25°C			33	mV
		V_{IN} =5.8V ~ 18.3V, T_J =25°C, I_{OUT}=1.0A			33	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =5.8V ~ 18.3V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		55		µV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-0.4		mV/°C
Ripple Rejection	RR	V_{IN}=6.3V–16.3V, f=120Hz, T_J =25°C		57		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN}=35V, T_J =25°C		250		mA

For UTC LM7847 (V_{IN} =9.7V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	4.512	4.70	4.888	V
		V_{IN} =7.2V ~ 19.7V, I_{OUT}=5mA - 1.0A, P_D≦15W	4.465		4.935	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C,I_{OUT}=5mA - 1.0A			47	mV
		T_J =25°C,I_{OUT}=0.25A - 0.75A			24	mV
Line regulation	ΔV_{OUT}	V_{IN} =7.2V ~ 19.7V, T_J =25°C			47	mV
		V_{IN} =7.2V ~ 19.7V, T_J =25°C, I_{OUT}=1.0A			47	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =7.2V ~ 19.7V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		40		µV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-0.6		mV/°C
Ripple Rejection	RR	V_{IN} =7.7V -17.7V, f=120Hz, T_J =25°C	62	80		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

■ ELECTRICAL CHARACTERISTICS(Cont.)

For UTC LM7805 (V_{IN} =10V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	4.80	5.0	5.20	V
		V_{IN} =7.5V ~ 20V, I_{OUT}=5mA - 1.0A, $P_D \leqq$ 15W	4.75		5.25	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A			50	mV
		T_J =25°C, I_{OUT}=0.25A - 0.75A			25	mV
Line regulation	ΔV_{OUT}	V_{IN} =7V ~ 25V, T_J =25°C			50	mV
		V_{IN} =7.5V ~ 20V, T_J =25°C, I_{OUT}=1.0A			50	mV
Quiescent Current	I_Q	T_J =25°C, $I_{OUT} \leqq$ 1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =7.5V ~ 20V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz $\leqq$ f $\leqq$ 100kHz		40		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-0.6		mV/°C
Ripple Rejection	RR	V_{IN} =8V - 18V, f=120Hz, T_J =25°C	62	80		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

For UTC LM7806 (V_{IN} =11V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	5.76	6.0	6.24	V
		V_{IN} =8.5V ~ 21V, I_{OUT}=5mA - 1.0A, $P_D \leqq$ 15W	5.70		6.30	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A			60	mV
		T_J =25°C, I_{OUT}=0.25A - 0.75A			30	mV
Line regulation	ΔV_{OUT}	V_{IN} =8V ~ 25V, T_J =25°C			60	mV
		V_{IN} =8.5V ~ 21V, T_J =25°C, I_{OUT}=1.0A			60	mV
Quiescent Current	I_Q	T_J =25°C, $I_{OUT} \leqq$ 1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =8.5V ~ 21V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz $\leqq$ f $\leqq$ 100kHz		45		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-0.7		mV/°C
Ripple Rejection	RR	V_{IN} =9V - 19V, f=120Hz, T_J =25°C	59	75		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

■ ELECTRICAL CHARACTERISTICS(Cont.)

For UTC LM7807 (V_{IN} =13V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	6.72	7.0	7.28	V
		V_{IN} =9.5V ~ 22V, I_{OUT}=5mA - 1.0A, $P_D \leqq$ 15W	6.65		7.35	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A			70	mV
		T_J =25°C, I_{OUT}=0.25A - 0.75A			35	mV
Line regulation	ΔV_{OUT}	V_{IN} =9V ~ 25V, T_J =25°C			70	mV
		V_{IN} =9.5V ~ 22V, T_J =25°C, I_{OUT}=1.0A			70	mV
Quiescent Current	I_Q	T_J =25°C, $I_{OUT} \leqq$ 1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =9.5V ~ 22V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz $\leqq$ f $\leqq$ 100kHz		50		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-0.8		mV/°C
Ripple Rejection	RR	V_{IN} =10V - 20V, f=120Hz, T_J =25°C	59	75		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.7		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

For UTC LM7808 (V_{IN} =14V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	7.68	8.0	8.32	V
		V_{IN} =10.5V ~ 23V, I_{OUT}=5mA - 1.0A, $P_D \leqq$ 15W	7.60		8.40	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A			80	mV
		T_J =25°C, I_{OUT}=0.25A - 0.75A			40	mV
Line regulation	ΔV_{OUT}	V_{IN} =10.5V ~ 25V, T_J =25°C			80	mV
		V_{IN} =10.5V ~ 23V, T_J =25°C, I_{OUT}=1.0A			80	mV
Quiescent Current	I_Q	T_J =25°C, $I_{OUT} \leqq$ 1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =10.5V ~ 23V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz $\leqq$ f $\leqq$ 100kHz		58		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-0.9		mV/°C
Ripple Rejection	RR	V_{IN} =11.5V ~ 21.5V, f=120Hz, T_J =25°C	56	72		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

■ ELECTRICAL CHARACTERISTICS(Cont.)

For UTC LM7809 (V_{IN} =15V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	8.64	9.0	9.36	V
		V_{IN} =11.5V ~ 24V, I_{OUT}=5mA - 1.0A,P_D≦15W	8.55		9.45	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C,I_{OUT}=5mA - 1.0A			90	mV
		T_J =25°C,I_{OUT}=0.25A - 0.75A			45	mV
Line regulation	ΔV_{OUT}	V_{IN} =11.5V ~ 25 V, T_J =25°C			90	mV
		V_{IN} =11.5V ~ 24V, T_J =25°C, I_{OUT}=1.0A			90	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =11.5V ~ 24V			1.0	mA
		I_{OUT}=5mA – 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		58		µV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-1.1		mV/°C
Ripple Rejection	RR	V_{IN} =12.5V ~ 22.5V,f=120Hz, T_J =25°C	56	72		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

For UTC LM7810 (V_{IN} =16V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	9.60	10.0	10.40	V
		V_{IN} =12.5V ~ 25V, I_{OUT}=5mA - 1.0A,P_D≦15W	9.50		10.50	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C,I_{OUT}=5mA - 1.0A			100	mV
		T_J =25°C,I_{OUT}=0.25A - 0.75A			50	mV
Line regulation	ΔV_{OUT}	V_{IN} =13V ~ 25V, T_J =25°C			100	mV
		V_{IN} =13V ~ 25V, T_J =25°C,I_{OUT}=1.0A			100	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =12.6V ~ 25V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		58		µV
Temperature coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-1.1		mV/°C
Ripple Rejection	RR	V_{IN} =13V - 23V,f=120Hz, T_J =25°C	56	72		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

■ ELECTRICAL CHARACTERISTICS(Cont.)

For UTC LM7812 (V_{IN} =19V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	11.52	12.0	12.48	V
		V_{IN} =14.5V ~ 27V, I_{OUT}=5mA - 1.0A, P_D≦15W	11.40		12.60	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A			120	mV
		T_J =25°C, I_{OUT}=0.25A - 0.75A			60	mV
Line regulation	ΔV_{OUT}	V_{IN} =14.5V ~ 30V, T_J =25°C			120	mV
		V_{IN} =14.6V ~ 27V, T_J =25°C, I_{OUT}=1.0A			120	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =14.5V ~ 30V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		75		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-1.5		mV/°C
Ripple Rejection	RR	V_{IN} =15V - 25V, f=120Hz, T_J =25°C	55	72		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

For UTC LM7815 (V_{IN} =23V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	14.40	15.0	15.60	V
		V_{IN} =17.5V ~ 30V, I_{OUT}=5mA - 1.0A, P_D≦15W	14.25		15.75	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A			150	mV
		T_J =25°C, I_{OUT}=0.25A - 0.75A			75	mV
Line regulation	ΔV_{OUT}	V_{IN} =18.5V ~ 30V, T_J =25°C			150	mV
		V_{IN} =17.7V ~ 30V, T_J =25°C, I_{OUT} =1.0A			150	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =17.5V ~ 30V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		90		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-1.8		mV/°C
Ripple Rejection	RR	V_{IN} =18.5V ~ 28.5V, f=120Hz, T_J =25°C	54	70		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

■ ELECTRICAL CHARACTERISTICS(Cont.)

