



APPLICATION NOTE  
LIQUID CRYSTAL DISPLAY MODULE  
Voltage Generating Circuits for LCD Contrast Control

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## Voltage Generating Circuits for LCD Contrast Control

Most Liquid Crystal Display modules require a Positive or Negative voltage that is higher than the logic voltage used to power the LCD. This voltage, called VI, Vee or Bias voltage, requires a second power supply. If this power source is not available, the LCD Bias voltage must be generated from an existing voltage, either the logic voltage (+3.0-+5v) or a battery. This application note illustrates circuits for generating either a Positive or Negative LCD Bias voltage from such a voltage source.

The LCD Bias voltage is used to directly power the circuits that drive the LCD glass. This voltage sets the contrast level of the LCD. Since any changes in this voltage will cause a visible change in the contrast of the LCD, it must be regulated to more than about 200mV. Any noise or ripple on this signal may cause visible artifacts on the LCD so they must be kept below about 100mV.

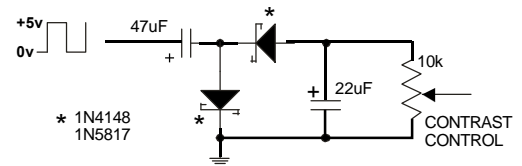
### Charge pump circuits:

The simplest and least expensive way of generating an LCD bias voltage is with a charge pump circuit. A charge pump generates a voltage that is some multiple of the peak to peak (P-P) voltage of the input square wave. The output can be either positive or negative.

These simple circuits can be used to generate the bias voltage for character type displays and small graphics types. They have the advantage of being very low in cost but are not regulated and cannot deliver much current. They are also sensitive to variations in the source voltage (Vdd) , so it cannot be driven directly from a battery.

The driving signal is usually derived from an existing clock signal or generated directly by an I/O pin on a microprocessor. The frequency of the signal can be anywhere from about 1kHz to 50kHz or higher. If the signal is above about 5kHz the simple 1N4148 diodes should be replaced by Schottky diodes such as the 1N5817. The capacitors should also be upgraded to low ESR types. The device generating the signal must be capable of delivering the load current times the multiplication value. In the circuit in Figure 1 driving a small character display the input signal should be able to sink and source at least 4mA.

**Fig 1** shows a simple charge pump circuit that generates a Negative 4v from a Positive 5v square wave. It is suitable for driving the VI line on an extended temperature LCD character module.



**Fig 1**

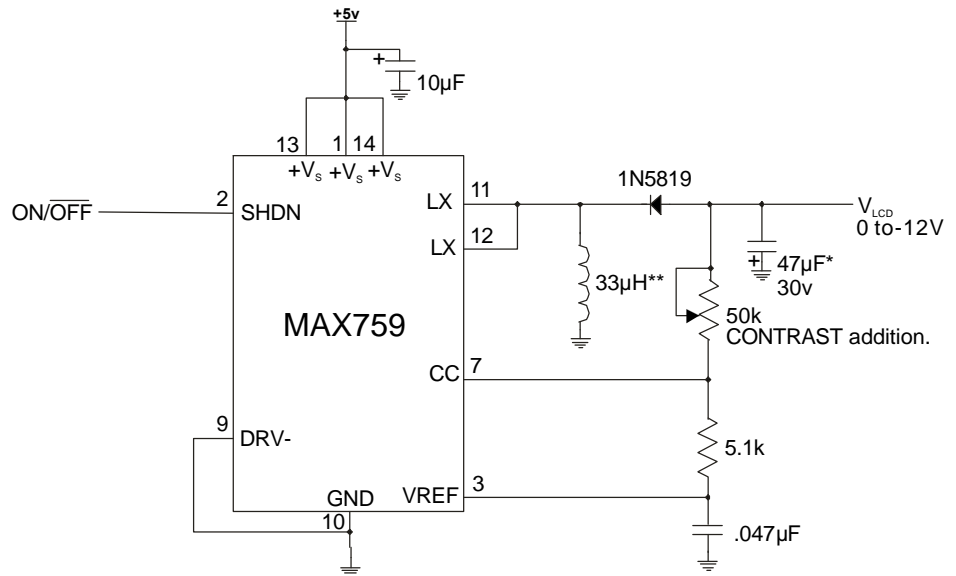
### Adjustable Voltage Inverter:

