

## ***Starting a USB Design Using MSP430™ MCUs***

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MSP430 Applications

### **ABSTRACT**

This document is a high-level starting point for those wanting to design USB devices with MSP430™ MCUs. It provides an overview of the TI MSP430 hardware and software offerings for USB, as well as guidance in quickly getting started.

Among the topics covered:

- An overview of the MSP430 hardware USB module
- An introduction to the MSP430 USB Developer's Package
- A hardware reference design for USB devices based on the MSP430 MCU
- A guide to early decisions the developer must make

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## 1 USB and the Art of Making Something Complex Look Simple

### 1.1 What has Made USB So Successful?

USB is nearly everywhere in the modern world. We are familiar with its ease of use; typically USB just works. It is reliable.

Its simplicity and predictable user model have made it extremely popular with the public. Its popularity and low cost have made it ubiquitous. Its ubiquity has even led to uses beyond data communication – for example, as a means of power delivery: both out of hosts (for example, into coffee warmers) and into devices as a means of battery charging.

But a lot is going on under the surface of USB. Making a fast, reliable data bus that automates common behaviors and tolerates hot plugging requires layers of protocol. And it requires a great deal of standardization among large numbers of industry players; in fact, multiple forces shape the USB experience today.

### 1.2 But It Looks So Simple!

The elegance of USB is that users see none of this complexity – it simply does what they need it to.

But developers can have more trouble avoiding this complexity. Compared to UART, SPI, or I<sup>2</sup>C, layers of protocol are required to give USB its unique capabilities. This means that sending data over USB takes more effort than simply writing a byte to an output buffer. On-chip USB modules offset some of this complexity, but they cannot do all of this; layers of software need to be employed.

Good USB software can insulate the application developer from many of these complexities. But like icebergs, the tips of these concerns can still be seen by the application. How should the device respond when attached or not attached to a host? How should software be written to ensure it keeps flowing even when the host or bus is busy or unreliable? The simplest USB applications might be able to ignore these concerns, but professional applications often cannot.

An industry of middleware and consultants is available to help developers through this process. But, many developers still rely on silicon vendors and the community to provide both software and support.

### 1.3 TI's Approach for MSP430 USB

The TI MSP430 USB Developers Package provides a solution intended to be simple and accessible for a broad range of customers. At the same time, it maintains the design flexibility that professional USB applications need.

Development is aided by the MSP430 USB Descriptor Tool, a code generation tool that handles most of the USB-related customization for your application. The Tool contains contextual help that aids you in making your decisions. Example code and detailed reference guides help point the way. If you have a problem these cannot solve, TI's [E2E Forum](#) and other non-TI MSP430 forums are available to help.

TI also welcomes the ecosystem of USB consultants, middleware, and community solutions, and supports their continued contribution. They enlarge the base of possibilities for MSP430 customers, both for those using the MSP430 USB Developers Package and for those preferring to outsource USB design.

## 2 MSP430 USB Silicon

MSP430 MCUs include an on-chip USB module on several subfamilies. Each family's module is exactly the same, and each is compatible with the MSP430 USB Developers Package ([MSP430USBDEVPACK](#)).

Although bitbanging USB is possible, it cannot be done at full speed, and it is likely to consume much of the processor's capacity. Most USB applications tend to use the on-chip USB module.

### 2.1 How MSP430 Devices are Documented

The MSP430 device documentation is structured differently than some of our competitors. For any given MSP430 device derivative, the documentation is divided into two locations:

- The family user's guide: Contains all of the *architectural* information for the family. For example, it contains register sets and block diagrams of all the peripheral modules. All USB-equipped MSP430 devices are described in the *MSP430x5xx and MSP430x6xx Family User's Guide* ([SLAU208](#)).
- The data sheet: Contains all of the *parametrics* and anything specific to this particular derivative.

This method reduces the number of pages the developer needs to download and read in order to comprehend the device. All device documentation is found in the combination of these two documents.

### 2.2 USB-Equipped MSP430 Derivatives

TI currently has four subfamilies of USB-equipped device derivatives (see [Table 1](#)).

**Table 1. USB-Equipped MSP430 Derivatives**

MSP430 Derivative	Flash (bytes)	RAM (bytes)	16-Bit Timers	Common Peripherals	ADC	Additional Features	Packages
F550x, F5510	8K-32K	4K(+2K)	4	<ul style="list-style-type: none"> <li>• USB</li> <li>• WDT</li> <li>• RTC</li> <li>• DMA (3-6)</li> <li>• MPY32</li> <li>• Comp_B</li> <li>• UART</li> <li>• SPI</li> <li>• I2C</li> <li>• PMM (BOR, SVS, SVM, LDO)</li> </ul>	10-bit SAR		<ul style="list-style-type: none"> <li>• 48RGZ</li> <li>• 48PT</li> <li>• 64RGC</li> </ul>
F551x, F552x	32K-256K	4K-8K(+2K)			12-bit SAR		<ul style="list-style-type: none"> <li>• 80PN</li> <li>• 64RGC</li> <li>• 80ZQE</li> <li>• 64YFD (chip-scale DSBGA)</li> </ul>
F563x, F663x	128K-256K	16K(+2K)				<ul style="list-style-type: none"> <li>• EDI</li> <li>• DAC12</li> <li>• Backup battery switch</li> <li>• LCD (on F663x and F665x)</li> </ul>	<ul style="list-style-type: none"> <li>• 100PZ</li> <li>• 113ZQW</li> </ul>
F565x, F665x	384K-512K	32K-64K(+2K)					

Note that TI documentation for USB-equipped MSP430 derivatives expresses the amount of RAM as "n+2K". The extra 2K refers to an area of RAM called *USB RAM*. When the USB module is enabled, this RAM is mapped into registers that are used by the module and, thus, becomes unavailable to the application. When the USB module is disabled, this RAM is available to the application, but it is not mapped by the standard linker files by default. So if you want to use this RAM for non-USB purposes, special measures must be taken.

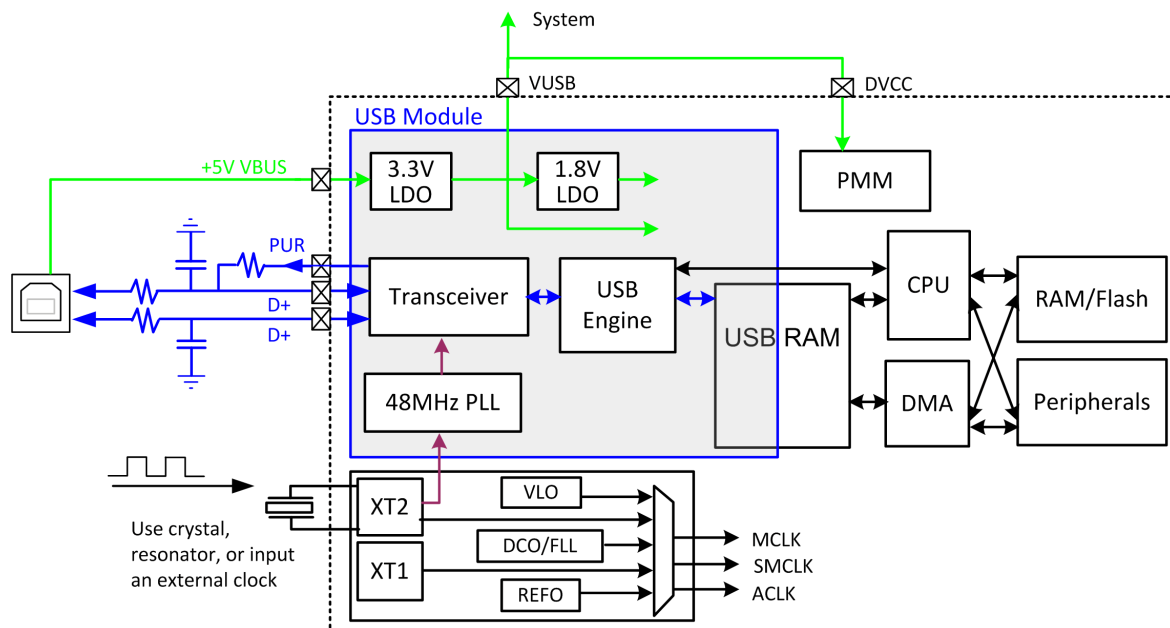
For more information about the differences between these devices, see the latest MSP430 product brochure at <http://www.ti.com/msp430>, which contains an easy-to-read comparison table.

## 2.3 MSP430 USB Module

Features of the MSP430 USB module are as follows:

- **Full-speed USB device (12 Mbps).** Full-speed is a great match for a 16-bit MCU. It facilitates communication with a USB host, with simplicity and low system cost. The module does not perform low- or high-speed transfers; it also does not function as a USB host controller.
- **Supports control, interrupt, and bulk transfers.** This enables support of the most popular USB device classes. (Streaming audio using isochronous transfers is not supported.)
- **Eight input and eight output endpoints.** The more endpoints that are supported, the more *USB interfaces* (logical devices) that can be implemented within a *composite USB device*. MSP430 MCUs have enough endpoints for as many as seven interfaces in composite (depending on the ones chosen), which is more than enough for the vast majority of USB applications.
- **An integrated 3.3-V LDO, for operation directly from 5-V VBUS from the host.** In some applications, this eliminates the need for an external LDO, because in addition to sourcing the MCU, the integrated LDO can be used to source the entire system, up to 12 mA. (See the device data sheet for parameters).
- **An integrated D+ pullup.** This pullup is the way in which a USB device tells the host it is ready to be *enumerated*. In contrast, some USB devices from other vendors require external circuitry to enable the pullup.
- **Programmable PLL.** An integrated PLL generates the 48-MHz clock needed for USB operation. The reference for this PLL comes from the MCU's XT2 oscillator. A wide variety of sources can be used for the reference.
- **Integrated transceiver (PHY).** There is no need to buy one separately.

Figure 1 shows a system block diagram.



**Figure 1. MSP430 USB Block Diagram**

Parts of this block diagram are described as part of the MSP430 USB hardware reference design in Section 5. The ultimate reference for the module is the USB chapter of the *MSP430x5xx and MSP430x6xx Family User's Guide* ([SLAU208](#)).

