AN258

Low Cost USB Microcontroller Programmer
The building of the PICkit™ 1 FLASH Starter Kit

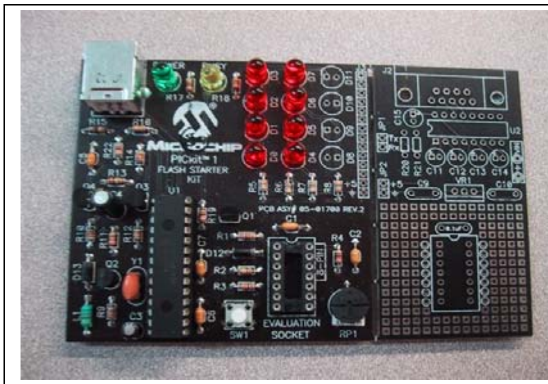
Authors: Reston Condit
Dan Butler
Microchip Technology Inc.

INTRODUCTION

The PICkit™ 1 FLASH Starter Kit is a low cost programmer for Microchip's 8/14-pin FLASH microcontrollers. On the surface, the PICkit 1 is an easy to use programmer. What may not be so obvious to its user is the PICkit 1 is also a useful design example illustrating primarily two things: (1) a Windows®-based low speed USB application and (2) a simple boost power supply design. This application note discusses all aspects of design that went into creating the PICkit 1. This application note will explore in detail the hardware design, Windows-based software, and PIC16C745 firmware. The following is a list of features that make the PICkit 1 a useful design example.

- USB Benefits
  - Plug and play
  - Non-bulky cables
  - No driver development needed (for Human Interface Device class)
  - Powered by PC (extra cable not needed)
- Low cost boost power supply
  - Firmware implemented PID control
  - Use of on-board CCP and ADC
  - Software configurable V_{PP} level from 9V to 14V
- Windows-based programming Interface
  - Simple ASCII based communication with device
  - Portable Visual Basic USB functions

FIGURE 1: PICkit™ 1 FLASH STARTER KIT PRINTED CIRCUIT BOARD



USB SIDE OF THINGS

USB devices have provided consumers with easy to use peripherals. The advantages of USB peripherals are numerous over earlier peripheral communication protocols, namely the serial and parallel ports. A standardized cable is used for all USB peripherals and the cable itself is less bulky compared to serial or parallel cables. USB connectors are distinguishable from one end to the other and are small and convenient. As laptop computers, PDAs and tablet PCs become slimmer and more compact, fewer and fewer support the previous peripheral protocols. USB devices can be bus powered, or powered directly by the PC, therefore eliminating the need for an extra power cord. USB devices are hot pluggable without risking damage to the PC or device. As a result of these benefits, peripheral developers are almost exclusively developing USB devices. For the developer who knows very little about the USB specification, this can be a daunting task. In an attempt to alleviate this task, this section will detail the software and firmware used to create USB communication between the PICkit 1 programmer board and PICkit 1 Graphical User Interface (GUI). Both the firmware and software can easily be modified to fit a variety of other applications.

Implementation: Firmware

The PIC16C745 is Microchip's low speed USB microcontroller used to facilitate USB communication between the host computer and the PICkit 1 programmer board. The PIC16C745's on-chip USB peripheral, or Serial Interface Engine (SIE), provides the lowest level interface to the USB. Microchip provides USB Support Firmware to provide a mid-level interface between the SIE and main loop in the application. This firmware, also called the Ch. 9 library firmware, primarily implements the functionality described in Ch. 9 of the USB Specification, version 1.1. Ch. 9 describes what requests the host makes of a USB device and how the device responds appropriately to these requests. Get and Put functions are provided in the Ch. 9 library to facilitate moving data onto and off of the bus in the main loop. The USB Support Firmware was used as a starting place to develop the PICkit 1 firmware.

The USB Support Firmware is more than just a library, it is also a working demo. The firmware creates a device that enumerates as a USB mouse and then sends mouse data that causes the cursor to move in a circle. This functionality was replaced by the functionality the PICkit 1 requires. Two things were changed: (1) the USB descriptors and (2) the main loop. Initialization of the SIE (Serial Interface Engine) was left the same as found in the USB Support Firmware. USB initialization consists of calling the function InitUSB and macro ConfiguredUSB.