It might be desirable to allow the end user of a product to have access to the contrast adjustment. The circuit in **Fig 2** utilizes a pot to adjust the contrast voltage from 0v to -12v. The voltage output can be set to any range of voltages within the 0 to -12v limits by adding one or two resistors in series with the pot. The total resistance of the pot and any added resistors should not exceed 50k. If the end user is not to have control of the contrast the pot can be substituted with a fixed resistor to set the voltage to the

LCD to give the best contrast, which would also eliminate the need to adjust a pot during production. The efficiency is high enough to be used with battery operated equipment and the output can drive most small graphics displays, up to about 240 x 64 pixels resolution.

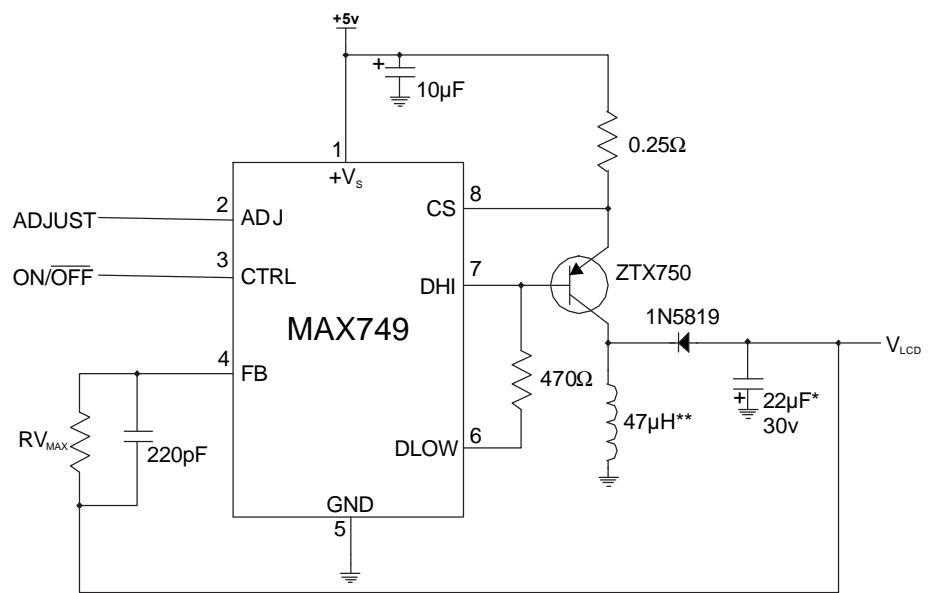
**Digitally adjustable inverter.**

Some applications require the user to have control of the contrast but do not lend themselves to using a pot to make the adjustment. The circuit in **Fig 3** allows a micro controller to adjust the  $V_L$  voltage in a very simple manner. It also provides an input to shut off the negative voltage so the display can be shut down by the micro controller if desired. This shutdown signal can also be used to properly sequence the power to the display during power-up and power-down sequences.



**Fig 2**

\* Tantalum or low ESR aluminum electrolytic  
 \*\* Less than 0.25 ohms DC resistance.