## 2.4 USB Certification of the Silicon

To maintain a consistent user experience, it is important that USB devices adhere to compliance standards. Much of this compliance is driven by the USB silicon and software. The MSP430 device derivatives, running the USB API, have passed USB certification testing for all of the device classes that they support. All certification was performed at [MCCI](#), a test house approved by the USB Implementers Forum (USB-IF).

An output of the USB certification process is a *test ID*, or *TID*. [Table 2](#) shows the TIDs for all current MSP430 silicon.

**Table 2. MSP430 Device Test IDs (TIDs)**

MSP430 Derivative	Package	TID
<a href="#">MSP430F552x</a>	PT, RGC, RGZ (QFP, QFN)	40000973
	ZQE (BGA)	40001139
<a href="#">MSP430F550x</a> , <a href="#">MSP430F5510</a>	PT, RGC, RGZ (QFP, QFN) (Note: F5504 in RGZ is not included in this TID; see the next entry)	40001138
<a href="#">MSP430F5504</a>	RGZ (QFN)	41001138
<a href="#">MSP430F563x</a> , <a href="#">MSP430F663x</a>	PZ (QFP)	40001250
	ZQW (BGA)	40001442
<a href="#">MSP430F565x</a> , <a href="#">MSP430F665x</a>	PZ (QFP, QFN)	40001444
	ZQW (BGA)	40001443

All MSP430 devices were certified under a vendor ID (VID) unique to the MSP430 MCU (0x2047), separate from TI's main VID (0x0451).

## 3 Software

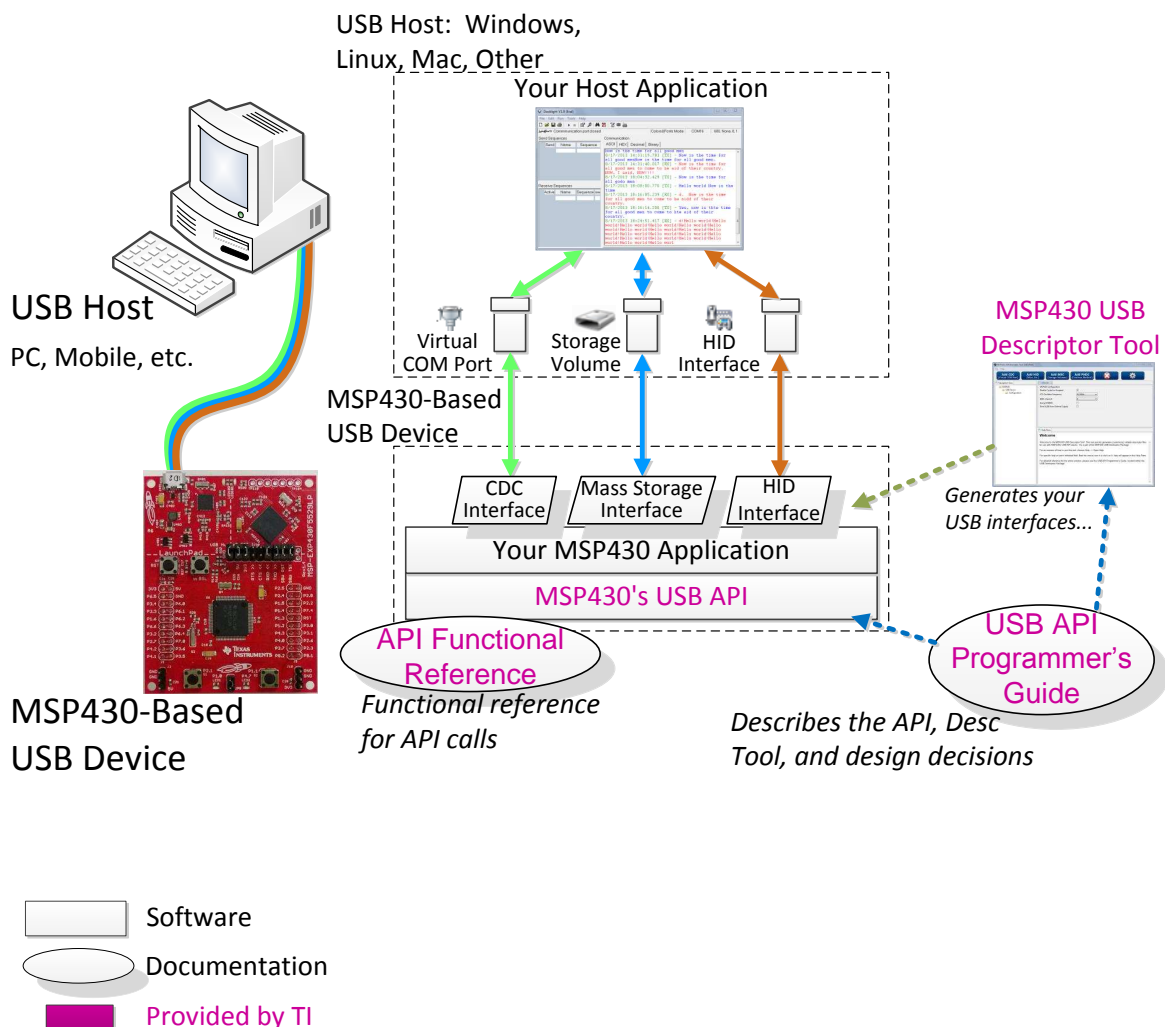
### 3.1 USB Developers Package: Overview

TI provides its MSP430 USB software offering inside the *MSP430 USB Developers Package*.

**Table 3. MSP430 USB Developers Package: Contents**

Item		Description
<b>Host USB Software</b>		
	Java HID Demo App	Host-side example for implementing HID. It complements the HID-Datapipe API, simplifying creation of a general-purpose USB HID device.
	Python USB Firmware Upgrader	Python-based host-side USB firmware update solution.
<b>MSP430 USB Software</b>		
<b>Documentation</b>		
	API Functional Reference	Doxygen-generated function reference for all the USB API calls
	Examples Guide	A guide for the person <i>evaluating</i> the USB API, using the examples
	MSP430 USB API Programmer's Guide	A detailed reference for someone that's <i>developing</i> a USB device using the MSP430 USB Developer's Package.
	Release Notes HTML file	Contains anything unique to a particular revision, including bug fixes, benchmarks, compiler dependencies, and migration information.
<b>MSP430 USB API</b>		
	Examples	
	emptyUsbProject	A project containing only a main.c populated with a suggested main loop framework. The framework is commented with instructions.
	CDC Examples	Examples for implementing virtual COM ports using the CDC class.
	HID Examples	Examples using the HID class
	HID-Datapipe	Examples of HID-Datapipe, a means of UART-style data exchange based on the HID class.
	HID-Traditional	Examples of ordinary HID interfaces, like mice and keyboards
	MSC Examples	Examples for implementing mass storage devices, like SD card and emulated on-chip flash drives.
	Composite Examples	Examples of composite USB devices; that is, devices comprising more than one of the interfaces above
	SYS/BIOS Examples	Examples showing us of the USB API with TI's SYS/BIOS RTOS
	driverlib (driver library)	Contains the standard MSP430 driverlib. It is referenced by all the examples.
	USB_API	These are the actual USB API code files. It is referenced by all the examples.
	<b>MSP430 USB Descriptor Tool</b>	Automatically generates reliable descriptors for any combination of USB interfaces. It saves the developer's time and reduces the chance for errors. Using this tool is part of the standard recommended design flow.

If your application will only use USB for updating the MSP430 firmware, you can jump to [Section 3.6](#). Most of the software components in the package, about to be described, apply to applications using USB as part of their main function.



**Figure 2. USB System and USB Developers Package Components**

The items marked with purple text are provided by TI and correspond with items in [Table 3](#).

The Descriptor Tool generates the USB interfaces you need. You then write an MSP430 application that communicates with the host through these interfaces.

On the host, you can either write an application or, perhaps, use an existing one. In some cases for example, an existing COM port or storage-based application might serve your purposes.

Examples are very useful during development. On the MSP430 MCU side, TI provides more than 25 examples of USB applications in the developers package.

On the host side, COM ports and storage are very common, and large amounts of information about these are found online. In contrast, HID is not as common. For that reason, TI provides the *Java HID Demo App* as an example and as a utility.



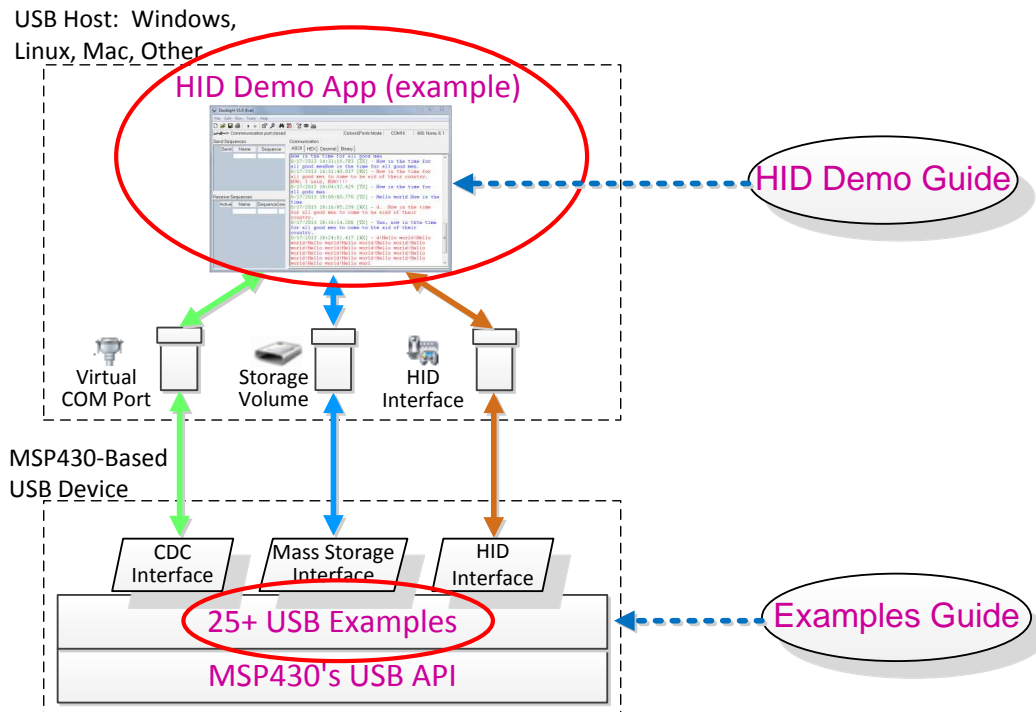


Figure 3. USB Developers Package: Examples from TI

The red-circled examples help get you started in your development. Each is supported by documentation. All these items are in the MSP430 USB Developers Package, and described further below.

