
PIC16(L)F19197 LCD Bias Generation and Contrast Control Using the Internal LCD Charge Pump

Introduction

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The PIC16(L)F19197 8-bit microcontroller features an integrated Liquid Crystal Display (LCD) Controller module that provides the necessary components internally to directly drive a wide range of segmented displays, while meeting the low-power design requirements of many LCD applications. It features integrated bias generation and software contrast control, with the option of using the internal LCD charge pump to generate the voltages necessary to drive an LCD panel. The features that are found in this LCD module provide the flexibility to drive a wide variety of LCD panels with ease, while removing the need for an extensive list of external hardware components to generate bias voltages and control the contrast of the display while maintaining low-power consumption. This technical brief will give an overview of the LCD module, and go into detail regarding bias generation and contrast control using the internal LCD charge pump.



Info: The contents of this technical brief are applicable to all microcontrollers that possess this LCD controller module including the PIC16(L)F19195/6/7 family of devices as well as the PIC16(L)F19155/56/75/76/85/86 family of devices. For simplicity, any specific examples or references throughout this document will refer only to the PIC16F19197 device. For more information about the different devices that contain this LCD Module [visit www.microchip.com](http://www.microchip.com).

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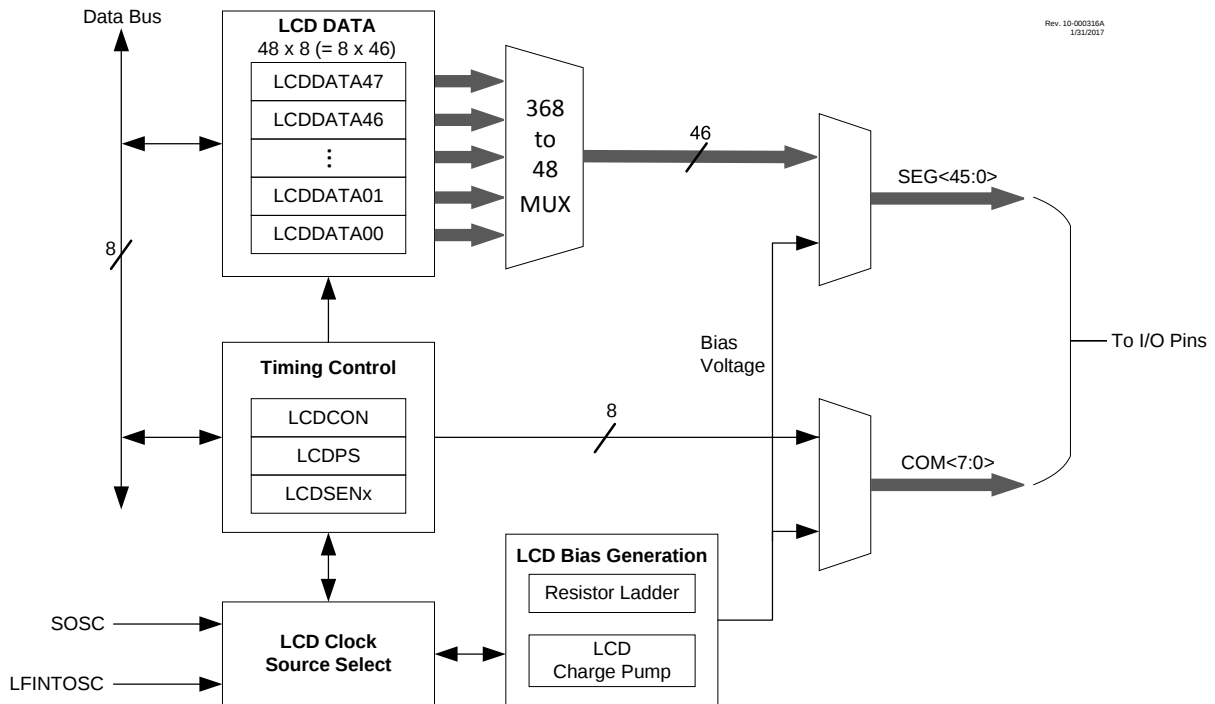
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1. LCD Charge Pump Overview

The LCD charge pump is ideal for low-voltage battery powered applications because it can boost the V_{DD} voltage up using internal circuitry to a level high enough for driving a wide range of LCD panels. When enabled, the charge pump will generate the top level LCD bias voltage (VLCD3) from the V_{DD} source available. In addition to boosting insufficient V_{DD} voltage to drive different displays, the charge pump circuitry can also regulate V_{DD} down to the necessary drive voltage for the display if V_{DD} is too high.