Note:	ConfiguredUSB sets the Zero flag (STATUS, Z) when the device is configured. The device must be configured in order to send or receive user data. The device must reach the configured state before using GetEP1 or PutEP1.

DESCRIPTORS

The first thing altered in the USB Support Firmware was the descriptors. Descriptors describe to the host what information will be sent to the host. For the PICkit 1 application, generic data is sent back and forth to the host via Endpoint 1. By utilizing the Human Interface Device (HID) class, it is possible to create a device that does not require the development of a driver on the host side. HID devices are supported automatically by Microsoft® Windows (98 SE and later.) Therefore, the descriptors for the PICkit 1 describe a vendor-defined HID class device that sends eight bytes to and from the host via Endpoint One. The vendor-defined designation is made in the report descriptor, a descriptor required by HID devices. This designation makes it possible to use the Jan Axelson functions discussed later in this document in “Implementation: Software”. All descriptors are listed with comments in Appendix A. These descriptors are easily transferable to another application, with the exception that the vendor ID (owned by Microchip) and string descriptors be changed.

Note:	The PICkit 1 descriptors describe two configurations. For the purposes of this application note the second configuration can be ignored. This configuration was created so that the PICkit 1 can interface with Macintosh® computers. Non-HID descriptors are more easily interfaced by the Macintosh operating system.

MAIN LOOP

The main loop of the PICkit 1 firmware accomplishes the following primary tasks:

1. Services USB flags
2. Receives commands and data from the host
3. Transmits requested data to the host
4. Translates ASCII commands into actions

Servicing the flags generated by the Serial Interface Engine (SIE) is accomplished by calling the function ServiceUSB. This function must be called at least once every 50 ms in order to maintain reliable USB communication. The critical USB flags are serviced in the interrupt service routine (ISR) so this was left unchanged from the USB Support Firmware. All USB flags are serviced by ServiceUSB and the ISR, so other than polling ServiceUSB, the Ch.9 library makes handling USB requests transparent to the developer. A simple Get/Put interface is provided by the Ch.9 library to make getting data from and sending data over the USB easy to implement in the main loop.

Data is received from the host computer by the GetEP1 function (GetEP2 is provided if Endpoint 2 is the desired OUT endpoint.) This function is polled until the carry flag is set. The carry flag (STATUS, C) is set when the endpoint buffer is full, indicating data has been received from the host. GetEP1 transfers the data from the endpoint buffer to the user's buffer defined at the address pointed to by the FSR register and IRP bit. This parameter must be set up prior to polling the GetEP1 function. GetEP1 returns the number of bytes received in W.

Data is sent to the host in a similar fashion, using the PutEP1 function. Before calling PutEP1, the buffer where data is waiting to be sent to the host must be pointed to by the FSR register and IRP bit, and length of the buffer loaded into in the W register. If the endpoint buffer is empty, the carry flag will be sent after calling PutEP1, indicating that the data will successfully be sent to the host. PutEP1 should be polled until the carry flag is set in order to ensure the data is sent to the host successfully.

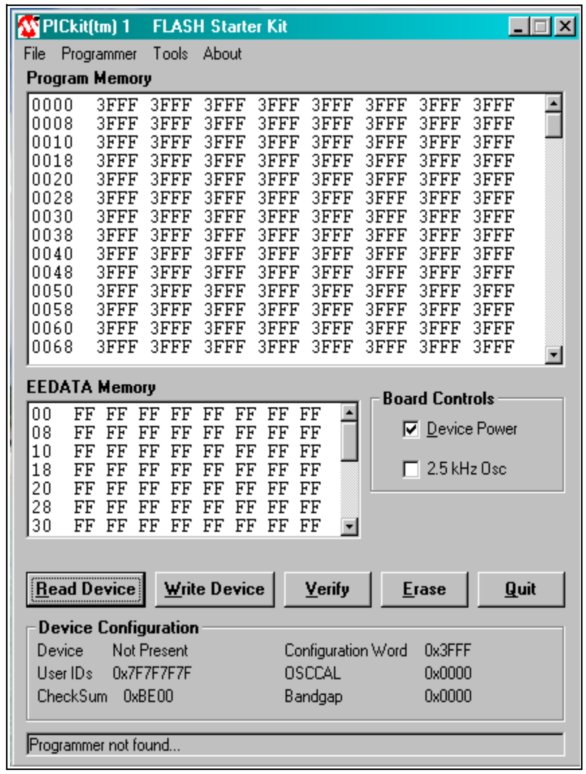
"Implementation: Software" talks about the ASCII commands sent by the host to the PIC16C745. The PIC16C745 translates these commands into actions. For instance, a "P" received from the host corresponds to the action "Enter Programming mode." The firmware interprets this command into the necessary action by toggling V_{DD} and V_{PP} to the 8/14-pin FLASH microcontroller in the appropriate sequence so that the 8/14-pin device enters Programming mode. All programming commands cause the PIC16C745 to initiate the corresponding actions defined in the programming specifications for the 8/14-pin FLASH microcontrollers (DS41173 Rev B, DS41191 Rev B.)