### 3.2 USB API Stacks: Features

The API is the foundation of the MSP430 USB Developers Package. It supports three of the most common USB device classes:

- **Communications Device Class (CDC):** (ACM class) Results in a virtual COM port on the host
- **Human Interface Device class (HID):** The MSP430 USB Developers Package defines four subtypes:
  - Datapipe (an unformatted general-purpose interface resembling CDC)
  - Mouse
  - Keyboard
  - Custom
- **Mass Storage Class (MSC):** When the host sees an MSC interface, it begins mounting a storage volume from it.

These classes provide a good selection for general-purpose use. See [Section 5.1](#) for a discussion of how to choose your interface.

Features of the API include:

- Small peripheral footprint (only the USB module and XT2 oscillator)
- Small memory footprint
- Can use either the DMA or CPU to move data
- Provided as source code
- BSD-licensed, providing maximum flexibility



CDC and HID-Datapipe provide the developer a simple data exchange interface. As a brief example of this interface, a simple application follows.

```

VOID main(VOID)
{
    // Init clocks, power, ports
    WDT_A_hold(WDT_A_BASE);
    PMM_setVCore(PMM_BASE, PMM_CORE_LEVEL_2);
    initPorts();
    initClocks(8000000);    // CPU frequency, in Hz

    initTimer();            // Set up one-second intervals to wake from LPM0
    USB_setup(TRUE,TRUE);   // USB API call; initializes USB and connects to the host
    __enable_interrupt();

    while (1)
    {
        __bis_SR_register(LPM0_bits + GIE); // Enter LPM0 sleep

        if (cdcSendDataInBackground(helloWorldStr, 12, CDC0_INTFNUM, 1000))
        {
            handleFailedSend(); // Might fail if cable is disconnected, bus is
                                // busy, or host has become unresponsive
        }
    }
}

```

This application wakes up once per second (using a timer interrupt, not shown) and sends a string over USB to a virtual COM port on the host.

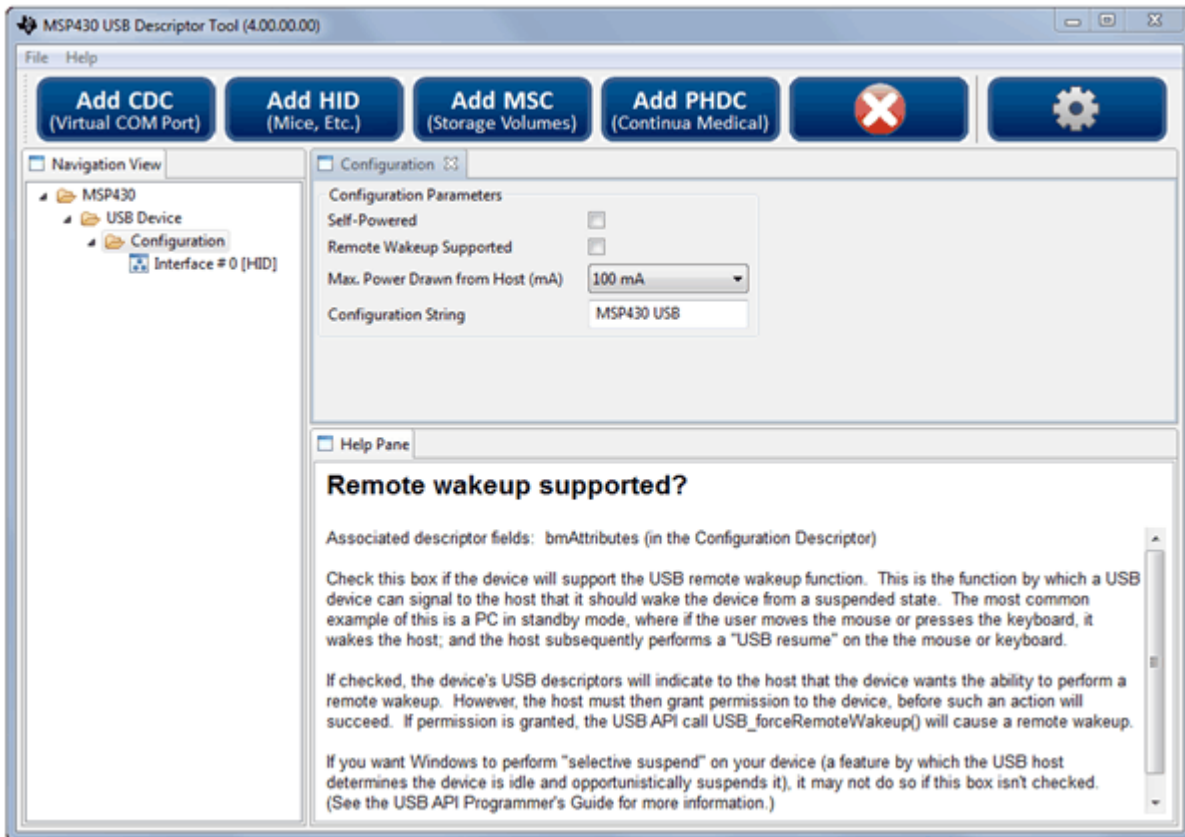
To send data over a CDC interface (to a virtual COM port), you can simply build the interface with the Descriptor Tool, prepare your data, and call the API construct function `cdcSendDataInBackground()`, which accepts these parameters:

- Data buffer
- The buffer's size
- Which CDC interface
- The number of retries before the attempt is considered a failure.

This is only one simple example; much more is possible with the USB API. See the *MSP430 USB API Programmer's Guide* and examples in the MSP430 USB Developers Package for more information.

### 3.3 MSP430 USB Descriptor Tool

TI provides a unique tool for USB development: the *MSP430 USB Descriptor Tool*.



**Figure 4. MSP430 USB Descriptor Tool**

As the name implies, it quickly and automatically generates *USB descriptors*. This is a big help, because:

- Writing descriptors can be tedious.
- Composite devices are far **more** tedious.
- Tracking down mistakes can take time.
- Failure resulting from incorrect descriptors is not always obvious.
- Not all host operating systems accept every spec-compliant descriptor.
- You cannot always find an example for every composite combination you want to use.

The tool generates reliable descriptors, on the first try, for literally any combination of CDC, HID, and MSC interfaces. It does this in just a few minutes of your time.

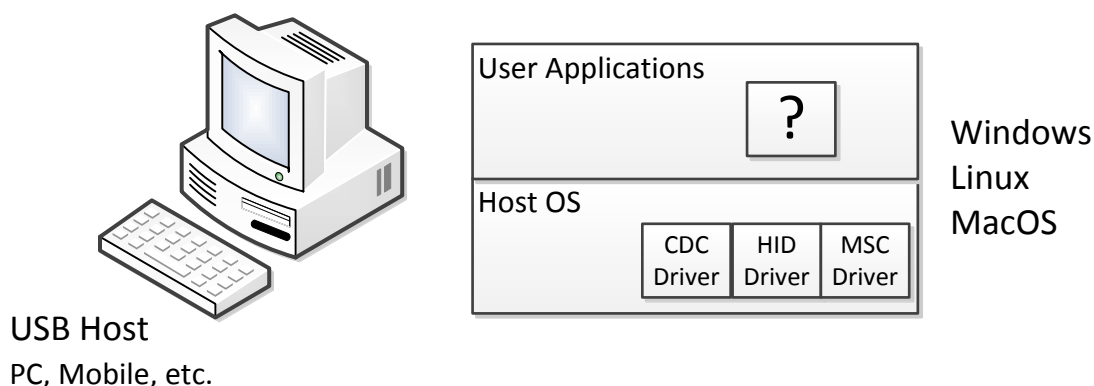
On another level, you can think of the tool as building the USB interfaces your application will interact with (see [Figure 2](#)). As such, it is the first step in developing an MSP430 USB project.

If the device contains a CDC interface, the tool also generates an INF file, eliminating the need to create one manually. The INF file is already customized to the application, based on the data that was entered for descriptors.

As seen in [Figure 4](#), the tool contains a help pane that explains the tradeoffs of every decision the engineer needs to make in setting up the API. The tool also warns the engineer when creating a descriptor set that will not work on all common host operating systems.

### 3.4 Host Software, and the Java HID Demo App

The kernel-level host drivers for CDC, HID, and MSC are already present within the common host operating systems (Windows™, Mac OS X™, and Linux®). But the developer must identify or create an application on the host that interfaces with the USB device.