When using the LCD charge pump found on the PIC16(L)F19197 device, it is recommended that a flyback capacitor be connected to the C_{FLY1} and C_{FLY2} pins. The purpose of the flyback capacitor is to help with charge storage for the larger LCD loads, and it helps obtain the required voltage boost. In addition to the flyback capacitor should be used, capacitors should be used on each of the VLCDx pins for charge hold and storage to combat the LCD loads associated with larger panels and increased pixel counts. [Figure 1-1](#) shows the functional block diagram for the LCD controller module – this technical brief will discuss what happens within the LCD Bias Generation block of the figure below.

Figure 1-1. PIC16(L)F19197 LCD Controller Module Block Diagram



2. Configuration of the LCD Charge Pump

The LCD charge pump is enabled by setting LCDPEN of Configuration Word 1. Once the LCD charge pump has been enabled, it should be expected that it will generate VLCD3, thus providing power directly to the display. The LCD charge pump can be bypassed by clearing LCDPEN of Configuration Word 1, which would force it off and the LCD bias voltages would need to be derived using the other source options. For more information about using the LCD module without the charge pump enabled, please refer to the device data sheet. The LCD charge pump can be configured in a variety of different ways to satisfy specific LCD panel drive requirements, which will be discussed in the sections to follow.

Once enabled, the LCD charge voltage settings must be configured to meet the requirements of the display being used. The LCDVCON1 and LCDVCON2 registers contain several different configurations that pertain to the voltage and power options pertaining to the LCD module. The LCD voltage source is completely configurable by the user and should be programmed appropriately when the charge pump is enabled. The LCD voltage source is selected by programming the LCD Voltage Source Control bits (LCDVSRC<3:0>) of the LCDVCON2 register. Table 2-1 summarizes the various LCDVSRC<3:0> settings available. When using the LCD charge pump in an application, these bits should be programmed to '1001', '0111' or '0110'. Otherwise, the module will behave as if all sources are disabled. All other settings for this register are valid only when the charge pump has been bypassed (LCDPEN = 0).

Table 2-1. LCD Voltage Source Control Options

LCDVSRC<3:0>	LCD Voltage Source
1001	Charge Pump + External Resistor Ladder
1000	External Resistor Ladder
0111	Charge Pump + Internal Resistor Ladder
0110	Charge Pump Only (No Resistor Ladder)
0101	Internal Resistor Ladder + External Capacitors + V _{DD} for VLCD3
0100	Internal Resistor Ladder + External Capacitor + External VLCD3
0011	Internal Resistor Ladder + FVR for VLCD3
0010	Internal Resistor Ladder + V _{DD} for VLCD3
0001	Internal Resistor Ladder + External VLCD3
0000	All Voltage Sources are Disabled

2.1 LCD Charge Pump Voltage Range Selection

Once the charge pump has been enabled and the appropriate LCD voltage source has been selected using the LCDVSRC bits of the LCDVCON2 register, it must be configured to drive glass within either the 3.6V voltage range or the 5.0V voltage range, depending upon the specifications provided by the manufacturer. The LCD voltage range from the charge pump is configured by programming the EN5V bit of LCDVCON1. For applications where an LCD panel has a drive voltage lower than 3.6V, EN5V should be cleared (EN5V = 0) to ensure that the charge pump operates in the 3.6V voltage range when generating VLCD3 and the other necessary bias voltages. When a display with an LCD drive voltage higher than 3.6V but lower than 5.01V is being used, EN5V should be set (EN5V = 1) so that the boost

pump will operate within the 5.0V voltage range for the generation of VLCD3 and any other necessary bias voltages.

After the charge pump voltage range has been selected, the user can configure the specific charge pump output voltage. This is done by programming the BIAS<2:0> bits of LCDVCON1. [Table 2-2](#) summarizes the different charge pump output voltages that can be selected when operating within the 5.0V voltage range. [Table 2-3](#) summarizes the available charge pump output voltages when operating within the 3.6V voltage range. The Boost Pump Voltage Output Control (BIAS<2:0>) configuration is only valid when LCDVSRC has been set such that the LCD voltage is supplied from the charge pump. The BIAS<2:0> bits can also be used to control the contrast of the display by raising or lowering the LCD drive output voltage levels based upon the drive requirements of the glass.