Note:	The specifics of the bit bang operations performed for each command are left to the reader to explore in the PICkit 1 PIC16C745 firmware (extensively commented) included with this application note, and/or in the PIC12F629/675 and PIC16F630/16F676 programming specifications.

Implementation: Software

The Graphical User Interface (GUI) for PICkit 1 was written using Visual Basic® 6.0. This section will explore the low level interface of the Visual Basic® software that communicates with the PIC16C745 via USB link. In addition, the high level interface, where the host directs the programming process, will be discussed briefly. The high level interface is not discussed in depth as it is unlikely the reader will want to adapt this functionality to his/her application. The software and firmware are extensively commented should the reader be curious. Figure 2 shows what the PICkit 1 Visual Basic® based GUI looks like.

FIGURE 2: PICkit 1 FLASH STARTER KIT GUI INTERFACE



Low Level Details

Much of this section is adapted from Jan Axelson's book, "*USB Complete, 2nd edition*." In Chapters 15 and 16 she discusses in depth, the Windows API functions that are available for interfacing to HID devices. Also, these chapters show how to declare and call the functions in both Visual C++® and Visual Basic®. This application note limits the scope of describing these functions to the Visual Basic® functions utilized in the PICkit 1 software.

The host will enumerate a device as soon as the device is connected to the computer. At this point, the device can be accessed from any Windows application. Jan Axelson describes the process for interfacing with a HID using the HID class application calls. The code to do this is available from Jan's web site www.lvr.com, both in Visual C++® and Visual Basic®, usbhidio2c.zip and usbhidio2.zip respectively. The function declaration modules included in the PICkit 1 software are spin-offs from the modules in these examples. The following paragraphs describe the process by which the PICkit 1 identifies and communicates with PICkit 1.

Low Level Programming

The first function call is HID_GetHidGuid. This is done in order to get the GUID, or Globally Unique Identifier, for the HID class. Once this is done, SetupDiGetClassDev is used to get a list of the enumerated HID devices. The software searches the list for a device matching the PICkit's product and vendor IDs. If a match is found, the device's correct interface is found using SetupDiEnumDeviceInterface. The application then calls SetupDiEnumDeviceInterfaceDetail to get the device path. With this information, the application can open the device using CreateFile and communicate using standard IO Calls, ReadFile and WriteFile. This process is greatly abbreviated. Refer to Ch. 16 of “USB Complete” or the PICkit 1 software listing for details.

The PICkit 1 implements this process within the ReadReport and WriteToDevice functions. This eliminates the need for a separate OpenFile function. These functions keep track of whether a device is found, and if not, run though the process to find it. Developers adapting the PICkit 1 software to their own needs can use ReadReport and WriteToDevice outright without dealing with the process described in the previous paragraph. These functions are explained in more detail in the next paragraphs.

ReadReport returns a buffer from the USB device. PICkit 1 uses overlapped reads and writes. That means rather than blocking the process waiting for a buffer to be returned from the device, ReadReport immediately returns the oldest buffer received. If no buffer has been received, it still returns immediately with an error code. While non-overlapped reads may seem simpler, it presents a problem in that it blocks the process until the buffer has been returned. The process could wait forever if the board is not attached.

The following is a list of function parameters:

- Inputs - None from process. Uses constants for vendor and device IDs
- Outputs - ReadBuffer, global array of 8 bytes
- Status - Result, global integer

WriteToDevice sends an 8 byte command buffer to the device. The command is passed as a string type. Internally, WriteToDevice copies the string over to an array of 8 bytes. A leading '0' is used by the HID class driver as a report ID.