**Fig 3**

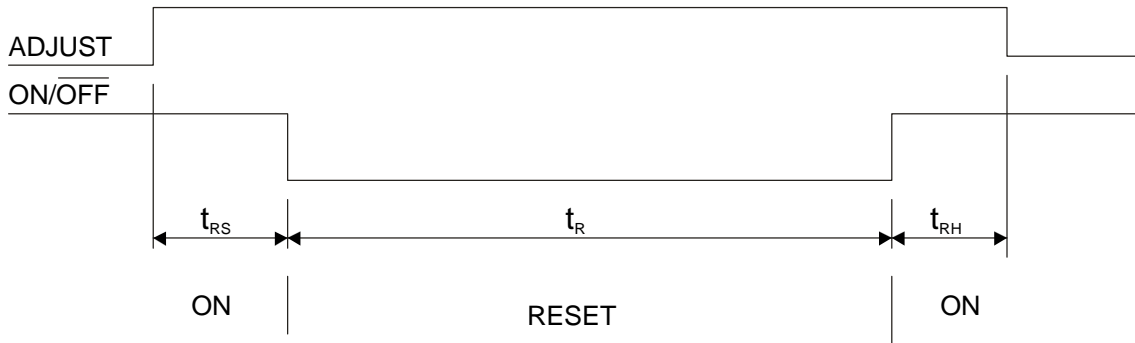
\* Tantalum or low ESR aluminum electrolytic  
 \*\* Less than 0.3ohms DC resistance.

ON/OFF signal. A logic 0 on this pin will turn the display off by removing the  $V_L$  voltage. If this signal is not needed, tie pin 3 to +5v.

Output voltage control. The maximum voltage is set using a single resistor,  $R_{VMAX}$ . See **Table 1**. The

| MAX OUTPUT VOLTAGE | -5V  | -8V  | -12V | -15V |
|--------------------|------|------|------|------|
| $R_{VMAX}$ (ohms)  | 240k | 360k | 580k | 750k |

output can then be adjusted from 33% to 100% of this value using the internal 64-step DAC / counter. On power-up or after a RESET command the output voltage is set to mid-range which is 67% of the maximum voltage. Each rising edge of the ADJUST signal increments the DAC output. When the DAC reaches 100% output, the next pulse will cause it to wrap-around to the 33% value.



**Fig 4**

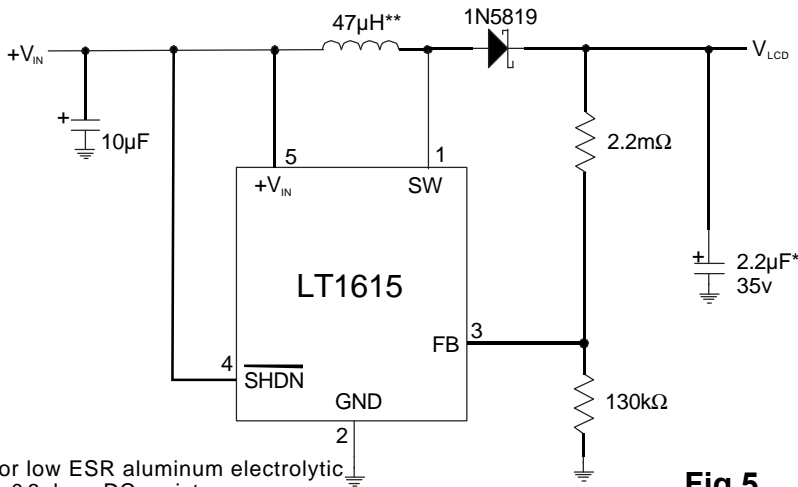
$t_R$  = Minimum pulse width, 25nS typ. 85nS max.  
 $t_{RS}, t_{RH}$  = Minimum setup/hold, 0nS min., 0nS min.

A RESET is accomplished by setting the ADJUST line high and then setting the ON/OFF line low for longer than 400nS. See **Fig 4**.

### High Voltage Circuits for Larger Panels:

Modern 1 / 4 VGA to full VGA size panels require Vee voltages above 20v. Most monochrome panels require a Negative Vee voltage while most color panels require a Positive voltage. Many of these panels are used in hand held, battery operated, applications and require very efficient conversion using a supply voltage that changes as the charge on the batteries is gradually depleted.