Table 2-2. Charge Pump Voltage Output Options (EN5V = 1)

BIAS <2:0>	Charge Pump Output Voltage
111	5.01V
110	4.83V
101	4.66V
100	4.48V
011	4.31V
010	4.13V
001	3.95V
000	3.78V

Table 2-3. Charge Pump Voltage Output Options (EN5V = 0)

BIAS <2:0>	Charge Pump Output Voltage
111	3.50V
110	3.40V
101	3.30V
100	3.20V
011	3.10V
010	3.00V
001	2.90V
000	2.80V

2.1.1 Bias Voltage Selection Example

The LCD charge pump output voltage selected when programming the BIAS<2:0> bits should correspond to the drive/operating voltage supplied by the manufacturer of the LCD panel. [Table 2-4](#) shows some of the key electrical specifications for the custom LCD panel manufactured by Varitronix used on the [PIC16F19197 Low-Power Touch Enabled LCD Demonstration](#). The manufacturer of this LCD panel specifies that the drive voltage (VLCD) required for the display is 4.3V. For an application using this particular glass, EN5V should be set (EN5V = 1) to operate within the 5.0V voltage range, and the BIAS<2:0> bits should be set to provide an output voltage of 4.31V (BIAS<2:0> = 011). Depending upon the specifications of the particular LCD glass being used in an application, the BIAS<2:0> bits can be configured accordingly to satisfy the drive requirements. An example code snippet demonstrating the initialization of the LCD module on the PIC16F19197 to drive a display using the built in LCD charge pump is included in [4. LCD Module Configuration Example](#).

Table 2-4. LCD Electrical Specifications (PIC16F19197 Low-Power Touch Enabled LCD Demo)

LCD Electrical Parameter	Value
Type:	Twisted Nematic (TN), Positive Image
Viewing Direction:	6:00 O'clock (Bottom)
Driving Scheme:	1/8 Duty, 1/3 Bias
Driving Voltage (VLCD):	$V_{OP} = \sim 4.3V$
Operating Temperature:	0°C to + 50°C
Storage Temperature:	10°C to + 60°C
Connection:	Straight Pin

2.2 LCD Charge Pump Low-Power (Low-Current) Mode

The LCD charge pump can be configured to operate in Low-Power (Low-Current) mode or in Normal Mode, depending upon the application. The setting for this configuration can be determined based upon the V_{DD} voltage present in the application. When V_{DD} is ensured to always be above 2.2V during LCD operation, the charge pump can be configured to operate in Low-Power (Low-Current) mode. This is done by setting the LPEN bit of the LCDVCON1 register (LPEN = 1). In instances where V_{DD} is always ensured to be above 2.2V during normal operation, the voltage does not need to be boosted as much as a V_{DD} voltage lower than 2.2V would need to be. This allows one of the charging stages (capacitors) to be bypassed from the internal circuitry of the charge pump, and in turn, directly decreases the overall power consumption from the LCD charge pump.

In instances where V_{DD} is not ensured to maintain a voltage level above 2.2V during LCD operation, the charge pump should be configured to operate in Normal mode to ensure that the voltages are boosted to the proper level. This can be done by clearing the LPEN bit of LCDVCON1 (LPEN = 0). It is recommended that the charge pump is configured to operate in Low-Power (Low-Current) mode to ensure maximum contrast on the display when possible.

2.3 LCD Charge Pump Watchdog Timer

The LCD module includes a built-in Watchdog Timer that monitors the charge pump to ensure that the internal capacitors have completely discharged before disabling or resetting. Without the LCD Charge Pump Watchdog Timer Reset state a disable of the charge pump will cause the I/O pins to switch internally from LCD to GPIO. The charge pump Watchdog Timer provides a time out period during which the capacitors can discharge. Once the time out period has expired, it will switch the I/O pins from LCD to GPIO and perform the Reset or disable. It is recommended to leave the charge pump Watchdog Timer enabled to prevent damage to the LCD charge pump in the event where there is still excess charge stored on the internal capacitors. This is done by clearing the CPWDT bit of LCDVCON2 (CPWDT = 0). If the user wishes to disable this bit to reduce the amount of time it takes to Reset or disable the LCD charge pump, this can be done by setting the CPWDT bit (CPWDT = 1). Although disabling the charge pump Watchdog Timer may reduce Reset time, it poses a risk of the charge pump not completely discharging before being Reset or disabled, which could potentially damage the device internally.