The following is a list of function parameters:

- Inputs - Command string
- Outputs - None
- Status - Result, global integer

One limitation to ReadReport and WriteToDevice is that they require communication to occur 8 bytes at a time. Short packets are not allowed, so OUT transactions are padded with a null command to the device. Likewise IN transactions are padded with null bytes. The next section will clarify this issue.

PICkit 1 is supported on Windows® 98SE, Windows® ME, Windows® 2000, and Windows® XP. PICkit 1 will not work on Windows® NT or Windows® 98 Gold. The reason PICkit 1 will not work on Windows 98 Gold is that the PICkit 1 uses an Interrupt OUT endpoint. Interrupt OUT endpoints were not introduced until version 1.10 of the USB Specification. Windows 98 Gold supported only version 1.00.

HIGH LEVEL PROGRAMMING

The PICkit 1 PIC16C745 device implements only the most primitive programming operations, very closely aligned with the actual programming commands provided in the part. These commands are described in the PIC12F629/675 and PIC16F630/676 programming specifications. It is the host that directs the sequence of these primitive functions in order to implement the programming of the 8/14-pin device. This was done so that as long as the command table doesn't change from device to device, future devices of varying memory sizes can be accommodated with only a change to host software, not firmware.

Currently there are thirteen commands implemented:

- 'P' - Enter Programming mode. Enables Programming mode in the device. Must be done before any other commands can be executed.
- 'p' - Exit Programming mode. Shuts down Programming mode.
- 'E' - Bulk erase program memory
- 'e' - Bulk erase data memory
- 'W' - Write program memory and increment PC to the next word address
- 'D' - Write byte to EE Data memory
- 'C' - Advance PC to Configuration memory (0x2000)
- 'I' - Increment address n times
- 'R' - Read four words from program memory
- 'r' - read eight bytes from EE Data memory
- 'V' - Control device power and 2.5 kHz control
- 'v' - Return firmware version, three bytes <major>, <minor>, <dot>
- 'S' - Calculate checksums for both Program memory and EE Data memory.
- 'Z' - Null command, used to pad out the 8 byte command packets

Commands are packed conveniently into the 8 byte packets (e.g., Write commands take three bytes: 'W', <high byte>, <low byte>). Two of these are packed into each 8 byte packet and the last two bytes are padded with null commands. The Read commands read as much as will fit into a return packet. Read Program memory reads and returns 4 words; Read EE Data returns 8 bytes. Since eight of these commands can be packed into each OUT transaction, 32 words or 64 bytes may be read as a result of one OUT transaction.

The erase process is complicated by calibration values that must be preserved. The OSCCAL value is stored at the last location of program memory and the Bandgap calibration is in the high order bits of the configuration word. These must be read prior to erasing and restored after the erase.