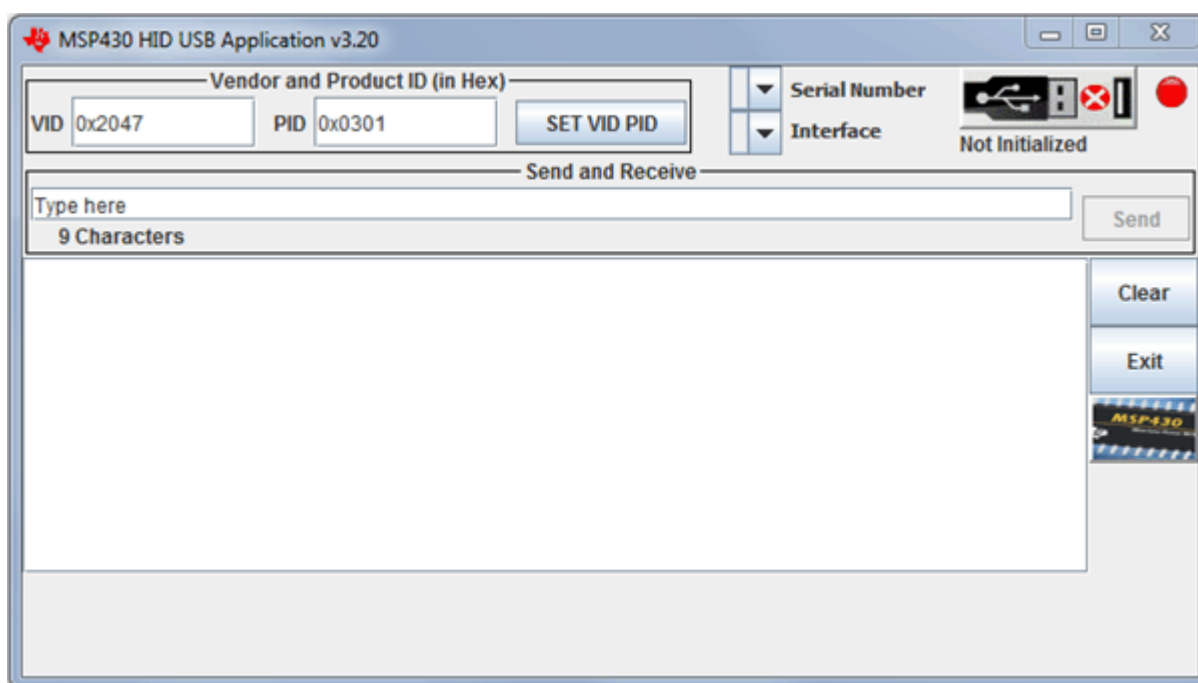


**Figure 5. USB Host Software**

Writing host software for CDC and MSC interfaces is very straightforward, because they present interfaces to the host that are very commonly understood: virtual COM ports and storage volumes. These interfaces are not specific to USB, and resources on writing code for them are very easy to find.

HID interfaces are different, because they are more specific to USB. Some HID interfaces are actually PC peripherals that the host operating system itself interacts with it directly, like a mouse or keyboard. These do not need additional host software.

But sometimes HID interfaces are beneficial for general communication (like the MSP430 HID-Datapipe interface). Writing custom applications to talk with an HID interface can be slightly more complicated than interfacing with a COM port or storage volume. For this reason, TI provides the Java HID Demo App (see [Figure 6](#)). This application is provided as both a source code example and an executable that serves as a utility. Because it is written in Java, it is meant to be extendable across multiple host platforms.



**Figure 6. Java HID Demo App**

### 3.5 USB API Programmer's Guide and Examples Guide

A complete programmer's guide is included in the developers package to answer your questions. It describes every aspect of writing USB applications with the API.

A separate examples guide is provided. The *MSP430 USB API Examples Guide* is intended for the person only evaluating and running the examples, while the *MSP430 USB API Programmer's Guide* focuses on development.

An HTML-based API reference document set is also provided for detailed information on each API function.

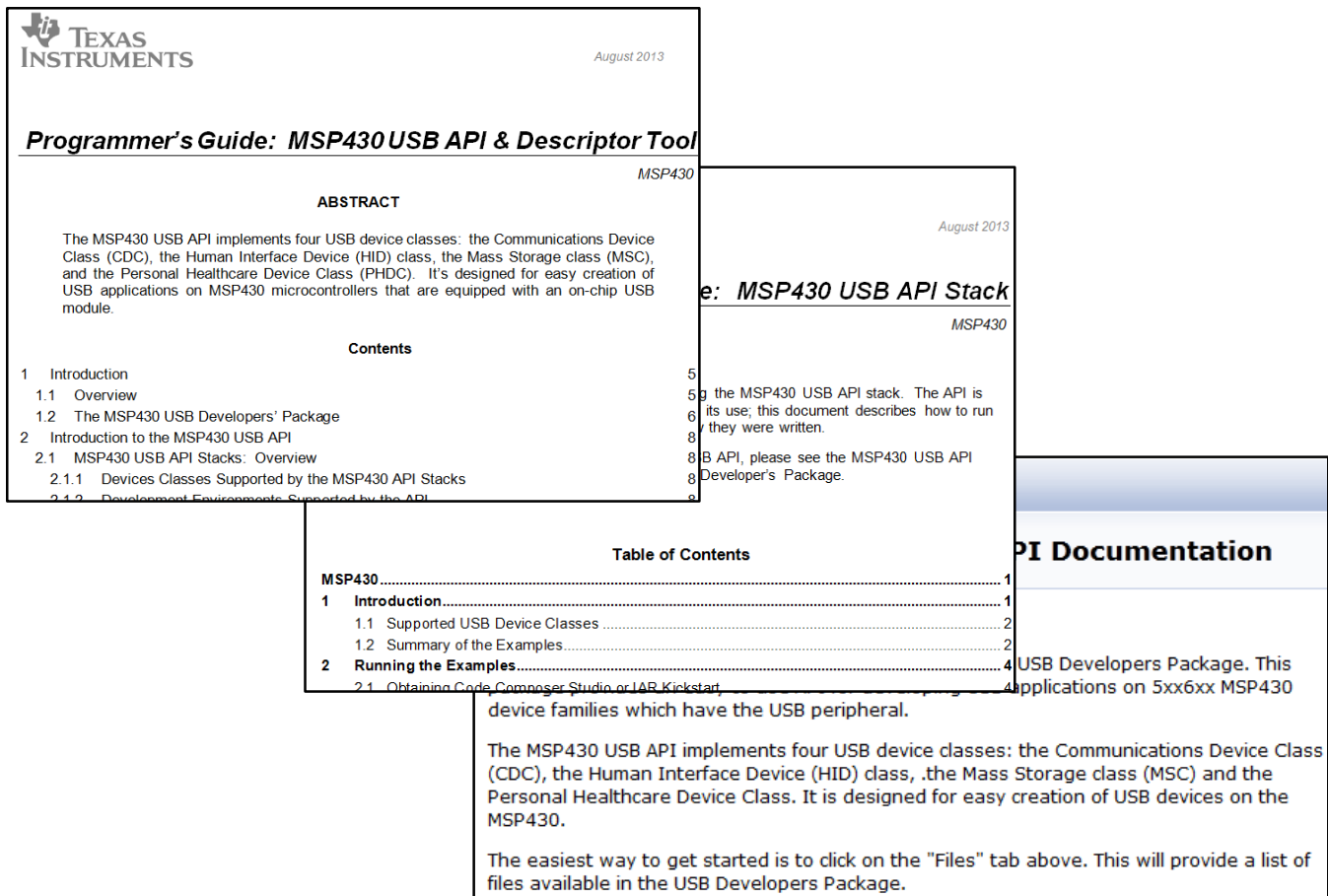


Figure 7. MSP430 USB API Documentation

### 3.6 MSP430 USB Field Firmware Upgrade Tools

A common use of USB is to enable end users to update the firmware. Among the advantages of this is that bug fixes can be pushed proactively, increasing user satisfaction and reducing returns.

The vast majority of MSP430 derivative devices have an on-chip bootstrap loader (BSL). The BSL is a program that resides in a special protected location in MSP430 flash memory and facilitates communication with an external host. Like tools with JTAG access, it can read and write to the MCU's flash memory. But unlike JTAG tools, it cannot be used to emulate code.

The BSL interface is often a UART, or sometimes I<sup>2</sup>C. On the USB-equipped derivatives listed in [Table 1](#), the BSL's interface is USB.

In addition to field updates, the BSL can be used for production programming. It also plays an important role when JTAG access is not available. For example, it can be used to recover the device when something has corrupted internal flash.

Because of potential use in the field, the BSL is password-protected to prevent unwanted access to proprietary application software.

The BSL must be *invoked*, meaning that CPU execution must be transferred to it. On the USB BSL, this can happen in one of three ways:

- The application software in main flash can jump into it
- A BOR reset while the reset vector is blank
- A BOR reset while the PUR pin is held high externally – perhaps by way of a pushbutton switch

Field applications of the USB BSL are likely to use the first method, because a main application is already in control of the device. In this way, the developer can design a simple end user experience for the update. However, if main software becomes corrupted, this method might not work.

The second method is used during production of a device based on the MSP430 MCU, because the reset vector is blank when it leaves TI's factory; you can simply assemble the board and attach the device to a USB host, and it will enumerate under BSL control. This method also plays an important role in recovering from interrupted BSL sessions, because the reset vector is left blank throughout the update process.

The third method is the most reliable but often requires the additional cost of a pushbutton.

The BSL is designed to automatically recognize four frequencies applied to XT2:

- 4 MHz
- 8 MHz
- 12 MHz
- 24 MHz

If using BSL for production programming, you must use one of these four frequencies. If using BSL after a JTAG session has been performed, you can use that JTAG session to program a modified version of the BSL that can recognize your frequency.