3. Bias Generation and Contrast Control Using the LCD Charge Pump

LCD panels can be classified into two basic types: Static (Direct Drive) and Multiplex Displays. For a static LCD display, only two levels of voltage are needed to drive the display. These different voltage levels needed are referred to as the LCD bias voltages. For a static LCD panel, only two voltage levels are needed to drive the display; for a multiplexed panel multiple drive voltage levels are required to properly drive the display. The voltage levels are commonly referred to as the LCD bias voltages. There are several ways to generate the bias voltages required to drive both types of LCD panels, but this technical brief will focus on techniques using the internal LCD charge pump that is found on the PIC16(L)F19197 microcontroller. The contrast of an LCD panel is dependent on the amplitude of the generated signal used to drive the display, and in turn directly related to the bias voltages generated. As previously mentioned in [1. LCD Charge Pump Overview](#), a flyback capacitor must be connected to the CFLYx pins of the PIC[®] microcontroller when using the internal LCD charge pump. In addition to the flyback capacitor, output hold and storage capacitors should be added to each of the VLCDx pins on the microcontroller to obtain the required voltage boost.



Tip: For more information about connecting external capacitors to the VLCDx and CFLYx pins on the PIC16(L)F19197 microcontroller, refer to the LCD chapter of the device data sheet.

3.1 Charge Pump Only Mode (LCDVSR<3:0> = 0110)

By setting the LCDVSR<3:0> bits of the LCDVCON2 register to '0110', the voltage will be supplied to the LCD panel from the charge pump only. When configured to operate in this mode, the internal LCD charge pump will generate all necessary LCD bias voltages (VLCDx) directly, boosting the V_{DD} voltage, if necessary. This mode cannot be used with 1/2 Bias LCD glass and is only valid for Static (two discrete levels), and 1/3 Bias (four discrete levels). The internal reference ladder is bypassed in this mode, and any changes to the LCD Contrast Control bits (LDCST) will not alter the contrast of the display. While operating within this LCDVSR configuration, contrast can be controlled by altering the output of the LCD charge pump by programming the BIAS<2:0> bits. An advantage to operating the LCD panel in this power mode is that it provides the most power efficient voltage biasing.

3.2 Charge Pump with Internal Resistor Ladder (LCDVSR<3:0> = 0111)

Setting the LCDVSR <3:0> bits of the LCDVCON2 register to '0111' will enable the LCD driver to provide voltage from the charge pump and the internal resistor ladder/contrast control circuit. This mode of operation offers the functionality of the integrated LCD charge pump to generate the LCD bias voltages, but also allows the user to utilize an internal resistor ladder to fine tune and optimize the LCD bias voltages to meet the specific requirement of their glass. When configured to operate in this mode, the internal LCD charge pump will generate VLCD3, the highest of the LCD bias voltages. All other LCD bias voltages are generated from VLCD3 using the internal resistor ladder. Contrast can be controlled in two different ways while operating in this mode: by altering the output of the LCD Charge pump (VLCD3) by programming the BIAS<2:0> bits, and by using the LCD Contrast Control Bits (LDCST) of the LCDREF register.

The internal resistor ladder used for contrast control consists of a 7-tap resistor ladder. The resistor ladder configuration is controlled by programming the LDCST<2:0> bits of the LCDREF register to determine the total resistance of the circuit used to generate the LCD bias voltages. Maximum resistance

from the internal resistor ladder (LDCST<2:0> = 111) results in minimum contrast, but also the lowest power consumption of all the resistor ladder settings. Minimum resistance from the internal resistor ladder (LDCST<2:0> = 000) would provide the maximum contrast, but in turn the most power consumption due to the increased current. It is important to take into consideration the additional power consumption associated with making these changes to increase display contrast. This mode is valid for the following LCD panel bias types: Static (two discrete levels), 1/2 Bias (three discrete levels), and 1/3 Bias (four discrete levels).