THE BOOST POWER SUPPLY

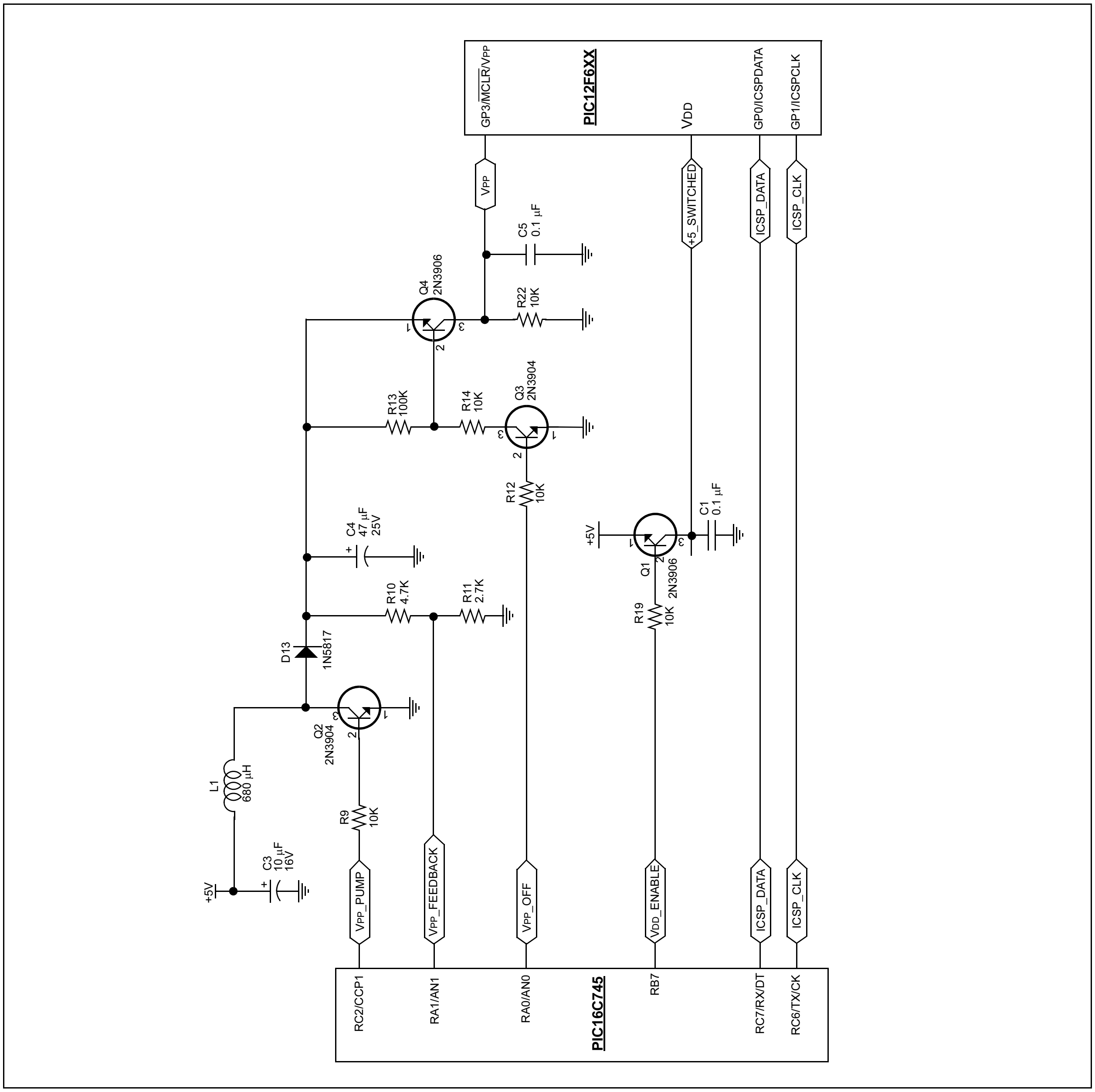
A boost power supply is needed on the PICkit 1 programmer board in order to create the programming voltage (VPP) called for in the PIC12F629/675 programming specification. The boost power supply is a combination of hardware and firmware design.

Implementation: Hardware

The hardware developed for the PICkit 1 FLASH Starter Kit intentionally uses as few components as necessary to keep the cost low. Most of the components on the PICkit 1 programmer board make up the boost power supply. The boost power supply, shown in Figure 3, creates the 13V voltage needed for programming Microchip's low pin count FLASH devices. CCP1 runs in PWM mode to create the input to the boost circuit. Timer2 sets the period of the PWM. An A/D channel (RA1) provides feedback to the PIC16C745.

VPP is switched on and off by pin RA0. Similarly, RB7 switches power to VDD. Finally, RC6 and RC7 bit bang programming commands to the device.

FIGURE 1-1: PROGRAMMING HARDWARE



Details on how a boost circuit works are discussed in Technical Brief TB053. What happens briefly is that when Q2 is turned on, inductor L1 charges. When Q2 is switched off, the energy stored in L1 flows through D13 to the storage capacitor (C4) and load. Q3 and Q4 make up a switch for turning VPP on and off to the FLASH device. The switch is toggled on and off by RA0. Assuming the resistive load is the held constant, VPP will change with respect to the energy released from L1. L1 stores energy during the high phase of the PWM and releases energy during the low phase of the PWM. This boost circuit runs in Discontinuous mode, meaning L1 will always discharge fully during the low phase of the PWM. VPP increases as the duty cycle of the PWM increases. The stability of VPP is achieved with a firmware PID.