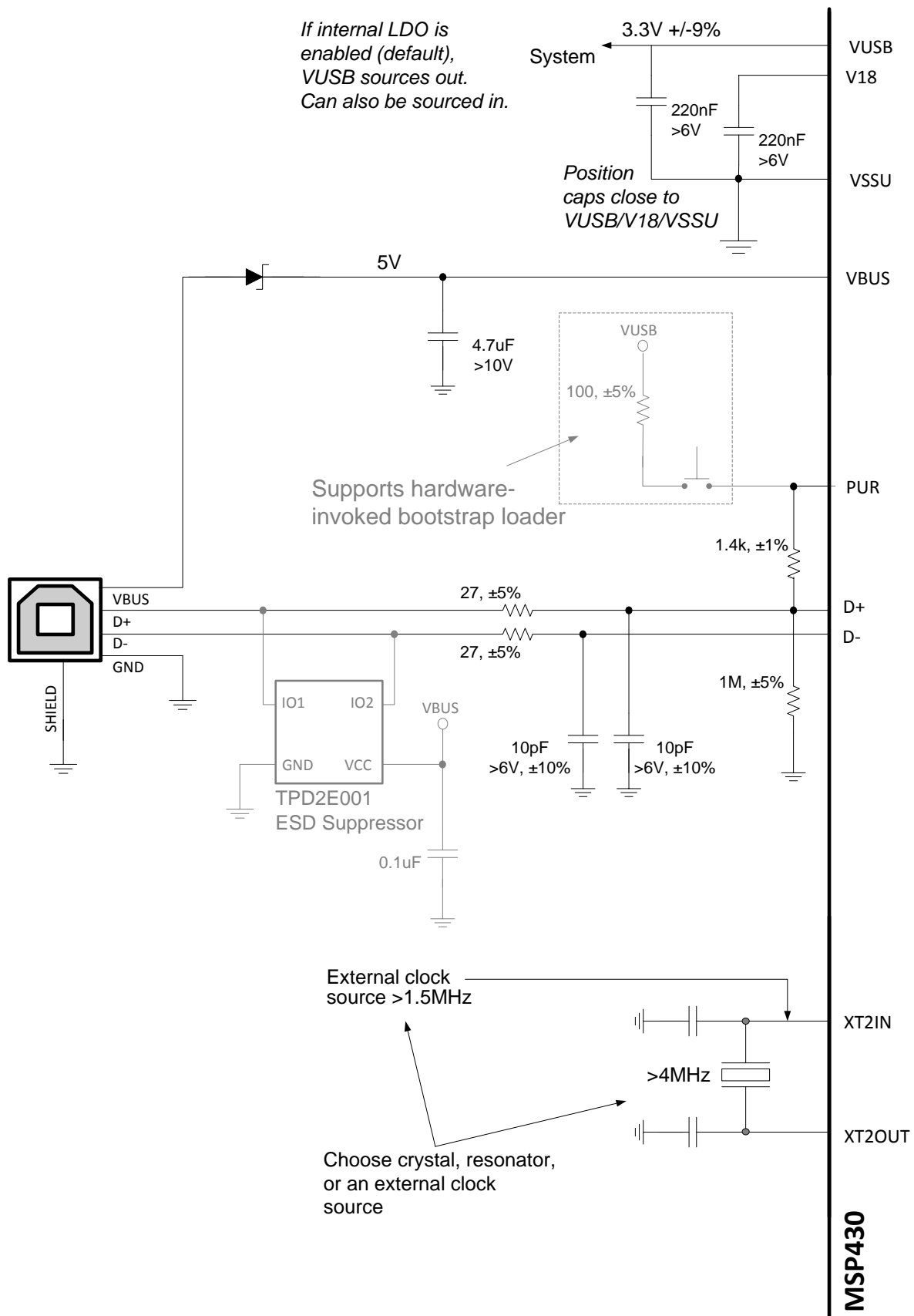
All of this is described in the application note *Field Firmware Updates on MSP430 MCUs* ([SLAA452](#)).

Supporting this application note, the MSP430 USB Developers Package includes the Python-based Firmware Updater application. This application is built on the open source package [python-msp430-tools](#). It can be used from a command line, or a GUI can be built on top of it.

## 4 MSP430 USB Hardware Design

### 4.1 TI Reference Design for USB Interface

[Figure 8](#) shows a detailed reference design, and commentary follows it.


**Figure 8. MSP430 Reference Design for USB-Related Pins**

The following sections comment on this reference design. They are not intended as a comprehensive guide to good USB design, but rather they address issues specific to MSP430 MCUs. Many good industry resources exist for USB layout and shielding recommendations.

## 4.2 Selecting a Power Configuration

The USB host provides 5-V power over the USB cable, called *VBUS*. A device can draw some or all of its power from *VBUS*. For devices that will be permanently "tethered" to the host, this can eliminate the need for a local power source.

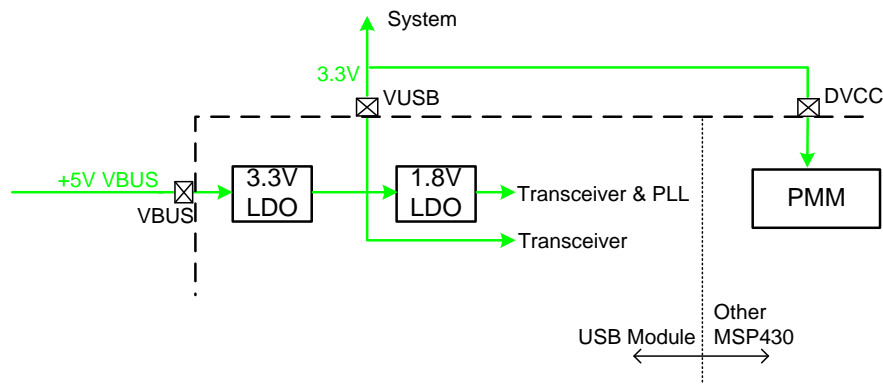
For battery-powered devices – those that must be able to operate when detached from the host – *VBUS* power is still very valuable, because USB attachment can keep a device active for long periods of time, increasing the power requirements beyond what would be required otherwise. These devices can switch their power to *VBUS* while attached, to avoid draining the battery.

USB-equipped MSP430 devices have an integrated LDO that reduces 5-V *VBUS* to a nominal 3.3 V. This rail can be used to source:

- the USB module
- the MSP430 DVCC power rail (most MSP430 devices use a 1.8-V to 3.6-V DVCC rail)
- the rest of the board

The connection between the LDO and the USB module is internal. The rail is also made available on the *VUSB* pin. There is no internal connection between *VUSB* and *DVCC*; they are isolated from each other. This preserves flexibility for the engineer designer to arrange power in a way that is best for a given application.

The maximum current that can be drawn out of the *VUSB* pin, for use on *DVCC* and elsewhere on the board, is approximately 12 mA (see the device data sheet for specific parametric values). In some applications, this is sufficient for the entire system and can eliminate the need for any other LDO.



**Figure 9. Powering the Entire System From the Internal LDO**

Many other power arrangements are possible. For example:

- *VUSB* might be used only for USB, using a different source for *DVCC* or the rest of the system. If more than 12 mA is needed, this is a convenient approach.
- The internal 3.3-V LDO might be disabled, and 3.3 V can be driven into *VUSB* from an external source. Choosing an external LDO with ultralow quiescent current can reduce current drain on *VBUS* during USB suspend.
- A switched approach can be employed: source *DVCC* and the system from a battery when USB is not attached but, upon attachment to a host, switch them to *VBUS* and *VUSB*.
- USB battery charging can be employed, using a device such as TI's BQ24030.

*VSSU* is the ground for the USB module, including the transceiver and LDOs. The capacitors on *VUSB* and *V18* should be kept as close as possible to *VSSU*, and *VSSU* should be tied to board ground.



For developers who want to source into VUSB from an external source, the Descriptor Tool includes a checkbox for this. If checked, it causes the USB API to keep the internal 3.3-V LDO disabled. However, you must still attach the VBUS signal from the USB cable to the VBUS pin, in the manner shown. The presence of 5 V on VBUS is the way in which USB devices determine whether a host is available; therefore, software needs this signal.

### 4.3 Selecting a Clock Configuration

The MSP430 USB module internally uses a 48-MHz clock, which is generated from an integrated PLL. The PLL needs a precise reference clock, which comes from the XT2 oscillator.

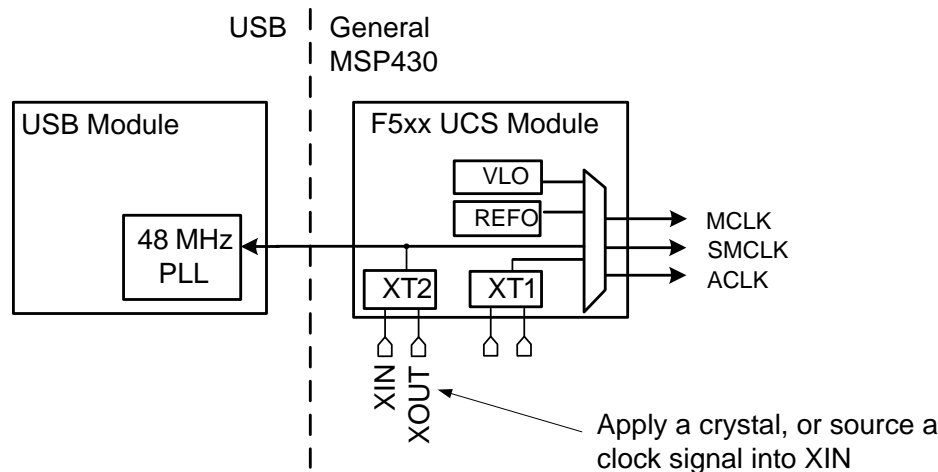


Figure 10. MSP430 USB Clock Connections

#### 4.3.1 Choosing a Source

The biggest consideration is precision. The USB specification requires the clock have a tolerance of  $\pm 2500$  ppm. Sources that do not meet this may actually work under some conditions, perhaps with compromised performance. But choosing a source that meets the requirement will provide consistent best performance and ensure USB compliance.

With this in mind, the engineer has three basic choices to source the PLL reference, shown in Table 4.

Table 4. Possible XT2 Clock Sources

Source	Frequency Range	When to Use?
External clock source (put XT2 in "bypass" mode)	1.5-32 MHz	If a clock that is always available during USB communication is present on the board, this is often the best choice, because it saves the cost of a crystal. However, if the USB BSL will be used, it must be modified for bypass mode, and this might affect its use for programming at production – see Section 3.6.
Crystal	4-32 MHz	Crystals provide great flexibility and excellent precision.
Ceramic resonator	4-32 MHz	Many resonators do not achieve the required tolerance. However, a few (for example, some parts within the Murata CERALOCK® family) do. These might be less expensive than crystals.

NOTE: Always verify parameters against the most recent device data sheet.

See the Unified Clock System (UCS) chapter of the *MSP430x5xx and MSP430x6xx Family User's Guide (SLAU208)* for information on sourcing a clock into XT2's XIN pin in bypass mode.