For UTC LM7818 (V_{IN} =27V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	17.28	18.0	18.72	V
		V_{IN} =21V ~ 33V, I_{OUT}=5mA - 1.0A, P_D≦15W	17.10		18.90	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C,I_{OUT}=5mA - 1.0A			180	mV
		T_J =25°C,I_{OUT}=0.25A - 0.75A			90	mV
Line regulation	ΔV_{OUT}	V_{IN} =21V ~ 33V,Tj=25°C			180	mV
		V_{IN} =21V ~ 33V, T_J =25°C, I_{OUT} =1.0A			180	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =21.5V ~ 33V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		110		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-2.2		mV/°C
Ripple Rejection	RR	V_{IN} =22V - 32V,f=120Hz, T_J =25°C	53	69		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

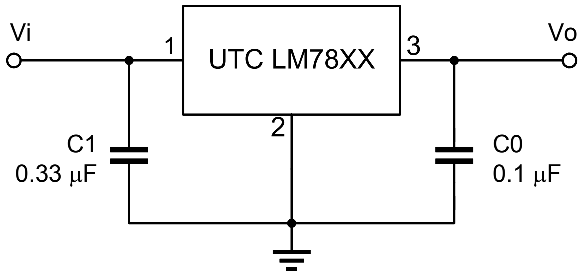
For UTC LM7824 (V_{IN} =33V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Voltage	V_{OUT}	T_J =25°C, I_{OUT}=5mA - 1.0A	23.04	24.0	24.96	V
		V_{IN} =27V ~ 38V, I_{OUT}=5mA - 1.0A, ,P_D≦15W	22.80		25.20	V
Dropout Voltage	V_D	T_J =25°C		2.0		V
Load Regulation	ΔV_{OUT}	T_J =25°C,I_{OUT}=5mA - 1.0A			240	mV
		T_J =25°C,I_{OUT}=0.25A - 0.75A			120	mV
Line regulation	ΔV_{OUT}	V_{IN} =27V ~ 38V, T_J =25°C			240	mV
		V_{IN} =27V ~ 38V, T_J =25°C,I_{OUT}=1.0A			240	mV
Quiescent Current	I_Q	T_J =25°C, I_{OUT}≦1.0A			8.0	mA
Quiescent Current Change	ΔI_Q	V_{IN} =28V ~ 38V			1.0	mA
		I_{OUT}=5mA - 1.0A			0.5	mA
Output Noise Voltage	eN	10Hz≦f≦100kHz		170		μV
Temperature Coefficient of Vo	ΔVo/ΔT	I_{OUT}=5mA		-2.8		mV/°C
Ripple Rejection	RR	V_{IN} =28V - 38V,f=120Hz, T_J =25°C	50	66		dB
Peak Output Current	I_{PEAK}	T_J =25°C		1.8		A
Short-Circuit Current	I_{SC}	V_{IN} =35V, T_J =25°C		250		mA

Note 1: The Maximum steady state usable output current are dependent on input voltage, heat sinking, lead length of the package and copper pattern of PCB. The data above represents pulse test conditions with junction temperatures specified at the initiation of test.

Note 2: Power dissipation<0.5W

■ APPLICATION CIRCUIT



Note 1: To specify an output voltage, substitute voltage value for "XX".

2: Bypass capacitors are recommended for optimum stability and transient response and should be located as close as possible to the regulators.

■ TYPICAL CHARACTERISTICS

Fig.1 Ambient temperature vs. Power dissipation

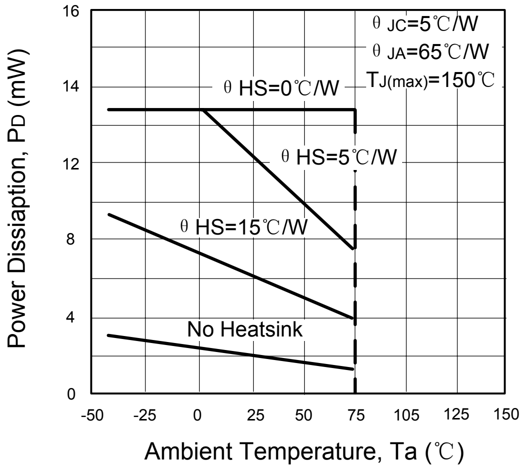


Fig.2 Output Voltage vs. Ambient temperature

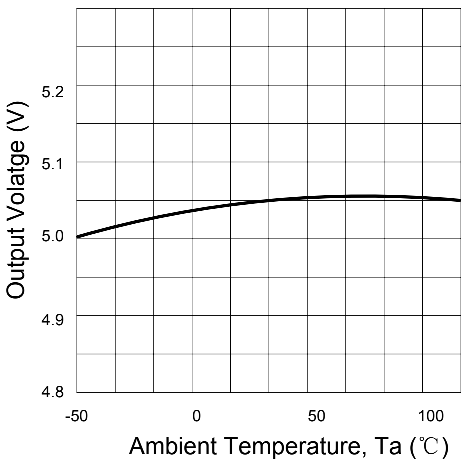
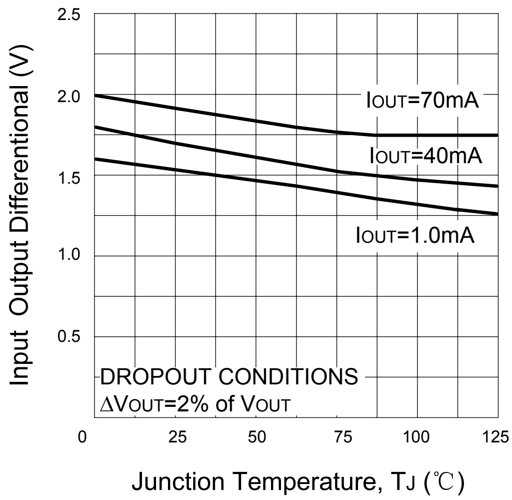


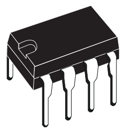
Fig.3 Dropout Voltage



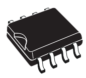
MC34063A
MC34063E

DC-DC CONVERTER CONTROL CIRCUITS

- OUTPUT SWITCH CURRENT IN EXCESS OF 1.5A
- 2% REFERENCE ACCURACY
- LOW QUIESCENT CURRENT: 2.5mA (TYP.)
- OPERATING FROM 3V TO 40V
- FREQUENCY OPERATION TO 100KHz
- ACTIVE CURRENT LIMITING



DIP-8



SO-8

DESCRIPTION

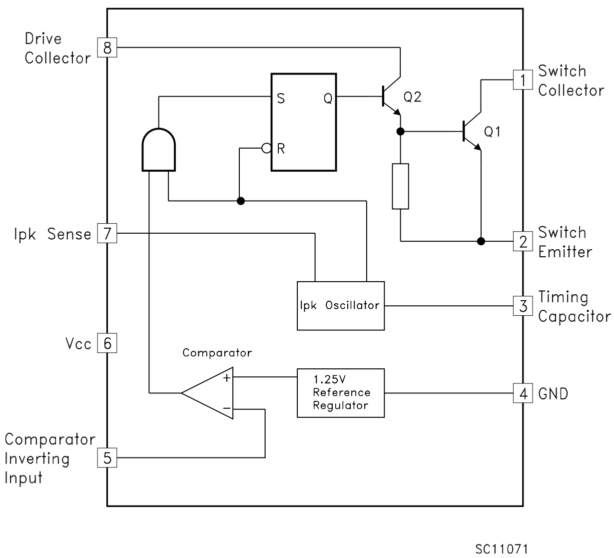
The MC34063A/E series is a monolithic control circuit delivering the main functions for DC-DC voltage converting.

The device contains an internal temperature compensated reference, comparator, duty cycle controlled oscillator with an active current limit circuit, driver and high current output switch.

Output voltage is adjustable through two external resistors with a 2% reference accuracy.

Employing a minimum number of external components the MC34063A/E devices series is designed for Step-Down, Step-Up and Voltage-Inverting applications.

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CC}	Power Supply Voltage	50	V
V_{ir}	Comparator Input Voltage Range	-0.3 to 40	V
V_{SWC}	Switch Collector Voltage	40	V
V_{SWE}	Switch Emitter Voltage (VSWC = 40V)	40	V
V_{CE}	Switch Collector toEmitter Voltage	40	V
V_{dc}	Driver Collector Voltage	40	V
I_{dc}	Driver Collector Current	100	mA
I_{SW}	Switch Current	1.5	A
P_{tot}	Power Dissipation at T_{amb} = 25 ^oC (for **Plastic Package**) (for **SOIC Package**)	1.25 0.625	W
T_{op}	Operating Ambient Temperature Range (for **AC and EC SERIES**) (for **AB SERIES**) (for **EB SERIES**)	0 to 70 - 40 to 85 - 40 to 125	^oC ^oC ^oC
T_{stg}	Storage Temperature Range	- 40 to 150	^oC

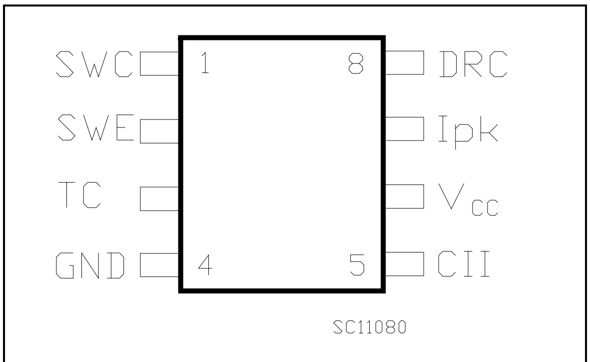
Absolute Maximum Rating are those values beyond which damage to the device may occur.
Functional operation under these condition is not implied.