Implementation: Firmware

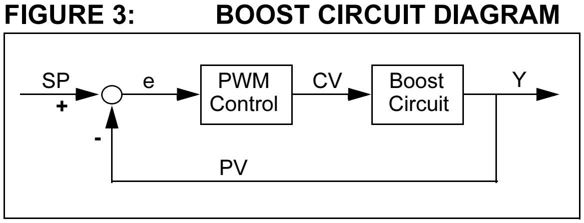
The boost circuit routines are located in two linked files: pid.asm and VPPCntl.asm. VPPCntl.asm contains the functions for initializing the PIC16C745 peripherals used to generate the boost circuit, turning VPP and VDD on and off, and clamping VPP high or low. This file also contains the DoSwitcher function which is called from the ISR when Timer2 interrupts. Timer2 is set up to overflow at a frequency of 93.75 kHz. The Timer2 postscaler is 1:16, therefore the Timer2 interrupt occurs at a frequency of 5.86 kHz. DoSwitcher reads the A/D value generated on the boost circuit feedback pin. DoSwitcher then transfers this value to the PID function where a correction factor is calculated. Several parameters are defined at the head of VPPCntl.asm. They are described in Table 1.

TABLE 1: PARAMETER

Parameter	Description
VCHECK	ADC value corresponding to VPP = 13V
PWM_MAX	Max duty cycle
skip_reload	Number of TMR2 interrupts between reading ADC

PID control is used to stabilize VPP. From a control standpoint the boost circuit looks like the following system:

FIGURE 3: BOOST CIRCUIT DIAGRAM



Any increase or decrease in the duty cycle causes a respective rise or fall in VPP. The variable governing the duty cycle is the control variable (CV). The control variable is calculated for the next cycle based on the proportional, integral and differential analysis of the feedback. Equation 1 shows this relation.

EQUATION 1:

$$CV_{k+1} = P_k + I_k + D_k$$

Pk, Ik, and Dk are all functions of the difference between the Set Point (SP) and Present Variable (PV). This difference is the error (e_k) for a present cycle. Equation 2 shows this relation.

EQUATION 2:

$$e_k = SP - PV_k$$

The proportional term in Equation 1 is directly proportional to e_k. It is defined as e_k multiplied by the proportionality gain constant, K_p (Equation 3). The proportional term's contribution to the output is based only on the amount of error. By increasing K_p, the response time of the output decreases and the overshoot increases. If K_p is too large the system will be unstable. In summary, P_k compensates for a change in what CV currently is and what it needs to be.

EQUATION 3:

$$P_k = K_p e_k$$

The integral term I_k is equal to the previous integral calculation plus the deviation from the Set Point, e_k, multiplied by the integration gain constant, K_i (Equation 4). From a conceptional standpoint, I_k effects the output based on how long the error has been around, as well as the amount of error. The longer the error is present, the greater I_k contributes to changing the output. I_k tends to integrate the error to zero.

EQUATION 4:

$$I_k = I_{k-1} + K_i e_k$$

The final contribution to Equation 1 is the derivative term. This term is equal to the derivative gain constant, K_d, multiplied by the difference between the previous deviation from the Set Point, e_{k-1}, and the current deviation, e_k. The derivative term affects the output based on the rate of change of the error. The faster the rate of change of the error, the greater affect this term has on the output. D_k compensates for a dynamically changing CV requirement.

EQUATION 5:

$$D_k = K_d\,(e_{k-1} - e_k)$$

Trial and error was used to find the values of K_p, K_i, and K_d that gave VPP the best balance between rise time, stability and overshoot. These values are defined in pid.inc.

Conclusion

The USB design for the PICkit 1 FLASH starter kit is very versatile and can be used in a variety of other applications with minimal changes to its firmware and Visual Basic software. For developers looking to create a Windows-based USB application using the PIC16C745, the PICkit 1 design offers a ready made example of how to do it. In addition, the PICkit 1 also provides an example of boost circuit design using minimal components. As a design example, the PICkit 1 offers more to engineers than just a low cost PIC® MCU programmer.