The source must also not contain excessive jitter that would interfere with the PLL's ability to lock to it. (For this reason, the MSP430 FLL output cannot be used as a reference for the PLL.) Whether using a crystal or bypass mode, be sure the frequency is compatible with the options available for the programmable PLL (see the *MSP430x5xx and MSP430x6xx Family User's Guide*).

If using a crystal, the load capacitors should be properly chosen, according to the crystal's specification. This is especially true if the oscillator will be shut down during USB suspend to save power consumption, in which case improper capacitor selection could result in a slow response to USB resume. Improper capacitor values could cause crystal startup to take longer than it should, and the device has a total of 10 ms to become USB-ready when the host performs a USB resume on the device. If the oscillator had been disabled during suspend for power savings, then its re-enabling is part of this 10-ms budget. (A properly-tuned oscillator will easily meet the requirements.)

Note that XT2 derives its power from the DVCC pin, rather from the internal USB LDO. Also note that XT2 consumes approximately 200-400  $\mu$ A, depending on the frequency. (See the device data sheet for actual values.)

### 4.3.2 Choosing a Frequency

A wide range of frequencies is possible, because the USB PLL has a very flexible programmable input divider. Each MSP430 header file contains predefined constants for 43 possible frequencies, and many more are possible. (The pre-defined ones are of the format `USBPLL_SETCLK_xx_yy`, where `xx_yy` is frequency-specific.)

As shown in [Section 4.3.1](#), each clock source is subject to a frequency range.

There are two considerations in frequency selection:

- Lower-frequency crystals or resonators consume less power than higher ones. (See the device data sheet power consumption values for XT2.)
- If using the USB BSL for factory programming of the MSP430 device, only 4, 8, 12, and 24 MHz are auto-recognized by the BSL. See [Section 3.6](#).

USB-equipped MSP430 boards from TI usually use a 4-MHz ceramic resonator that meets USB precision requirements. Being the lowest-frequency crystal possible, these have the advantage of minimizing power consumption. 4 MHz is also auto-detected by the on-chip BSL.

## 4.4 Other Reference Design Commentary

The circuitry within the dashed rectangle in [Figure 8](#) is required only if the bootstrap loader (BSL) is to be invoked using a pushbutton switch, for performing firmware updates through USB. PUR is normally an output, but in the moments following a BOR reset, it is an input that determines whether or not the BSL will be invoked. This pushbutton is only one way to invoke the BSL; see [Section 3.6](#) for more information.

The weak pulldown resistor on PUR ensures that the PUR pin stays low if the pushbutton is not pressed. (It is weak enough to not disrupt D+ during USB operation.) This pulldown should never be eliminated, as doing so might result in unintended invocation of the BSL.

At 12 MHz, full-speed USB usually is not highly sensitive to transmission line characteristics, but it is recommended to keep D+ and D- reasonably short.

A USB port can represent an ESD vulnerability, because it extends a conductive path to the outside of the enclosure, which the user frequently touches. Under these conditions, the protection integrated into most ICs is not enough withstand the levels of discharge it might experience. Therefore, a dedicated ESD suppressor is recommended, such as the TPD2E001 shown. It is important to follow all the design recommendations in the TPD2E001's data sheet.

## 5 MSP430 USB Software Design

Most of the MSP430 USB software documentation is located in the *USB API Programmer's Guide*, located in the USB Developers Package. Therefore, this section is only an introduction.

### 5.1 How to Choose a USB Device Class

Tradeoffs between the three device classes are shown in [Table 5](#). (Plain text indicates advantages or neutral comments, and *italic text* indicates possible disadvantages.)

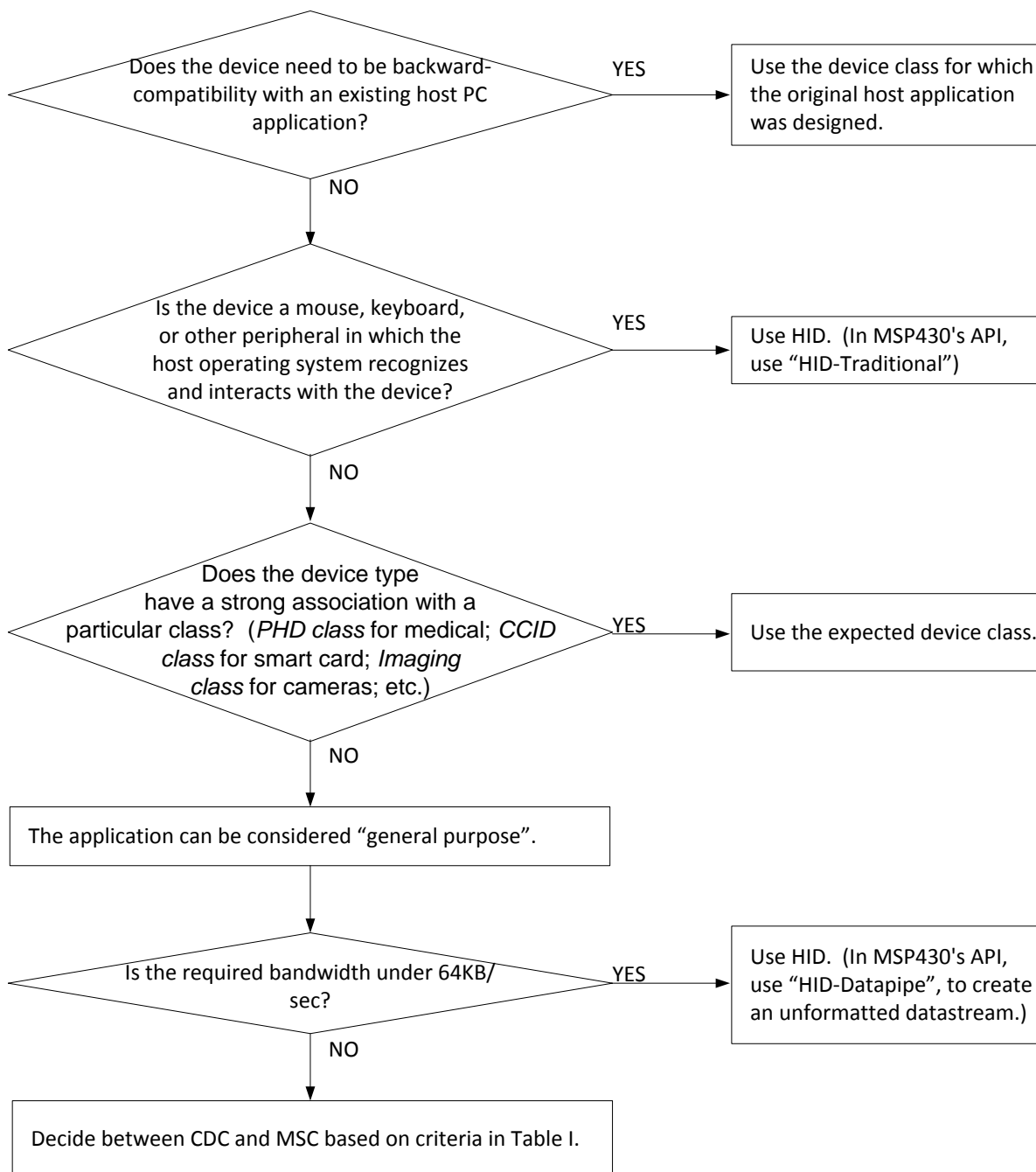
**Table 5. Device Class Tradeoffs**

Characteristic	CDC (Communications Device Class)	HID (Human Interface Device Class)	MSC (Mass Storage Class)
The interface generated on the host	<ul style="list-style-type: none"> <li>Virtual COM port</li> </ul>	<ul style="list-style-type: none"> <li>A human interface device</li> </ul>	<ul style="list-style-type: none"> <li>Storage volume</li> </ul>
Industry expertise for this interface	<ul style="list-style-type: none"> <li>COM ports are common in the industry; widely-supported and well-understood</li> </ul>	<ul style="list-style-type: none"> <li><i>Unlike COM ports or storage volumes, HID interfaces are somewhat USB-specific, and less known in the industry</i></li> </ul>	<ul style="list-style-type: none"> <li>Storage volumes are common in the industry; widely-supported and well-understood</li> </ul>
Installation on the host	<ul style="list-style-type: none"> <li><i>Windows PCs must undergo a device installation process that requires end user interaction.<sup>(1)</sup></i></li> <li><i>Admin rights on this Windows PC are required</i></li> <li><i>Despite the actual binary files already existing in Windows, the user must supply an INF file</i></li> </ul>	<ul style="list-style-type: none"> <li>Loads silently in most operating systems – simply begins working.</li> <li>No driver files required</li> </ul>	<ul style="list-style-type: none"> <li>Loads silently in most operating systems – simply begins working.</li> <li>No driver files required</li> </ul>
How the end user interacts with it	<ul style="list-style-type: none"> <li>An application on the host that interfaces with COM ports</li> <li>The application might be custom, or any existing application that uses COM ports</li> </ul>	<ul style="list-style-type: none"> <li>A custom application on the host that interfaces with HID devices</li> </ul>	<ul style="list-style-type: none"> <li>The device mounts a storage volume onto the system; applications read and write files on the volume.</li> <li>The application might be custom, or any application that reads or writes files</li> </ul>
Driver certification needs	<ul style="list-style-type: none"> <li><i>Unless the INF file is WHQL certified (signed), Windows will report that the driver is 'uncertified'.<sup>(2)</sup></i></li> </ul>	<ul style="list-style-type: none"> <li>No 'uncertified' message is generated</li> </ul>	<ul style="list-style-type: none"> <li>No 'uncertified' message is generated</li> </ul>
Code footprint and complexity	<ul style="list-style-type: none"> <li>Small code footprint (4-6K)</li> <li>Simple architecture</li> </ul>	<ul style="list-style-type: none"> <li>Small code footprint (4-6K)</li> <li>Simple architecture</li> </ul>	<ul style="list-style-type: none"> <li><i>Larger code footprint (8-15K)</i></li> <li><i>Requires a file system, increasing cost, size, and complexity.</i></li> </ul>
Throughput	<ul style="list-style-type: none"> <li>Fast (hundreds of KB/sec)</li> <li>Uses bulk USB transfers.</li> </ul>	<ul style="list-style-type: none"> <li><i>Slower (64 KB/sec)</i></li> <li>Uses interrupt USB transfers.</li> </ul>	<ul style="list-style-type: none"> <li>Fast (hundreds of KB/sec)</li> <li>Uses bulk USB transfers.</li> </ul>
Good for point-to-point communication between host and device	<ul style="list-style-type: none"> <li>Yes</li> </ul>	<ul style="list-style-type: none"> <li>Yes</li> </ul>	<ul style="list-style-type: none"> <li>No</li> </ul>
Good for bulk data transfer	<ul style="list-style-type: none"> <li>Yes</li> </ul>	<ul style="list-style-type: none"> <li>No</li> </ul>	<ul style="list-style-type: none"> <li>Yes</li> </ul>

<sup>(1)</sup> This is the process that occurs the first time the device is attached to the host. In Windows, this process may begin with a "Found New Hardware" dialog box. The user must locate the INF file provided by the OEM.

