TB1098

Low-Power Techniques for LCD Applications

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INTRODUCTION

Low power is often a requirement in LCD applications. The low-power features of PIC® microcontrollers and the ability to drive an LCD directly can help in meeting this requirement. While the LCD Driver module makes driving LCDs very easy, there are important factors to take into account in configuring the module so that application can be optimized for low power.

Two specific factors that affect power consumption with respect to the LCD Driver module are the resistor ladder, which generates the bias voltages for the LCD waveforms, and the clock source configuration. By intelligently selecting a resistor ladder size and clock source best suited for the application, an LCD application using PIC microcontrollers can be optimized for low power.

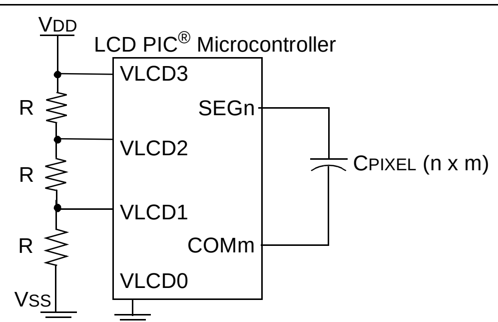
Resistor Ladder Sizing

Voltage is provided to the LCD Driver module in one of three configurations (Static, 1/2, and 1/3 biasing). In 1/2 and 1/3 biasing, a resistor ladder is used to provide the bias levels for the LCD Driver. In Static mode, V_{DD} must be provided and no resistor ladder is needed. The goal is to maximize the resistor ladder values, as the resistor ladder will draw current at all times.

Resistor value is constrained by two factors: the refresh rate of the LCD and the size of the LCD. The LCD module is essentially an analog multiplexer that connects the LCD bias voltages to various segment and common pins that connect to LCD pixels.

Shown below is an LCD circuit.

FIGURE 1: LCD CIRCUIT



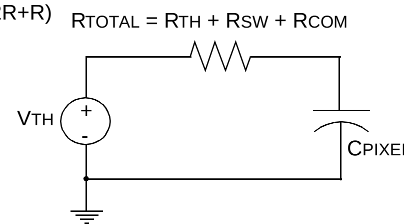
Each pixel/segment of the LCD display can be modeled as a capacitor. Including both the internal common resistance and switch circuit multiplexing resistance, the circuit can be simplified to a Thévenin equivalent circuit shown below. V_{TH} is equal to either 2/3 V_{DD} or 1/3 V_{DD} for cases where the Thévenin resistance in non-zero.

FIGURE 2: SIMPLIFIED LCD CIRCUIT

$R_{TH} = (2R*R)/(2R+R)$
$R_{TH} = 2R^2/3R$
$R_{TH} = 2R/3$

$R_{SW} = 4.7K$

$R_{COM} = 0.4K$



Note: R_{SW} and R_{COM} are estimates.

Using the simplified circuit, the step response of the voltage across each pixel can be described by the following equation:

EQUATION 1:

$$V_{PIXEL} = V_{TH}\ (1 - e^{-t/(R_{TOTAL}C_{PIXEL})})$$

Manipulation of this equation (see Equation 2) dictates that it will take approximately 4 time constants (RC) for the pixel voltage to reach 98% of V_{TH}. Ideally, the resistor ladder should be sized such that pixel voltage reaches at least 98% of V_{TH}.

EQUATION 2:

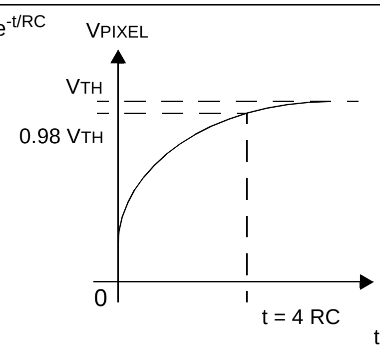
$V_{PIXEL}/V_{TH} = 1 - e^{-t/RC}$

$98\% = 1 - e^{-t/RC}$

$2\% = e^{-t/RC}$

$\ln(.02) = -t/RC$

$t = \sim 4\ RC$



This analysis says that the resistor ladder can be made larger if:

1. More time is allowed for the pixel to charge (slower refresh rate), or
2. The capacitance of each pixel is smaller (smaller size display).

Refresh rate should be as slow as possible in order to maximize resistor ladder size. These settings are configured in <LP3:LP0> bits of the LCDPS register. Keep in mind however, that human visual perception can detect a frequency of 30 Hz or less.

The capacitance of each LCD pixel depends on its size. A larger display will typically have more capacitance than a smaller display. Therefore, a larger display will require smaller resistors.