THERMAL DATA

Symbol	Parameter	DIP-8	SO-8	Unit
$R_{thj-amb}$	Thermal Resistance Junction-ambient (*) Max	100	160	$^oC/W$

(*) This value depends from thermal design of PCB on which the device is mounted.

CONNECTION DIAGRAM (top view)



PIN CONNECTIONS

Pin No	Symbol	Name and Function
1	SWC	Switch Collector
2	SWE	Switch Emitter
3	TC	Timing Capacitor
4	GND	Ground
5	CII	Comparator Inverting Input
6	V_{CC}	Voltage Supply
7	I_{pk}	I_{pk} Sense
8	DRC	Voltage Driver Collector

ORDERING NUMBERS

Type	DIP-8	SO-8	SO-8 (tape & reel)
MC34063AB (*)	MC34063ABN	MC34063ABD	MC34063ABD-TR
MC34063AC (*)	MC34063ACN	MC34063ACD	MC34063ACD-TR
MC34063EB	MC34063EBN	MC34063EBD	MC34063EBD-TR
MC34063EC	MC34063ECN	MC34063ECD	MC34063ECD-TR

(*) The "A" version is not recommended for new designs.

ELECTRICAL CHARACTERISTICS (Refer to the test circuits, V_{CC} = 5V, T_a = T_{LOW} to T_{HIGH}, unless otherwise specified, see note 2)

OSCILLATOR

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
f_{OSC}	Frequency	V_{pin5} = 0 V C_T = 1 nF T_a = 25 °C	24	33	42	KHz
I_{chg}	Charge Currernt	V_{CC} = 5 to 40 V T_a = 25 °C	24	33	42	µA
I_{dischg}	Discharge Current	V_{CC} = 5 to 40 V T_a = 25 °C	140	200	260	µA
I_{dischg}/I_{chg}	Discharge to Charge Current Ratio	Pin 7 = V_{CC} T_a = 25 °C	5.2	6.2	7.5	
$V_{ipk(sense)}$	Current Limit Sense Voltage	I_{chg} = I_{dischg} T_a = 25 °C	250	300	350	mV

OUTPUT SWITCH

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$V_{CE(sat)}$	Saturation Voltage, Darlington Connection	I_{SW} = 1 A Pins 1, 8 connected		1	1.3	V
$V_{CE(sat)}$	Saturation Voltage	I_{SW} = 1 A R_{pin8} = 82 Ω to V_{CC}, Forced β ~ 20		0.45	0.7	V
h_{FE}	DC Current Gain	I_{SW} = 1 A V_{CE} = 5 V T_a = 25 °C	50	120		
$I_{C(off)}$	Collector Off-State Current	V_{CE} = 40 V		0.01	100	µA

COMPARATOR

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V_{th}	Threshold Voltage	T_a = 25 °C T_a = T_{LOW} to T_{HIGH}	1.225 1.21	1.25	1.275 1.29	V V
Reg_{line}	Threshold Voltage Line Regulation	V_{CC} = 3 to 40 V		1	5	mV
I_{IB}	Input Bias Current	V_{IN} = 0 V		-5	-400	nA

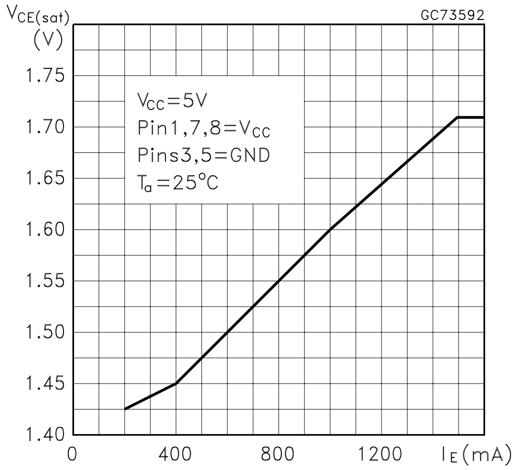
TOTAL DEVICE

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
I_{CC}	Supply Current	V_{CC} = 5 to 40 V C_T = 1 nF Pin 7 = V_{CC} V_{pin5} > V_{th} Pin 2 = GND Remaining pins open for **MC34063A** for **MC34063E**		2.5 1.5	4 4	mA mA
$V_{START-UP}$	Start-up Voltage (note 4)	T_a = 25 °C C_T = 1 µF Pin 5 = 0 V for **MC34063A** for **MC34063E**		2.1 1.5		V V

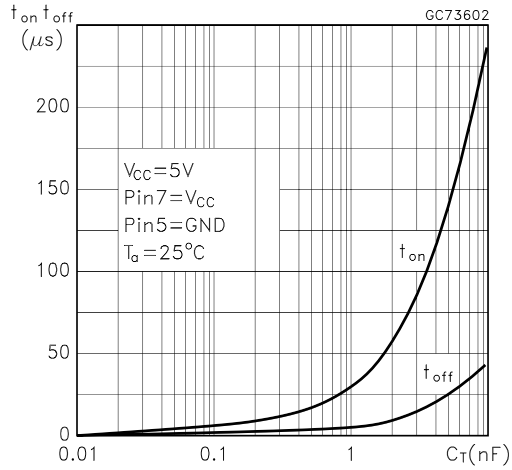
NOTES:
1) Maximum package power dissipation limit must be observed.
2) T_{LOW} = 0 °C, T_{HIGH} = 70 °C (AC and EC series); T_{LOW} = -40 °C, T_{HIGH} = 85 °C (AB series); T_{LOW} = -40 °C, T_{HIGH} = 125 °C (EB series).
3) If Darlington configuration is not used, care must be taken to avoid deep saturation of output switch. The resulting switch-off time may be adversely affected. In a Darlington configuration the following output driver condition is suggested:
Forced β of output current switch = $I_{COUTPUT}/(I_{CDRIVER}$ - 1mA*) ≥ 10
* Current less due to a built in 1KΩ antileakage resistor.
4) Start-up Voltage is the minimum Power Supply Voltage at which the internal oscillator begins to work.

TYPICAL ELECTRICAL CHARACTERISTICS

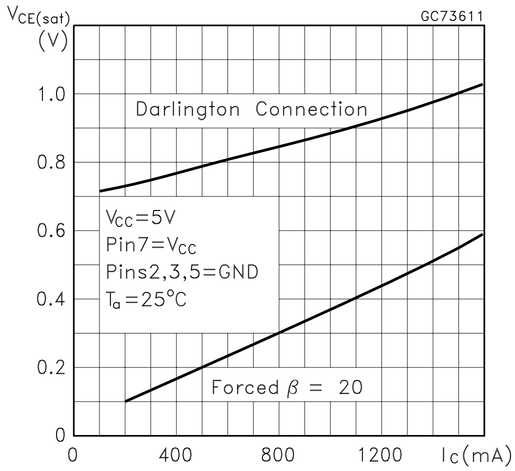
Emitter Follower Configuration Output Saturation Voltage vs Emitter Current



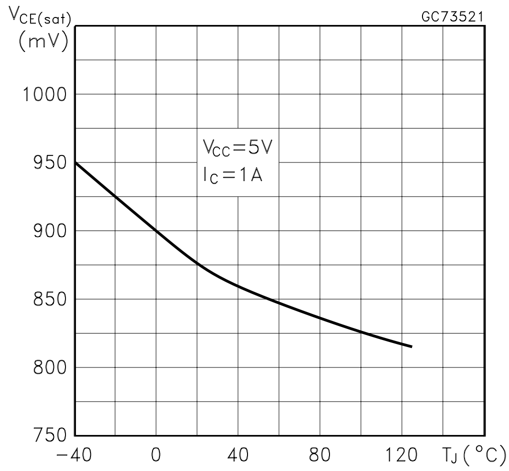
Output Switch ON-OFF Time vs Oscillator Timing Capacitor