3.3 Charge Pump with External Resistor Ladder (LCDVSR<3:0> = 1001)

By setting the LCDVSR<3:0> bits of the LCDVCON2 register to '1001', voltage will be supplied to the LCD panel from the charge pump with external resistors. This mode of operation offers the flexibility of the internal LCD charge pump, along with the ability to use a custom designed external resistor ladder that allows the user to meet the specific drive requirements of their glass in applications where the internal resistor ladder is not sufficient. When configured to operate in this mode, the internal LCD charge pump will generate VLCD3, the highest of the LCD bias voltages. All other LCD bias voltages are generated from VLCD3 using an external resistor ladder that is connected to the various VLCDx pins on the PIC[®] microcontroller. The internal resistor ladder is bypassed in this mode, and any changes to the LCD Contrast Control bits (LDCST) will not alter the contrast of the display.

While operating within this mode, contrast can be controlled by altering the output of the LCD charge pump (VLCD3) by programming the BIAS<2:0> bits. Additionally, contrast can be controlled by adjusting the characteristics of the external resistor ladder being used. This mode is valid for the following LCD panel bias types: Static (two discrete levels), 1/2 Bias (three discrete levels), and 1/3 Bias (four discrete levels).



Tip: For more information about how to connect an external resistor ladder to the PIC16(L)F19197 microcontroller, refer to the LCD chapter of the device data sheet.

4. LCD Module Configuration Example

The following code snippet demonstrates the initialization of the LCD module found on the PIC16F19197 microcontroller to interface a custom Variation 5.0V LCD panel. The LCD charge pump found on this family of devices allows the microcontroller to operate from 3 AAA batteries using a regulated V_{DD} of 3.3V, while driving the LCD panel at 5.0V. The LCD charge pump was enabled by setting LCDPEN of Configuration Word 1, and the LCD voltage source was selected to be provided from the LCD charge pump only without the use of internal or external resistor ladder. Low-Power (Low-Current) mode of the LCD charge pump was enabled, and the charge pump was configured to generate voltages in the 5.0V voltage range to meet the requirements of the LCD panel. The boost pump output voltage was also programmed to generate an output of 5.01V (the maximum voltage from the charge pump). [Example 4-1](#) below shows the initialization routine used to configure the LCD module and internal LCD charge pump to drive this display.