<sup>(2)</sup> WHQL certification refers to Microsoft's Windows Hardware Quality Labs. See <http://www.microsoft.com/whdc/winlogo>.

Sometimes the choice of device class is clear. In other cases, the application can be considered general purpose, giving the developer options. Although there are many ways to approach this decision, one way is shown in [Figure 11](#).



**Figure 11. Example Process for Deciding on a USB Device Class**

For general-purpose use, HID-Datapipe should be considered, because of its combination of silent loading on the host (easy for the end user) and its small footprint and simplicity on the MSP430 MCUs, which speeds development. Coding of a corresponding host application is made easier with the MSP430 *Java HID Demo App*.

## 5.2 How to Select a Vendor ID (VID) and Product ID (PID)

A common question about USB is how to select the VID and PID.

### 5.2.1 What are the VID and PID?

When a USB device is attached to a host, the host asks for its *USB descriptors*. These tell the host the nature of the device and its capabilities.

Included in the descriptors are the 16-bit VID and PID values. The VID is associated with a particular vendor/OEM, and a PID is associated with a product sold by that vendor.

For example, if vendor "Vendor1" sells their first USB product ("Product1"), they will obtain a VID, which will now be associated with their company; and they need to then choose a PID to associate with "Product1". When they later release "Product2", they'll use the same VID, but now should use a new PID. It's up to the vendor to ensure they do not duplicate PIDs, which could result in conflicts in the field.

Therefore, a unique combination of a VID and PID allows a USB host to discern one USB product type from another. If the VID and PID of "Product1" and "Product2" are the same, and a host in the field encounters both products, conflicts might result from the host confusing the two products and loading an inappropriate driver. As a rule of thumb, if devices have any differences in their USB descriptors, they should have different PIDs.

### 5.2.2 How are They Chosen (or Obtained)?

VIDs are assigned by the USB Implementers Forum (USB-IF), which is the standards body that oversees USB. The vendor can choose to obtain the VID by joining the USB-IF or to license a VID without joining. At the time of writing, the former costs \$4000 annually, and the latter costs \$3500 for a two-year license. (See <http://www.usb.org/developers/vendor/> for more information.)

Alternatively, TI will license a PID to MSP430 customers for use with the MSP430 VID (0x2047) as part of its VID-sharing program. The license is free, with the basic stipulation that it only be used with TI USB devices. The program is intended to ensure that all MSP430 customers have easy access to a VID when going to market. To obtain a copy of the license, look for the link for this program at <http://www.ti.com/msp430usb>.

### 5.2.3 Using VIDs and PIDs During Development

Having a unique VID and PID pair on a USB device is important to prevent conflicts. A given USB host stores information about the USB device's driver requirements after its first encounter with a given VID and PID. It must be able to assume that any subsequent devices with the same VID and PID require the exact same host driver setup. Therefore, once released to market, a product's VID and PID should not be changed.

During development, however, the VID and PID might sometimes need to change as the developer arrives at the final USB descriptor set. The developer must prevent conflicts on the host machine being used. This can be done either by using a new PID value any time the USB descriptors change; or the original PID can be used, but the device must be uninstalled off the system and re-installed. See the *USB API Programmer's Guide* in the USB Developers Package, for more information.

## 6 Getting Started: Evaluating MSP430 USB

### 6.1 Software Development Environments

The primary development environments for TI MSP430 are TI's Code Composer Studio™ IDE (CCS) and IAR Embedded Workbench® IDE (IAR). MSP430GCC is also supported, but note that the USB Developers Package currently does not support it.

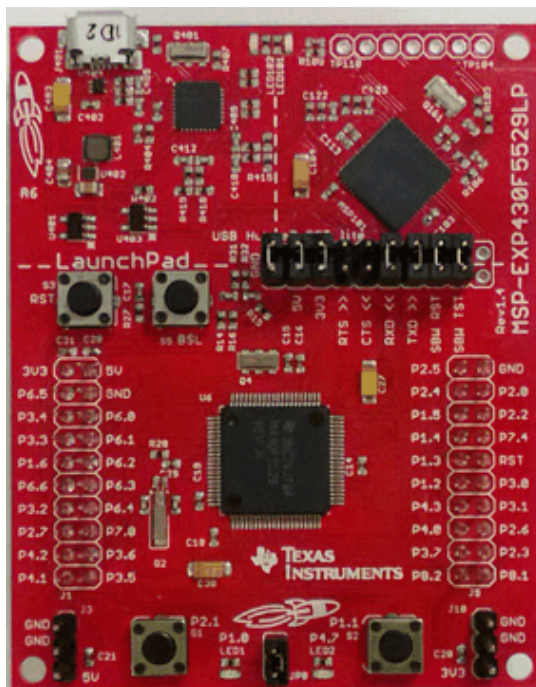
There are free code-size-limited versions of CCS (16KB) and IAR (8KB) available for download. The USB API examples are provided in both formats, and both are fully supported.

It is generally a good idea to download the latest versions of CCS or IAR. The Release Notes HTML file, inside the USB Developers Package, contains the specific versions required.

## 6.2 F5529 LaunchPad™

The [MSP-EXP430F5529LP LaunchPad](#) (the "F5529 LaunchPad") is a very inexpensive simple evaluation module for the MSP430F5529 USB microcontroller. It is an easy way to start developing on the MSP430 MCU, having on-board emulation for programming and debugging, as well as buttons and LEDs for simple user interface.

Rapid prototyping is simple, thanks to 40-pin Launchpad BoosterPack™ expansion headers, as well as a wide range of available BoosterPack plug-in modules. You can quickly add features like wireless, displays, sensors, and much more. You can either design your own BoosterPack or choose among many already available from TI and elsewhere. The 40-pin interface is compatible with any 20-pin BoosterPack that is compliant with the standard.



**Figure 12. MSP430F5529 LaunchPad**

Features of the F5529 LaunchPad include:

- USB-enabled [MSP430F5529](#) 16-bit MCU
  - Up to 25-MHz system clock; 1.8-V to 3.6-V operation
  - 128KB flash; 8KB RAM
  - Five timers
  - Up to four serial interfaces (SPI, UART, I<sup>2</sup>C)
  - 12-bit analog-to-digital converter
  - Analog comparator
  - Integrated USB, with a complete set of USB tools, libraries, examples, and reference guides
- Integrated eZ-FET lite emulator, with an application ("backchannel") UART.
- Ability to emulate and develop USB applications with a single USB cable, made possible with an on-board USB hub.
- Power sourced from the USB host. The 5-V bus power is reduced to 3.3 V, using an on-board dc/dc converter.
- Both male and female 40-pin BoosterPack headers, configured for stacking. 20-pin BoosterPacks can also be attached.
- Compatible with the 40-pin LaunchPad BoosterPack standard.



### 6.3 MSP430F5529 USB Experimenter's Board

The MSP430F5529 USB Experimenter's Board ([MSP-EXP430F5529](#)) has more features on a single board than any other MSP430 USB evaluation hardware from TI. It has multiple controls, ports, and power arrangements, allowing a wide variety of applications. Like the F5529 Launchpad, it also has an on-board emulator.