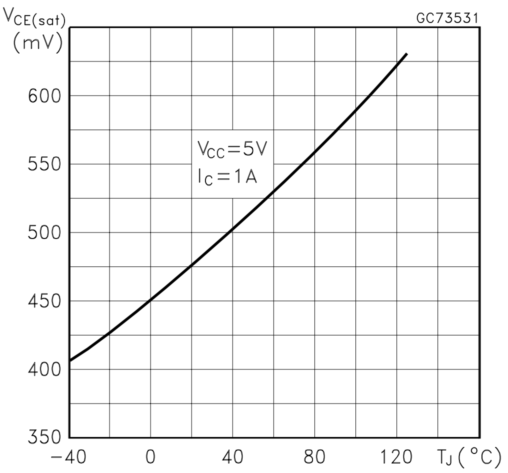
Common Emitter Configuration Output Switch Saturation Voltage vs Collector Current



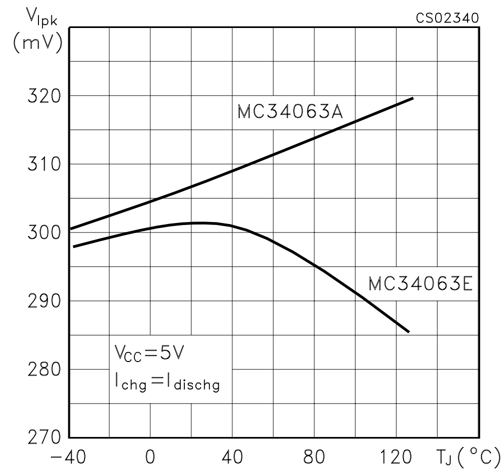
Darlington Configuration Collector Emitter Saturation Voltage ($V_{CE(sat)}$) vs Temperature



Power Collector Emitter Saturation Voltage ($V_{CE(sat)}$) vs Temperature

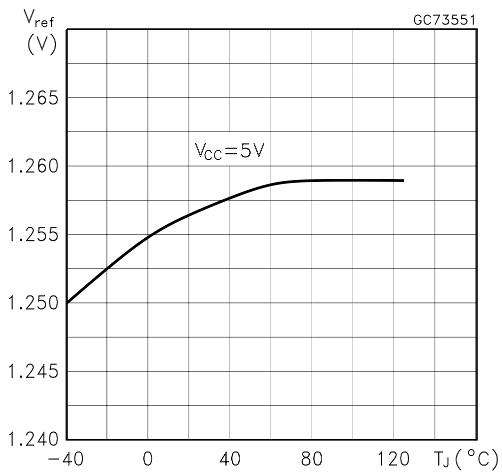


Current Limit Sense Voltage Voltage (V_{ipk}) vs Temperature

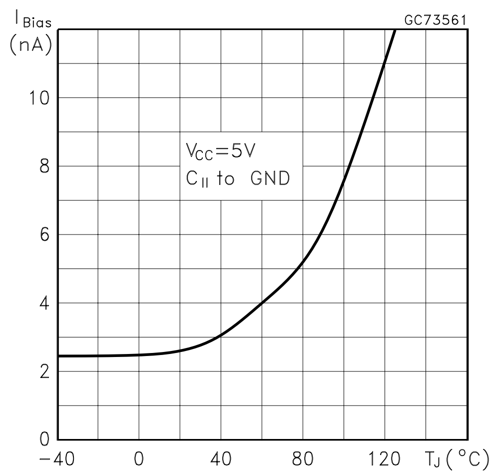


TYPICAL ELECTRICAL CHARACTERISTICS (Continued)

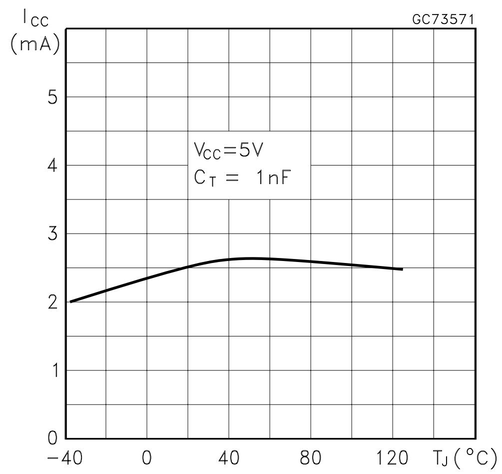
Reference Voltage vs Temperature



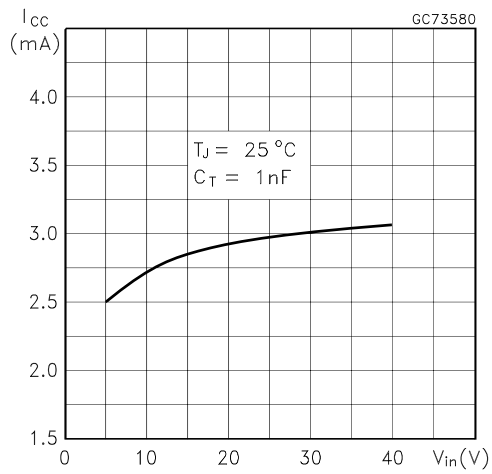
Bias Current vs Temperature



Supply Current vs Temperature

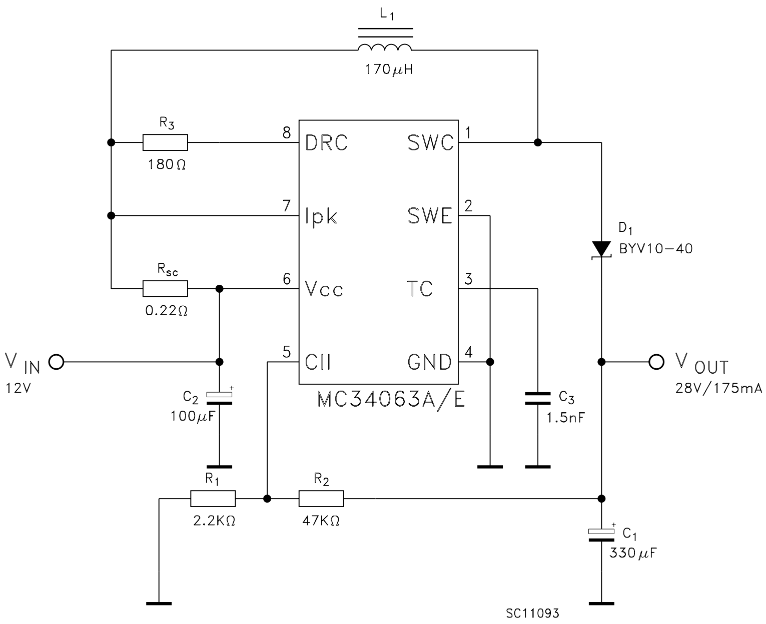


Supply Current vs Input Voltage

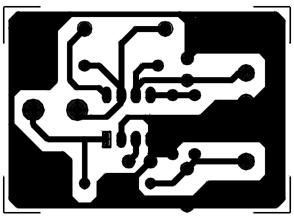


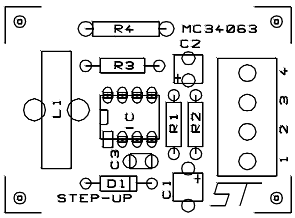
TYPICAL APPLICATION CIRCUIT

Step-Up Converter



Printed Demoboard



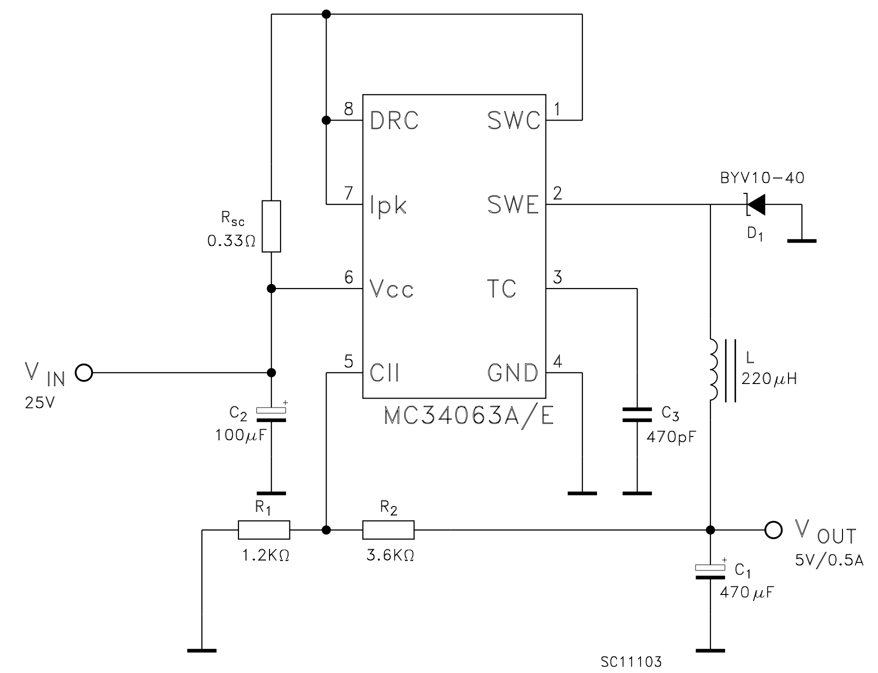


Symbol	Pin
Vout	1
GND	2
GND	3
Vin	4

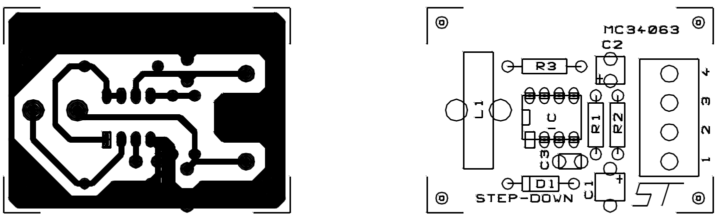
Test Condition (V_{OUT} = 28V)