Example 4-1. LCD Module Configuration (PIC16F19197 Low-Power Touch Enabled LCD Demo)

```
LCDCONbits.LCDEN = 0; // Disable module before configuring;
LCDPS = 0x02; // LP 1:3; WFT Type-A waveform;
LCDREF = 0x00; // LCDCST Max contrast (Min Resistance);
LCDRL = 0x00; // LRLAP disabled; LCDIRI disabled; LRLAT Always B Power mode;

LCDVCON1 = 0xC7; // BIAS 5.01V; EN5V enabled; LPEN enabled;
LCDVCON2 = 0x86; // CPWDT disabled; LCDVSRCH Charge Pump only;

LCDSE0 = 0xFF; // Enable used segments;
LCDSE1 = 0x3F; // Enable used segments;
LCDSE2 = 0xF8; // Enable used segments;
LCDSE3 = 0xBF; // Enable used segments;
LCDSE4 = 0xC0; // Enable used segments;
LCDSE5 = 0x3E; // Enable used segments;

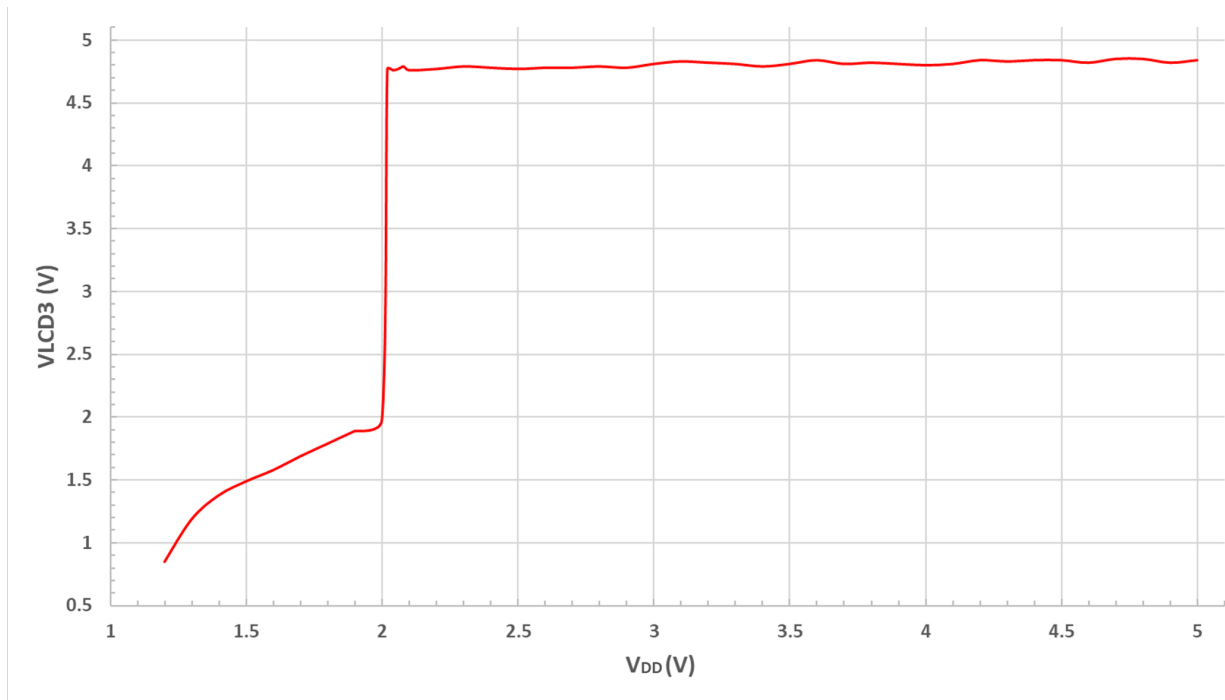
LCDCON = 0xC8; // CS LFINTOSC; SLPEN disabled; LMUX 1/8 COM(7:0);
LCDCONbits.LCDEN = 1; // Enable Module;
```

4.1 LCD Charge Pump VLCD3 vs. V_{DD}

The LCD panel being driven by the code snippet from Example 4-1 is a 5.0V piece of glass, however the board in this application was designed to be powered by 3 AAA batteries with a regulated V_{DD} voltage of 3.3V. The integrated LCD charge pump is an excellent choice for this type of application as it can boost the V_{DD} supply voltage to generate the necessary bias voltages for the LCD. Figure 4.1 below compares VLCD3 versus V_{DD} as V_{DD} is swept from 1.0V to 5.0V. The graph shows that the integrated LCD charge pump is capable of boosting V_{DD} up to the configured bias voltage (VLCD3) even as the supply drops close to 2.0V. This makes the integrated LCD charge pump ideal for battery powered applications, and helps ensure that the contrast of the display does not degrade as the batteries lose charge over time. Without the LCD charge pump, VLCD3 would decrease as the batteries lose charge over time directly affecting the contrast of the display.



Info: The LCD module was configured to operate in Low-Power (Low-Current) mode for Example 4-1. The Charge Pump drops off around 2.0V in Figure 4-1, but in applications where the LCD Charge Pump is configured to operate in Normal Current mode (LPEN = 0), the charge pump may work for a wider range of V_{DD} voltages.

Figure 4-1. Figure 4-1: V_{DD} vs. VLCD with LCD Charge Pump Enabled

5. Conclusion

This technical brief provided an overview of LCD bias generation and contrast control using the internal charge pump found on the PIC16F19197, along with other parts in this device family. The LCD charge pump makes this family of devices very well suited for battery powered LCD applications and allows users to maintain lower power consumption while being able to meet the drive requirements of their LCD panel. For more details about the LCD module refer to the LCD chapter of the device data sheet, utilize the MPLAB® Code Configurator plug-in available in MPLAB X IDE, or browse the MPLAB Xpress Example Library.



Tip: For more information about the LCD module of the PIC16F19197, refer to the device data sheet. Working demo code demonstrating the LCD module can be found on the MPLAB Xpress Cloud-Based IDE platform. See the example [PIC16F19197 Stopwatch and Clock on the Explorer Development Board](#).

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