Our first input/output interfaces will use the parallel ports or GPIO, allowing us to exchange digital information with the external world. From the very beginning of a project, we must consider how the system will be tested. In this chapter we present some debugging techniques that will be very useful for verifying proper operation of our system. Effective debugging tools are designed into the system becoming part of the system, rather than attached onto the system after it is built.

In this chapter, we present the I/O pin configurations for the TM4C123 microcontrollers. The regular function of a pin is to perform parallel I/O. Most pins, however, have an alternative function. For example, port pins PA1 and PA0 can be either regular parallel port pins or an asynchronous serial port called universal asynchronous receiver/transmitter (UART). The ability to manage time, as an input measurement and an output parameter, has made a significant impact on the market share growth of microcontrollers. Joint Test Action Group (**JTAG**), standardized as the IEEE 1149.1, is a standard test access port used to program and debug the microcontroller board. Each microcontroller uses five port pins for the JTAG interface.

Common Error: Even though it is possible to use the five JTAG pins as general I/O, debugging most microcontroller boards will be more stable if these five pins are left dedicated to the JTAG debugger.

I/O pins on Stellaris and Tiva microcontrollers have a wide range of alternative functions:

- **UART** **Universal asynchronous receiver/transmitter**
- **SSI** **Synchronous serial interface**
- **I^2C** **Inter-integrated circuit**
- **Timer** **Periodic interrupts, input capture, and output compare**
- **PWM** **Pulse width modulation**
- **ADC** **Analog to digital converter, measure analog signals**
- **Analog Comparator** **Compare two analog signals**
- **QEI** **Quadrature encoder interface**
- **USB** **Universal serial bus**
- **Ethernet** **High-speed network**

- **CAN** **Controller area network**

The **UART** can be used for serial communication between computers. It is asynchronous and allows for simultaneous communication in both directions. The **SSI** is alternately called serial peripheral interface (SPI). It is used to interface medium-speed I/O devices. In this book, we will use it to interface a graphics display. We could use SSI to interface a digital to analog converter (DAC) or a secure digital card (SDC). **I^2C** is a simple I/O bus that we will use to interface low speed peripheral devices. Input capture and output compare will be used to create periodic interrupts and measure period, pulse width, phase, and frequency. **PWM** outputs will be used to apply variable power to motor interfaces. In a typical motor controller, input capture measures rotational speed, and PWM controls power. A PWM output can also be used to create a DAC. The **ADC** will be used to measure the amplitude of analog signals and will be important in data acquisition systems. The analog comparator takes two analog inputs and produces a digital output depending on which analog input is greater. The **QEI** can be used to interface a brushless DC motor. **USB** is a high-speed serial communication channel. The **Ethernet** port can be used to bridge the microcontroller to the Internet or a local area network. The **CAN** creates a high-speed communication channel between microcontrollers and is commonly found in automotive and other distributed control applications.

Observation: The expression **mixed-signal** refers to a system with both analog and digital components. Notice how many I/O ports perform this analog↔digital bridge: ADC, DAC, analog comparator, PWM, QEI, Input capture, and output compare.

Help