Test	Conditions	Value (Typ.)	Unit
Line Regulation	V_{IN} = 8 to 16V, I_O = 175 mA	30	mV
Load Regulation	V_{IN} = 12V, I_O = 75 to 175 mA	10	mV
Output Ripple	V_{IN} = 12V, I_O = 175 mA	300	mV
Efficency	V_{IN} = 12V, I_O = 175 mA	89	%

Step-Down Converter



Printed Demoboard

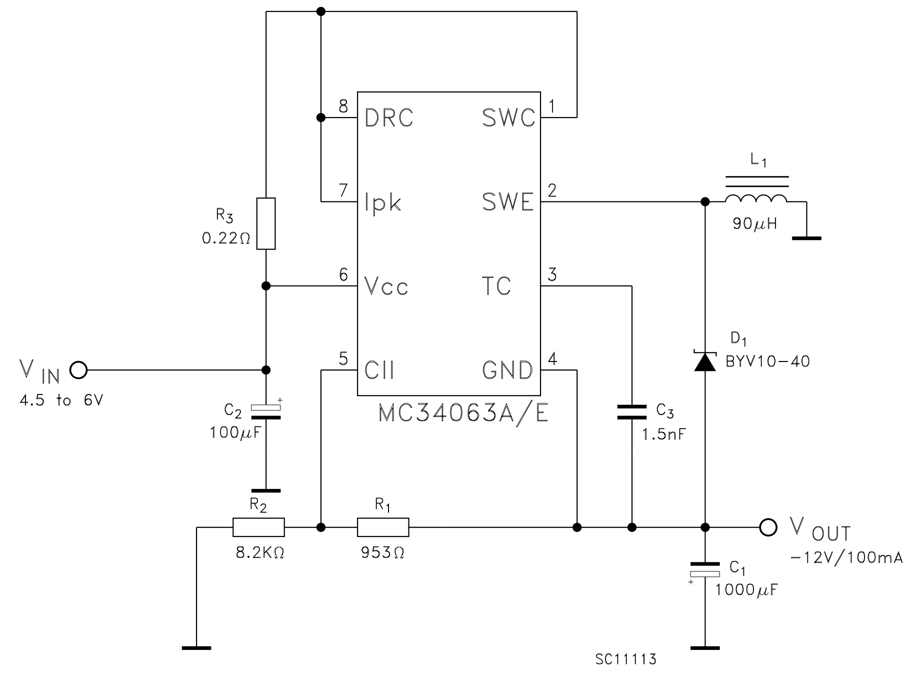


Symbol	Pin
Vout	1
GND	2
GND	3
Vin	4

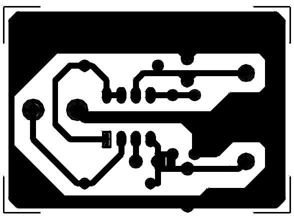
Test Condition (V_{OUT} = 5V)

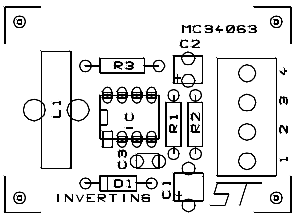
Test	Conditions	Value (Typ.)	Unit
Line Regulation	V_{IN} = 15 to 25V, I_O = 500 mA	5	mV
Load Regulation	V_{IN} = 25V, I_O = 50 to 500 mA	30	mV
Output Ripple	V_{IN} = 25V, I_O = 500 mA	100	mV
Efficency	V_{IN} = 25V, I_O = 500 mA	80	%
I_{SC}	V_{IN} = 25V, R_{LOAD} = 0.1Ω	1.2	A

Voltage Inverting Converter



Printed Demoboard





Symbol	Pin
Vout	1
GND	2
GND	3
Vin	4

Test Condition (V_{OUT} = -12V)

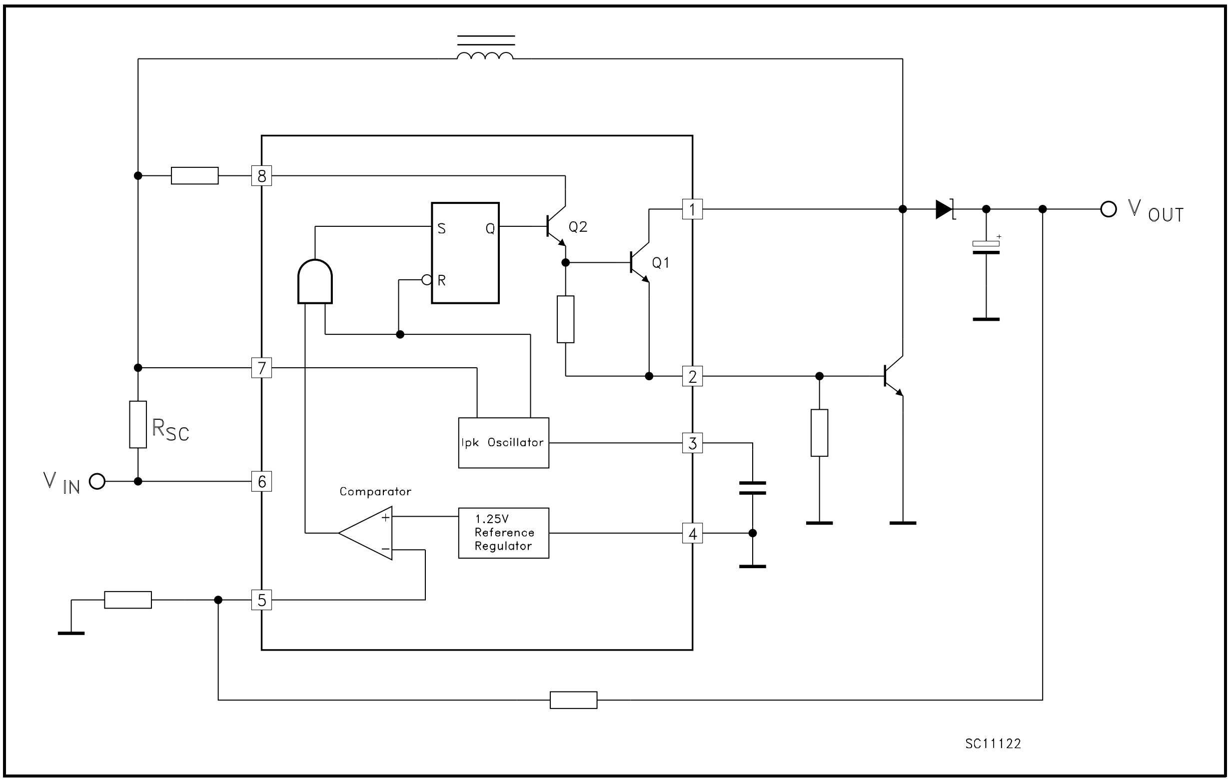
Test	Conditions	Value (Typ.)	Unit
Line Regulation	V_{IN} = 4.5 to 6V, I_O = 100 mA	15	mV
Load Regulation	V_{IN} = 5V, I_O = 10 to 100 mA	20	mV
Output Ripple	V_{IN} = 5V, I_O = 100 mA	230	mV
Efficency	V_{IN} = 5V, I_O = 100 mA	58	%
I_{SC}	V_{IN} = 5V, R_{ILOAD} = 0.1Ω	0.9	A