References

- Jan Axelson, "*USB Complete, Second Edition*", © 2001, Lakeview Research, Madison, WI
- Jan Axelson's website: `www.lvr.com`
- PICkit™ 1 User's Guide (DS40051C)
- PIC12F629/675 Programming Specification (DS41173C)
- TB053, "*Generating High Voltage Using the PIC16C781/782"* (DS91053A)
- Universal Serial Bus Specification, Revision 1.1 © 1998, Compaq Computer Corporation, Intel Corporation, Microsoft Corporation, NEC Corporation
- HID Class Definition, revision 1.1 © 1998, Compaq Computer Corporation, Intel Corporation, Microsoft Corporation, NEC Corporation
- USB Support Firmware User's Guide

NOTES:

APPENDIX A: USB DESCRIPTORS

Descriptor fields defined in Ch9 of USB Specification and HID Class Definition

```
Device Descriptor
      0x12          ; bLength                   Length of descriptor
      0x01          ; bDescType                 This is a DEVICE descriptor
      0x10          ; bcdUSBUSB                 USB spec. revision 1.10 (low byte)
      0x01          ;                           (high byte)
      0x00          ; bDeviceClass
      0x00          ; bDeviceSubClass
      0x00          ; bDeviceProtocol
      0x08          ; bMaxPacketSize0
      0xD8          ; idVendor                  0x04D8 is Microchip's Vendor ID
      0x04          ;                            (high byte)
      0x32          ; idProduct                 Product ID = 50 (low byte)
      0x00          ;                            (high byte)
      0x00          ; bcdDevice                  (low byte)
      0x00          ;                            (high byte)
      0x01          ; iManufacturer             String Index = 1
      0x02          ; iProduct                  String Index = 2
      0x00          ; iSerialNumber             0
      0x02          ; bNumConfigs               2 configurations

Configuration Descriptor 1 (Index 0)
      0x09          ; bLength                   Length of descriptor
      0x02          ; bDescType                 This is a CONFIGURATION descriptor
      0x29          ; wTotalLength              Total length of all descriptors in
      0x00                                       this configuration
      0x01          ; bNumInterfaces            Number of interfaces in this config
      0x01          ; bConfigValue              Configuration Value
      0x03          ; iConfig                   String Index = 3
      0x80          ; bmAttributes              bus powered, remote wakeup disabled
      0x32          ; MaxPower                  100mA (2mA*32h)
Interface Descriptor
      0x09          ; bLength                   Length of descriptor
      0x04          ; bDescType                 This is an INTERFACE descriptor
      0x00          ; bInterfaceNum             number of interface, 0 based array
      0x00          ; bAlternatSet              Alternate setting - N/A
      0x02          ; bNumEndpoints             # of endpoints in this interface
      0x03          ; bInterfaceClass           assigned by the USB
      0x00          ; bIntrfcSubClass           Not A boot device
      0x00          ; bIntrfcProtocol           none
      0x00          ; iInterface                String Index = 0 (none)
HID Descriptor
      0x09          ; bLength                   Length of descriptor
      0x21          ; bDescType                 This is an HID descriptor
      0x00          ; bcfHID                    HID spec. revision 1.00 (low byte)
      0x01                                       (high byte)
      0x00          ; bCountryCode              Localized country code (none)
      0x01          ; bNumDescriptors           # of HID class descriptors
      0x22          ; bDescType                 Report descriptor type
      0x1D          ; bDescLength               Length of Report descr. (low byte)
      0x00                                       (high byte)
Endpoint Descriptor
      0x07          ; bLength                   Length of descriptor
      0x05          ; bDescType                 This is an ENDPOINT descriptor
      0x81          ; bEndpointAddr             EP1, In
      0x03          ; bmAttributes              Transfer Type: Interrupt
      0x08          ; wMaxPacketSize            Maximum packet size (low byte)
      0x00                                       (high byte)
      0x0A          ; bInterval                 polling interval: 10ms
Endpoint Descriptor
      0x07          ; bLength                   Length of descriptor
      0x05          ; bDescType
      0x01          ; bEndpointAddr             EP1, OUT
```

```
     0x03        ; bmAttributes           Interrupt
     0x08        ; wMaxPacketSize         Maximum packet size (low byte)
     0x00                                  (high byte)
     0x0a        ; bInterval              polling interval: 10ms
```

Configuration Descriptor 2 (Index 1)

```
     0x09        ; bLength                Length of descriptor
     0x02        ; bDescType              This is a CONFIGURATION descriptor
     0x20        ; wTotalLength           Total length of all descriptors in
     0x00                                  this configuration
     0x01        ; bNumInterfaces         Number of interfaces in this config
     0x02        ; bConfigValue           Configuration Value
     0x04        ; iConfig                String Index = 4
     0x80         bmAttributes            bus powered, remote wakeup disabled
     0x32        ; MaxPower               100mA (2mA*32h)
```