Several semiconductor manufactures have responded to this need with new devices made especially for this application. While the voltage converter can be done "in-house" it is usually not economical to do so because of the complexity of a circuit that has the regulation qualities and the efficiency required.



**Fig 5** is a circuit based on the *Linear Technologies* LT1615 series chips. The circuit shown here generates a Positive voltage for a small 1 / 4 VGA (320x240) color graphics display that could be used in a palm sized PC running Windows CE.

\* Tantalum or low ESR aluminum electrolytic  
 \*\* Less than 0.3ohms DC resistance.

**Fig 5**

A Negative voltage version LT1617 is also available. The device in this example runs from a pair of AA batteries and must produce a stable output voltage with an input that varies from 2.0v ~ 3.2v.

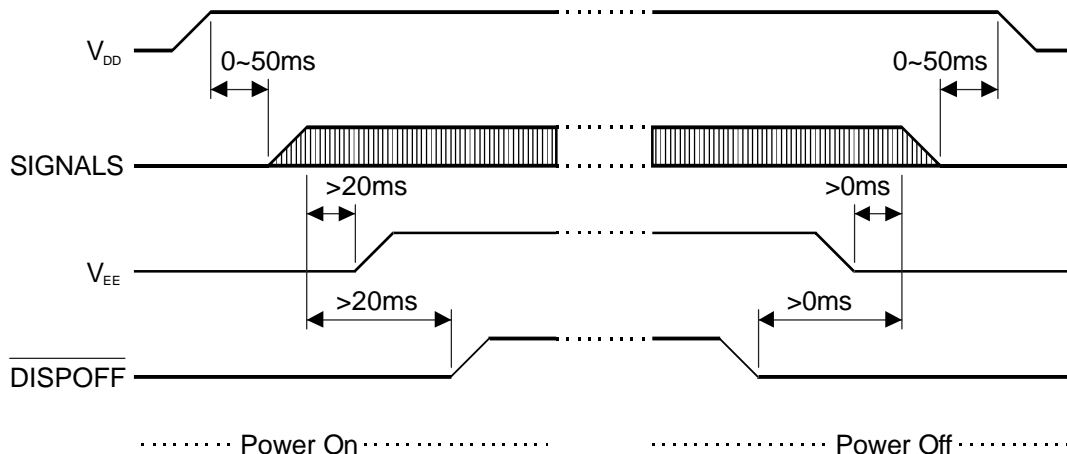
## General Circuit Considerations:

All components associated with the circuits in **Fig 2, 3 and 5** should be placed physically close to the IC. The decoupling capacitor on the input voltage line should be placed as close to the  $V_{IN}$  and GND pins of the IC as possible.

## Power Sequencing Considerations:

The order in which the power supplies are applied to an LCD, power sequencing, must be considered when designing an LCD bias power supply. The power sequencing requirement can be summarized by stating that the  $V_{EE}$  ( $V_L$ ) must never be present without  $V_{DD}$  also being present. If this condition exists, even for a short period of time, the display may be permanently damaged. The desired power sequencing for graphics type LCDs with an external controller is shown in Figure 6. For graphics type LCDs with a built in controller you can ignore the "signal" line as this is taken care of in the controller at power on time. For character displays only the  $V_{DD}$  and  $V_{EE}$  ( $V_L$ ) lines need be considered.

All of the circuits described here, except the charge pump in **Fig 1**, have provisions to shut down the voltage



**Fig 6**

generator with a logic signal. Using this signal the generator IC is kept in the shutdown mode until  $V_{DD}$  is stable and the LCD controller has been initialized and has started to scan the display. At this time  $V_{EE}$  can be applied to the display safely. The turn off procedure is just the reverse of the turn on procedure.

## Sources:

LinearTechnology  
1630McCarthyBlvd.  
Milpitas,CA95035  
(408)432-1900  
www.liner-tech.com

Maxim Integrated Products, Inc.  
120 San Gabriel Dr.  
Sunnyvale, CA 94086  
(408) 737-7600  
www.maxim-ic.com