Calculation

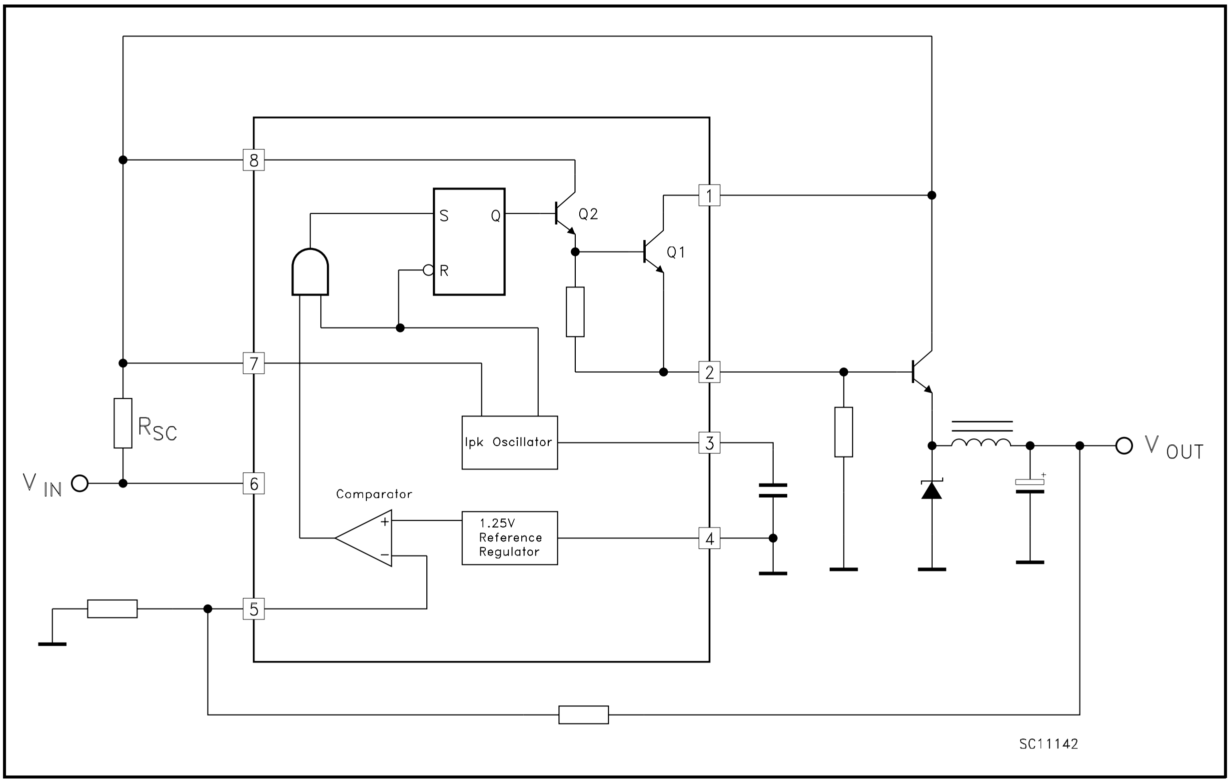
Parameter	Step-Up (Discontinuos mode)	Step-Down (Continuos mode)	Voltage Inverting (Discontinuos mode)
t_{on}/t_{off}	$\frac{V_{out}+V_F-V_{in(min)}}{V_{in(min)}-V_{sat}}$	$\frac{V_{out}+V_F}{V_{in(min)}-V_{sat}-V_{out}}$	$\frac{\lvert V_{out}\rvert+V_F}{V_{in}-V_{sat}}$
$(t_{on}+t_{off})max$	$1/f_{min}$	$1/f_{min}$	$1/f_{min}$
C_T	$4.5x10^{-5}t_{on}$	$4.5x10^{-5}t_{on}$	$4.5x10^{-5}t_{on}$
$I_{PK(switch)}$	$2I_{out(max)}[(t_{on}/t_{off})+1]$	$2I_{out(max)}$	$2I_{out(max)}[(t_{on}/t_{off})+1]$
R_{SC}	$0.3/I_{PK(switch)}$	$0.3/I_{PK(switch)}$	$0.3/I_{PK(switch)}$
C_O	$\cong\frac{I_{out}\,t_{on}}{V_{ripple\,(p-p)}}$	$\frac{I_{PK\,(switch)}(t_{on}+t_{off})}{8V_{ripple\,(p-p)}}$	$\cong\frac{I_{out}\,t_{on}}{V_{ripple\,(p-p)}}$
L(min)	$\frac{V_{in(min)}-V_{sat}}{I_{PK\,(switch)}}t_{on\,(max)}$	$\frac{V_{in(min)}-V_{sat}-V_{out}}{I_{PK\,(switch)}}t_{on\,(max)}$	$\frac{V_{in(min)}-V_{sat}}{I_{PK\,(switch)}}t_{on\,(max)}$

NOTES:
V_{sat} = Saturation voltage of the output switch
V_F = Foward voltage drop of the output rectifier
THE FOLLOWING POWER SUPPLY CHARACTERISTICS MUST BE CHOSEN:
V_{in} = Nominal input voltage
V_{out} = Desired output voltage, $|V_{out}| = 1.25(1+R_2/R_1)$
I_{out} = Desired output current
f_{min} = Minimum desired output switching frequency at the selected values of Vin and Io
V_{ripple} = Desired peak to peak output ripple voltage. In practice, the calculaed capacitor value will and to be increased due to its equivalent series resistance and board layout. The ripple voltage should be kept to a low value since it will directly affect the line and load regulation.