While it is possible to calculate the maximum resistor value analytically (see LCD Tips n' Tricks (DS41261) at www.microchip.com/lcd), these calculations should be used as a guide rather than a solution. Ultimately, it is a reiterative bench testing exercise to determine whether or not resistor size is optimal.

If the resistor value is too large, some pixels will be darker than others and the contrast will not be constant.

Shown below are two screenshots of LCD segment waveforms, with a 10K resistor ladder (Figure 3) and 220K resistor ladder (Figure 4).

FIGURE 3: 10K RESISTOR LADDER WAVEFORM

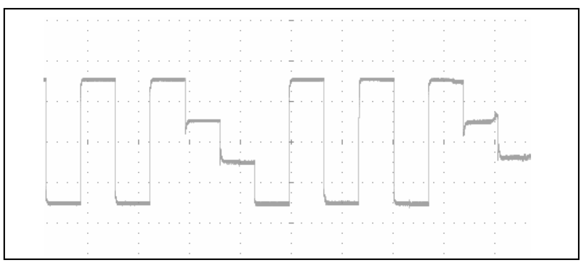
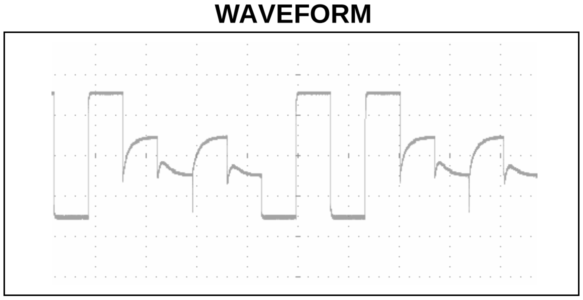


FIGURE 4: 220K RESISTOR LADDER WAVEFORM



The segment output waveforms from the PIC microcontroller in Figure 3 are sized based on the PIC microcontroller 10 kΩ data sheet design guidance. The LCD had good contrast.

In the next figure, Figure 4, the resistor value selected for the resistor ladder was 220 kΩ. The output waveforms show a much more obvious RC charge and discharge that does not meet the 4 time constant requirement. Nonetheless, the LCD display looked exactly the same as the LCD display with a 10 kΩ resistor ladder.

The lessons from this are that there is not an analytic solution to calculating the ideal resistor values for the voltage divider. Bench testing by stepping through various resistor values and visual inspecting the LCD output is a better method.

In general, the larger the LCD display, the smaller the resistors must be. In addition, the higher the refresh rate the smaller the resistors. Consequently, a lower refresh rate will allow for larger resistor values. These are factors to be taken to account when selecting an optimum resistor size.

LCD CLOCK SOURCE SELECTION

LCD clock source selection depends upon application. Because the LCD glass can be modeled as a capacitive load, a higher frequency drive waveform will require more current. Therefore, a lower frequency clock source will consume less current.

Selecting the proper clock source can affect power consumption in an application. This is because specific low-power LCD modes can only be utilized by certain clock sources. Therefore, each clock source has a number of advantages and disadvantages.

Below, are some pros and cons of each available clock source:

1. **Fosc**

   Pros:
   - No External Circuitry
   - Dual Purpose (also used for instruction execution)

   Cons:
   - Cannot drive LCD in Sleep Mode
   - Typically draws more current than the LFINTOSC

2. **LFINTOSC**

   Pros:
   - No External Circuitry
   - Low frequency (31 kHz)
   - Can drive the LCD is Sleep Mode
   - Dual Purpose (also used for instruction execution)

   Cons:
   - May consume more current than an external crystal

3. External Crystal

Pros:

- Can drive the LCD in Sleep Mode
- Dual Purpose (can be used for accurate time keeping)

Cons:

- Requires external circuitry

CONCLUSION

Two techniques that can significantly affect power consumption are resistor ladder sizing and clock source selection. A deterministic guide for selecting resistor ladder size has been demonstrated as well as a practical approach to finding an optimal resistor for an LCD application. Finally, the pros and cons of specific clock source selections have been shown. By following these techniques and taking these factors into account, low power can be achieved for specific LCD applications.

REFERENCES

LCD PIC® MCU Tips 'n Tricks, DS41261

AN658, *"LCD Fundamentals using PIC16C92X Microcontroller",* DS00658

TB084, *"Contrast Control Circuits for the PIC16F91X",* DS91084

DS41250, *"PIC16F946/917/916/914/913 Data Sheet",*

AN1070, *"Driving Liquid Crystal Displays with the PIC16F913/914/916/917/946",* DS01070

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