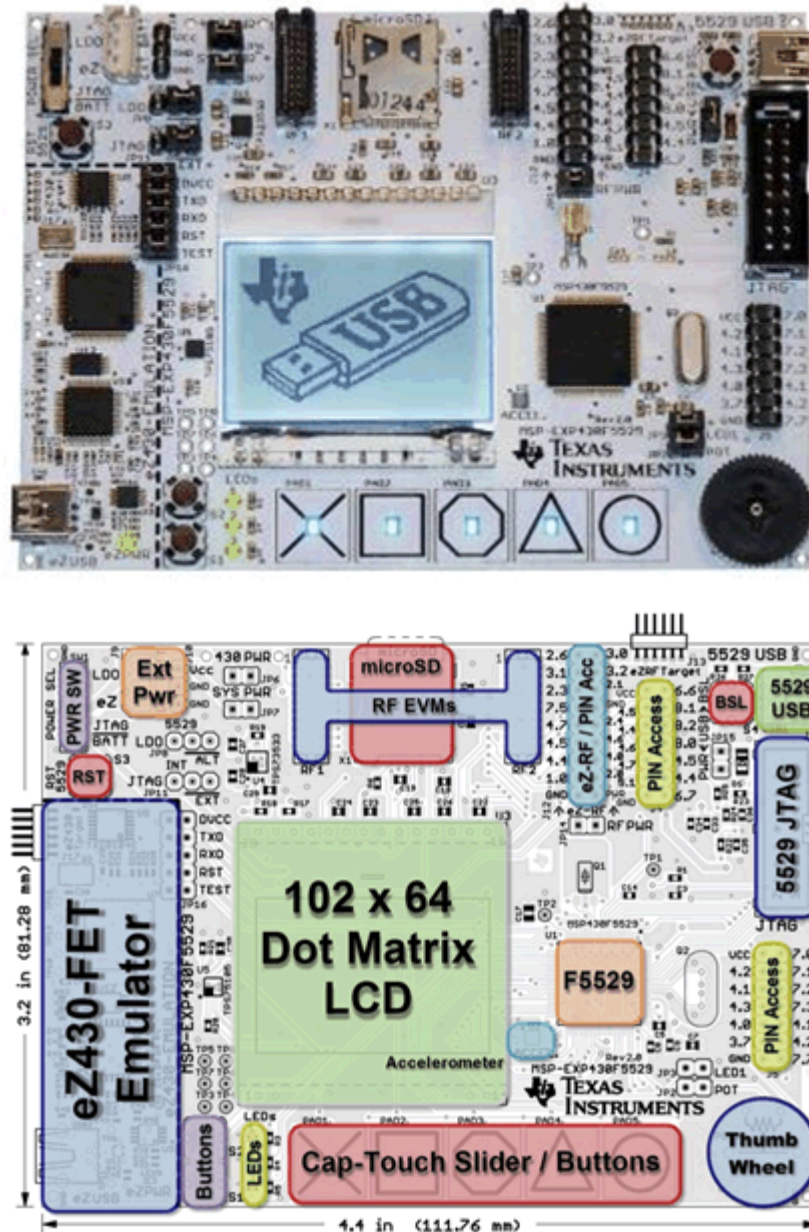
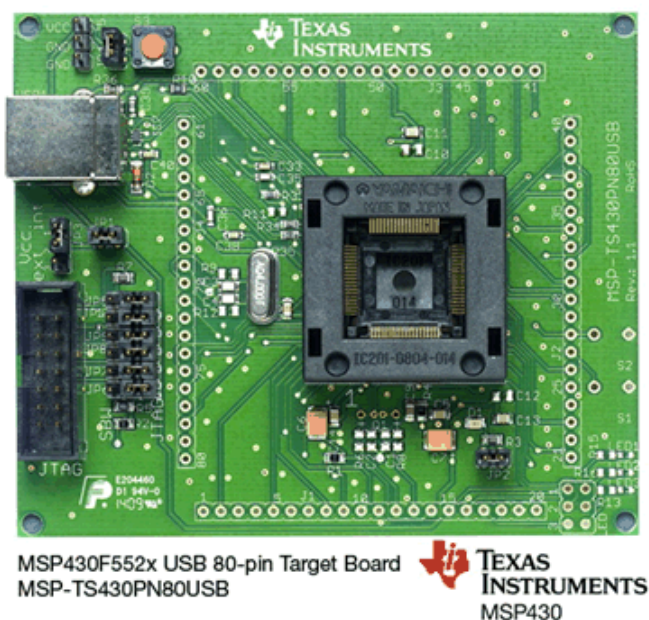


Figure 13. MSP430F5529 Experimenter's Board



## 6.4 FET Target Boards

For every MSP430 device, TI provides simple evaluation boards called "FET target boards".



**Figure 14. MSP-TS430PN80USB FET Target Board for F552x**

**Table 6. FET Target Boards for USB-Equipped MSP430 Derivatives**

USB-Equipped MSP430 Family	FET Target Board
MSP430F550x, MSP430F5510	<a href="#">MSP-TS430RGC64USB</a>
MSP430F552x	<a href="#">MSP-TS430RGC64USB</a>
	<a href="#">MSP-TS430PN80USB</a>
MSP430F563x, MSP430F663x	<a href="#">MSP-TS430PZ100USB</a>
MSP430F565x, MSP430F665x	<a href="#">MSP-TS430PZ100USB</a>

FET target boards are available for every MSP430 derivative, not just the MSP430F5529. However, they do not have an on-board emulator, as the F5529 LaunchPad and F5529 Experimenter's Board do; and so they require a [FET Tool](#) for emulation.



**Figure 15. FET Tool (MSP-FET430UIF) Emulator**

The FET Tool interfaces to hardware using the 14-pin JTAG header shown at left in [Figure 14](#).

FET target boards contain:

- A socket for the MSP430 device
- The minimum circuitry required for basic operation
- Two pushbuttons and an LED
- All of the MSP430 pins brought out to headers
- A USB connector

The FET target boards relevant to USB-equipped derivatives are shown at <http://www.ti.com/msp430usb>.

## 7 More Information

All of the tools and software described in this document can be found at the MSP430 USB landing page: <http://www.ti.com/msp430usb>. Check periodically for updates. Information can also be found on the product pages for individual devices.

For questions, go to <http://www.ti.com/support> for support options, particularly the TI Engineer-to-Engineer (E2E) community (<http://e2e.ti.com>).

- *MSP430x5xx and MSP430x6xx Family User's Guide* ([SLAU208](#)). This document contains *architectural* information common to the entire F5xx family.
- Individual device data sheets. These contain *parametric* and *device-specific* information.
- USB 2.0 specification (<http://www.usb.org/developers/docs/>)
- *USB Field Firmware Updates on MSP430 MCUs* ([SLAA452](#))
- See <http://www.ti.com/msp430usb> for all things related to MSP430 USB.

## Appendix A USB Glossary

1. **Bulk Transfers:** One of four data transfer types on the USB bus. Bulk transfers are designed for moving high volumes of data. They are capable of using any free bandwidth on the bus (that is, bandwidth not already used by the other transfer types). This allows them to achieve the highest data rates; but they are given no reserved bandwidth, so on a busy bus, bulk transfers might receive small bandwidth or experience high latency. Transfer types are determined by the choice of USB interface type; for example, CDC and MSC interfaces use bulk transfers.
2. **Composite USB Device:** A physical *USB device* (one USB connector) that contains more than one *USB interface* – for example, two CDC interfaces or CDC+HID. The host *enumerates* each interface as a separate logical entity.
3. **Control Transfers:** One of four data transfer types on the USB bus. Control transfers handle the administrative tasks of setting up the connection, like reporting USB descriptors. The host also sends other USB device requests, and the device responds using control transfers. There is a USB endpoint dedicated for these transfers: endpoint 0 (EP0).
4. **Device Class:** A defined USB protocol for a particular class of devices. Common device classes include the Communications Device Class (CDC), Human Interface Device (HID) class, and Mass Storage Class (MSC).
5. **Device Installation:** The first time a USB device is enumerated, the host may perform one-time functions to install the device. For example, Windows records information about the device in the system registry, using the device's VID and PID as an index. In subsequent enumerations, the host draws from the registry for much of its information about the device. Device installation may be silent (mostly invisible to the end user) or, in the case of CDC on Windows, may require user action.
6. **Endpoint:** The end of a *pipe*. It acts as a "mailbox" on the USB device for that pipe. A device usually has more than one active endpoint. When the host communicates on the bus, it first identifies the physical USB device, then the endpoint number within that device that it wishes to speak to. Endpoints are assigned specific functions according to the *USB interfaces* that were created. HID/MSC each use one IN and one OUT endpoint, while CDC uses two IN and one OUT endpoint. In the MSP430 API stacks, endpoint management is fully automated by the Descriptor Tool.
7. **Enumeration:** The process by which a host interrogates a physical USB device to determine what it is and loads an appropriate driver so that the host application can interface with it. Enumeration happens every time the device is attached.
8. **Interrupt Transfers:** One of the four USB data transfer types. Interrupt transfers are designed for guaranteed latency, bandwidth, and delivery. However, the bandwidth is limited to only a single USB packet (64 bytes for full-speed USB) per frame (1 ms). Transfer types are determined by the choice of USB interface type; for example, HID interfaces use interrupt transfers.
9. **Isochronous Transfers:** One of the four USB data transfer types. Isochronous transfers provide guaranteed latency and bandwidth but not delivery. That is, if error checking shows corrupted data, the attempt is not retried. This type is intended for streaming audio and video -- applications in which a retry would result in an interruption and thus be more noticeable to the user than simply missing the packet.
10. **INF (\*.inf) file:** A text-based file required during any USB device installation on Windows, allowing Windows to associate the device with a particular driver. For some device classes, Windows contains the INF internally, allowing for a silent device installation. For CDC, Windows prompts the end user for the INF file.
11. **Pipe:** A single line of communication between host and device. Pipes are either IN (into the host) or OUT (out of the host). They are characterized by a particular *transfer type* (for example, bulk or interrupt).
12. **Product ID (PID):** A unique 16-bit value assigned by a USB hardware vendor to one of its products. A VID and PID pair uniquely identifies a product type. (As a rule of thumb, if the USB descriptors of two products differ in any way, they should have different PIDs.)
13. **USB-IF:** The USB Implementers Forum. This is the standards body that defines USB specifications, governs USB certification, runs compliance workshops, and owns the legal rights to the USB logo.
14. **USB Host:** USB is hierarchal, with one (and only one) host that controls all communication.

15. **USB Device:** Also called a *USB function*. This is a logical or physical entity on the bus that contains one or more *USB interfaces*. It possesses one upstream-capable USB connector.
16. **USB Hub:** A device that provides communication between one upstream connector and multiple downstream connectors, allowing more USB devices to be attached to a host. In any given bus configuration, a device is either a host, device, or hub.
17. **USB Interface:** A logical USB entity that performs a particular function. An interface is typically associated with a particular *device class* – for example, a "CDC interface".
18. **USB Descriptors:** Data structures contained within a physical USB device that describe the device (including the interfaces it supports) and its capabilities. The host reads these during *enumeration*.
19. **USB Serial Number:** A unique string that allows a host to differentiate between devices attached to it that contain the same VID and PID values.
20. **USB speeds:** A USB connection is characterized by one of four speeds: low-speed (1.5 Mbps), full-speed (12 Mbps), high-speed (480 Mbps), or super-speed (4.8 Gbps). MSP430 MCUs are USB 2.0 full-speed devices. All MSP430 USB traffic is full-speed.
21. **VBUS:** The host is required to make 5-V power available to the device through the USB cable. The name of this power rail is *VBUS*. In addition to sourcing power, the USB device uses *VBUS* to determine whether or not an active host is present. Devices often respond to a *VBUS-on* event by asserting their presence to the host by pulling up the D+ signal.
22. **Vendor ID (VID):** A unique 16-bit value assigned by the USB Implementers Forum to a particular USB hardware vendor.

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Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
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