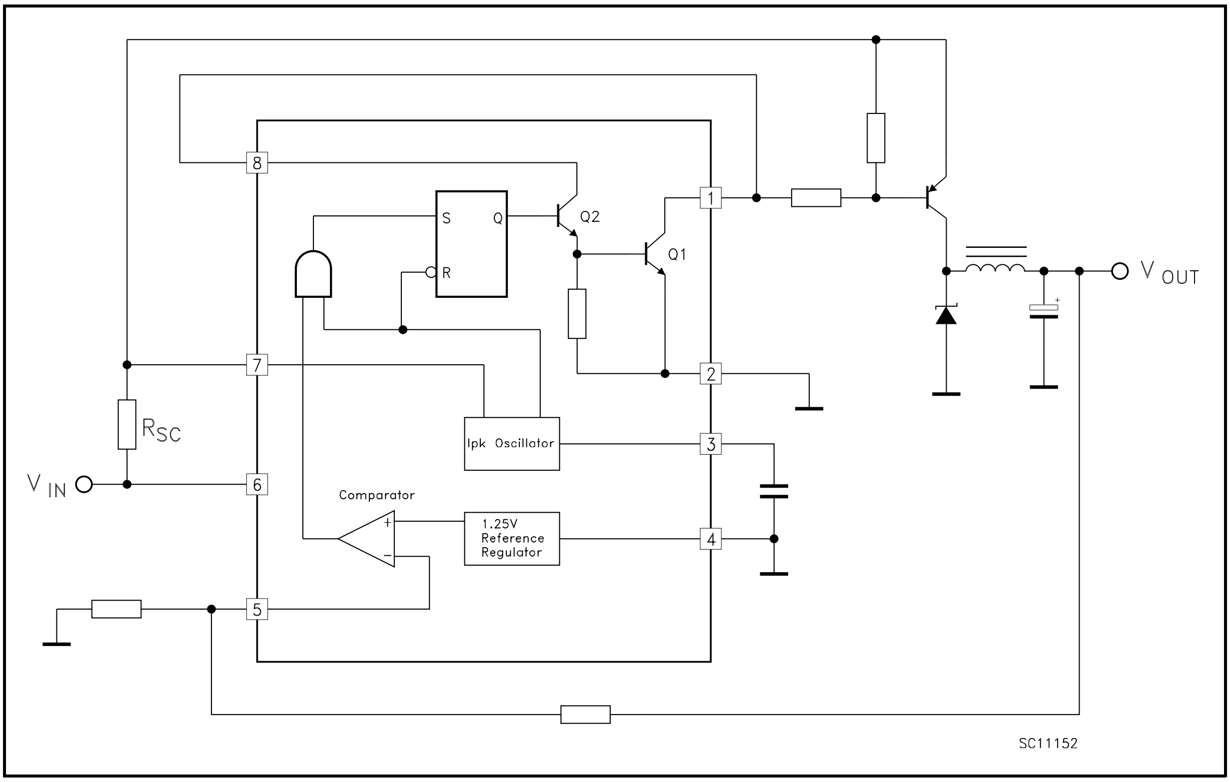
Step-up With External NPN Switch



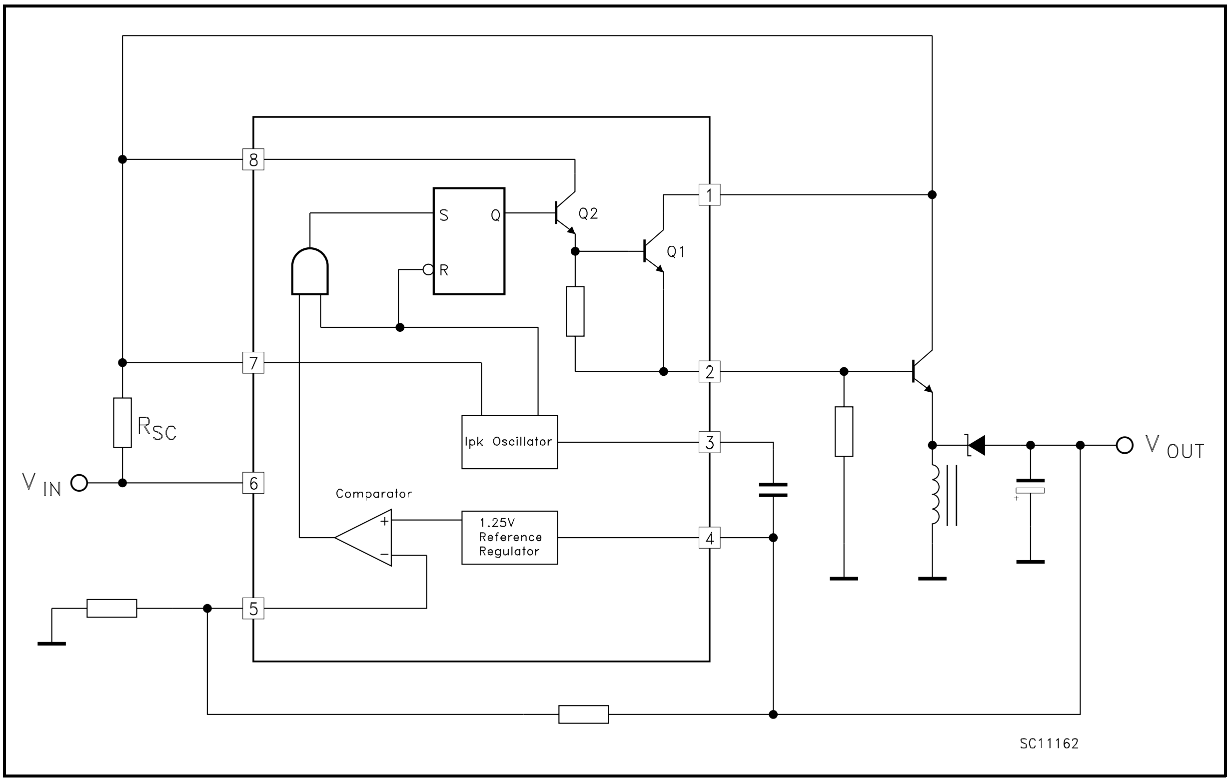
Step-down With External NPN Switch



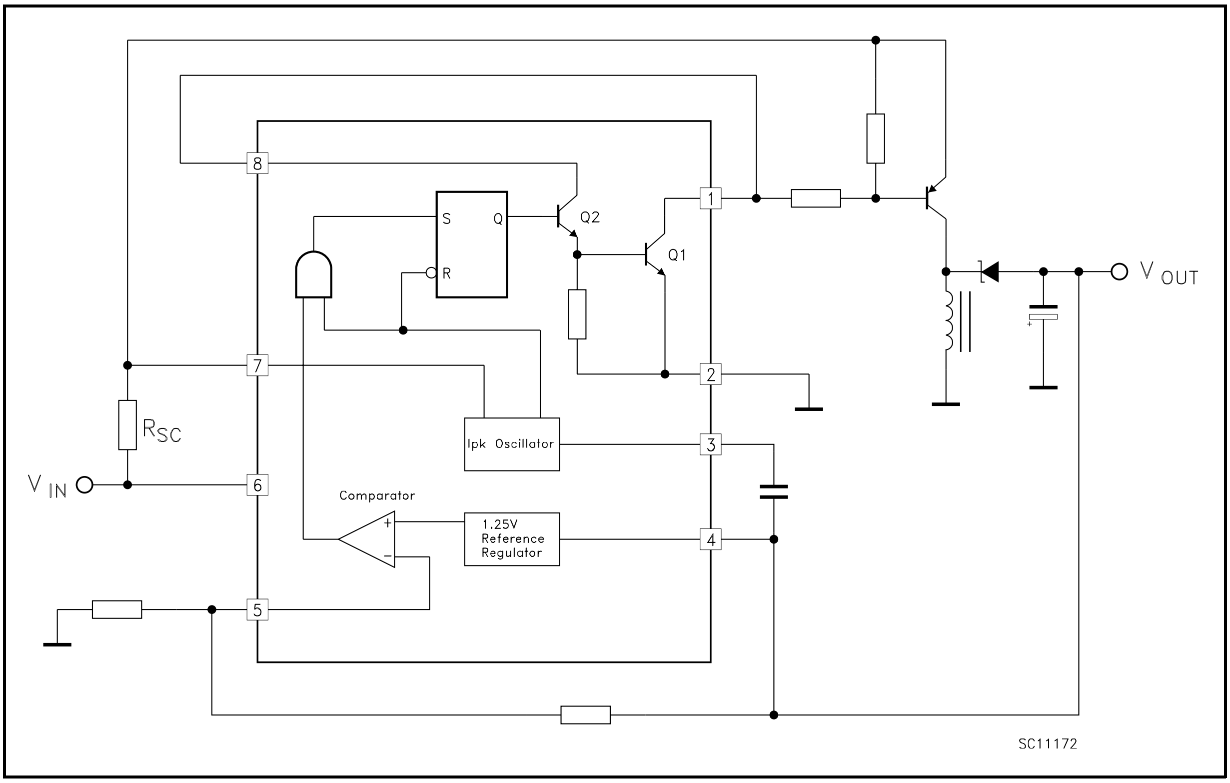
Step-down With External PNP Switch



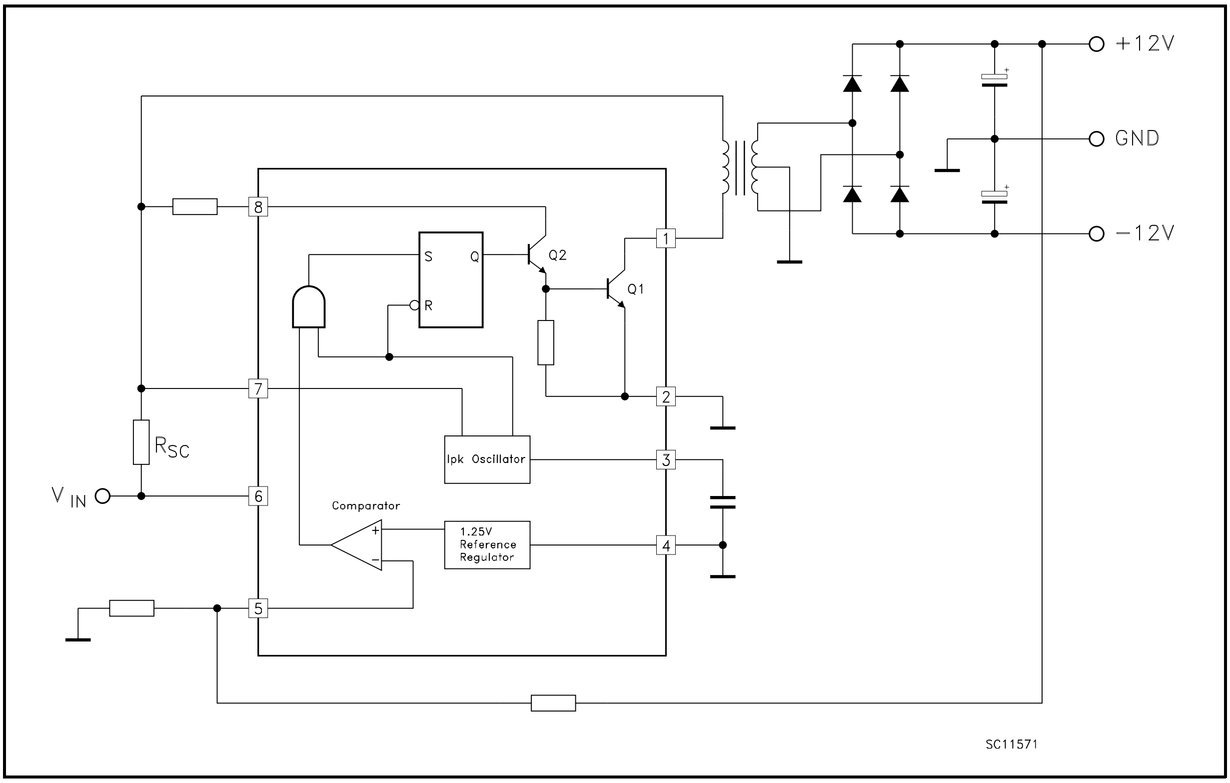
Voltage Inverting With External NPN Switch



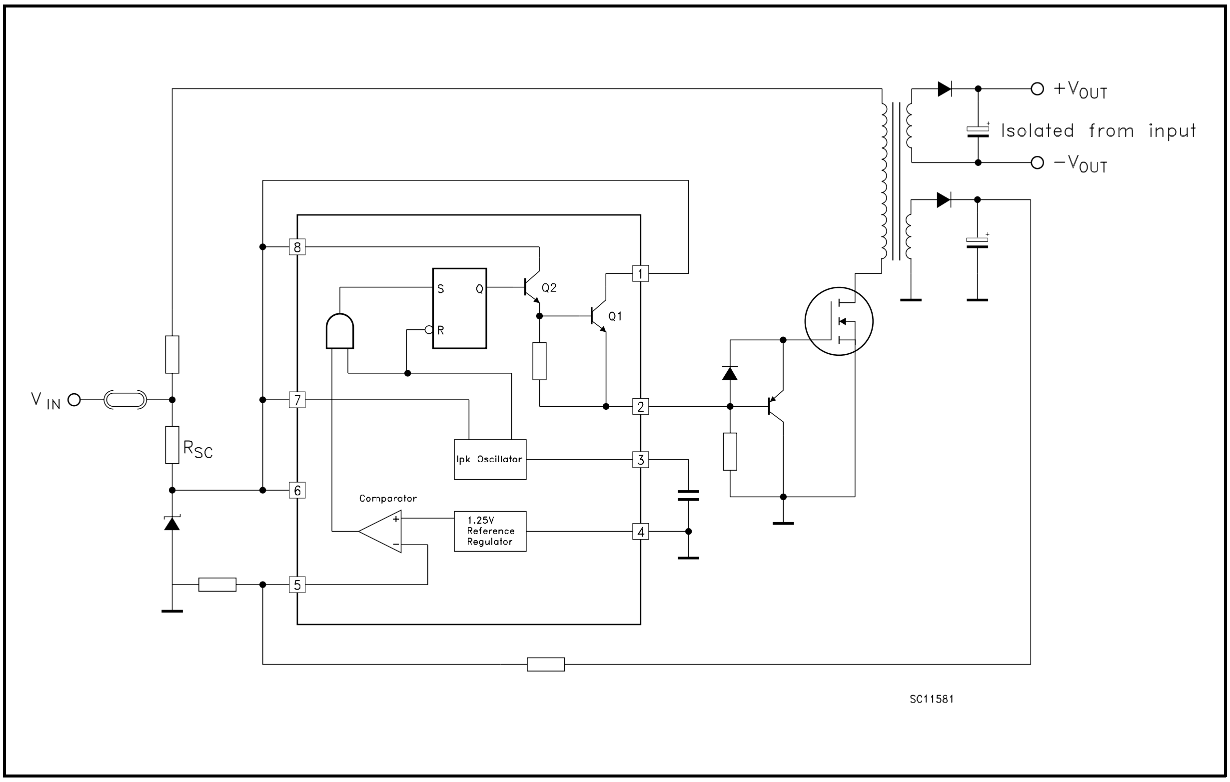
Voltage Inverting With External PNP Saturated Switch



Dual Output Voltage

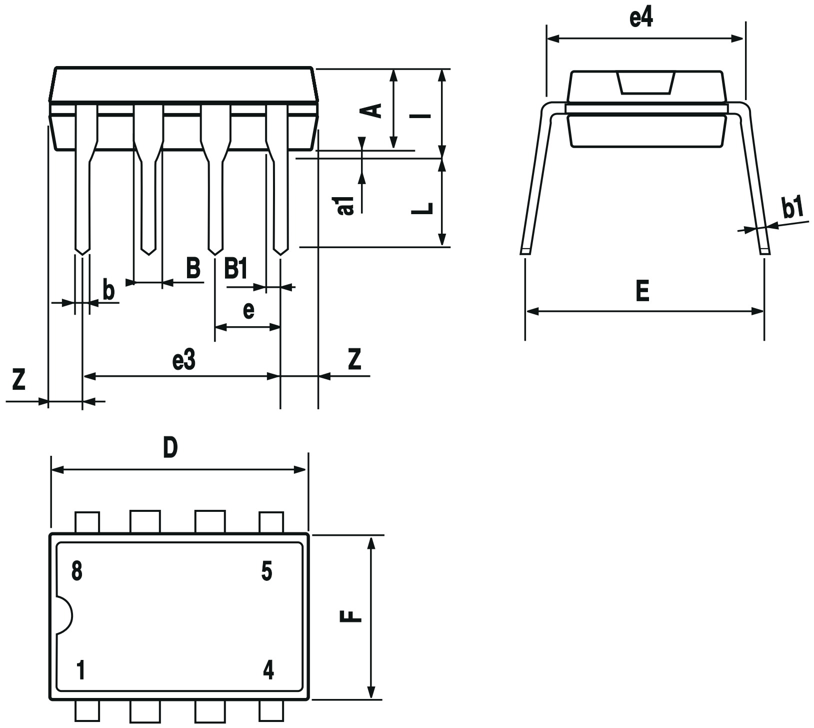


Higher Output Power, Higher Input Voltage



Plastic DIP-8 MECHANICAL DATA

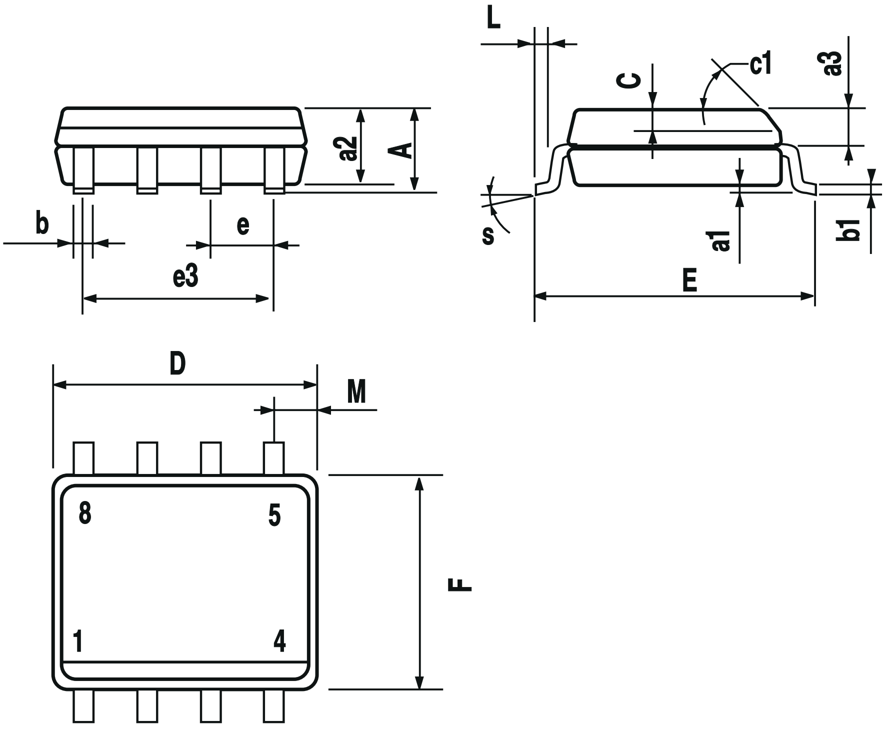
DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A		3.3			0.130	
a1	0.7			0.028		
B	1.39		1.65	0.055		0.065
B1	0.91		1.04	0.036		0.041
b		0.5			0.020	
b1	0.38		0.5	0.015		0.020
D			9.8			0.386
E		8.8			0.346	
e		2.54			0.100	
e3		7.62			0.300	
e4		7.62			0.300	
F			7.1			0.280
I			4.8			0.189
L		3.3			0.130	
Z	0.44		1.6	0.017		0.063



P001F

SO-8 MECHANICAL DATA

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			1.75			0.068
a1	0.1		0.25	0.003		0.009
a2			1.65			0.064
a3	0.65		0.85	0.025		0.033
b	0.35		0.48	0.013		0.018
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.019
c1	45 (typ.)					
D	4.8		5.0	0.188		0.196
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.14		0.157
L	0.4		1.27	0.015		0.050
M			0.6			0.023
S	8 (max.)					



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