Interface Descriptor

```
     0x09        ; bLength                Length of descriptor
     0x04        ; bDescType              This is an INTERFACE descriptor
     0x00        ; bInterfaceNum          number of interface, 0 based array
     0x00        ; bAlternatSet           Alternate setting - N/A
     0x02        ; bNumEndpoints          # of endpoints in this interface
     0xFF        ; bInterfaceClass        assigned by the USB
     0x00        ; bIntrfcSubClass        Not A boot device
     0x00        ; bIntrfcProtocol        none
     0x00        ; iInterface             String Index = 0 (none)
```

Endpoint Descriptor

```
     0x07        ; bLength                Length of descriptor
     0x05        ; bDescType              This is an ENDPOINT descriptor
     0x81        ; bEndpointAddr          EP1, In
     0x03        ; bmAttributes           Transfer Type: Interrupt
     0x08        ; wMaxPacketSize         Maximum packet size (low byte)
     0x00                                  (high byte)
     0x0A        ; bInterval              polling interval: 10ms
```

Endpoint Descriptor

```
     0x07        ; bLength                Length of descriptor
     0x05        ; bDescType
     0x01        ; bEndpointAddr          EP1, OUT
     0x03        ; bmAttributes           Interrupt
     0x08        ; wMaxPacketSize         Maximum packet size (low byte)
     0x00                                  (high byte)
     0x0a        ; bInterval              polling interval: 10ms
```

ReportDescriptor

```
     0x06, 0x00, 0xff     ; USAGE_PAGE (Vendor Defined Page 1)
     0x09, 0x01           ; USAGE (Vendor Usage 1)
     0xa1, 0x01           ; COLLECTION (Application)
     0x19, 0x01           ;   USAGE_MINIMUM (Vendor Usage 1)
     0x29, 0x08           ;   USAGE_MAXIMUM (Vendor Usage 8)
     0x15, 0x00           ;   LOGICAL_MINIMUM (0)
     0x26, 0xff, 0x00     ;   LOGICAL_MAXIMUM (255)
     0x75, 0x08           ;   REPORT_SIZE (8)
     0x95, 0x08           ;   REPORT_COUNT (8)
     0x81, 0x02           ;   INPUT (Data,Var,Abs)
     0x19, 0x01           ;   USAGE_MINIMUM (Vendor Usage 1)
     0x29, 0x08           ;   USAGE_MAXIMUM (Vendor Usage 8)
     0x91, 0x02           ;   OUTPUT (Data,Var,Abs)
     0xc0                 ; END_COLLECTION
```

String1*
```
"Microchip Technology Inc."
```

String2*
```
"PICkit™ 1 FLASH Starter Kit"
```

String3*
```
"Config. 1: HID"
```

String4*
```
"Config. 2: non-HID"
```

```
*Strings written in unicode format.  Refer to firmware for details.
```

APPENDIX B: SOURCE CODE

The complete source code, including the application software and device firmware are available for download as a single archive file from the Microchip corporate web site at:

www.microchip.com

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Kokomo, IN 46902
Tel: 765-864-8360 Fax: 765-864-8387

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Irvine, CA 92612
Tel: 949-263-1888 Fax: 949-263-1338

Phoenix
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Chandler, AZ 85224-6199
Tel: 480-792-7966 Fax: 480-792-4338

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

Toronto
6285 Northam Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

ASIA/PACIFIC

Australia
Microchip Technology Australia Pty Ltd
Marketing Support Division
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

China - Beijing
Microchip Technology Consulting (Shanghai) Co., Ltd., Beijing Liaison Office
Unit 915
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

China - Chengdu
Microchip Technology Consulting (Shanghai) Co., Ltd., Chengdu Liaison Office
Rm. 2401-2402, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-86766200 Fax: 86-28-86766599

China - Fuzhou
Microchip Technology Consulting (Shanghai) Co., Ltd., Fuzhou Liaison Office
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506 Fax: 86-591-7503521

China - Hong Kong SAR
Microchip Technology Hongkong Ltd.
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

China - Shanghai
Microchip Technology Consulting (Shanghai) Co., Ltd.
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xia Road
Shanghai, 200051
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

China - Shenzhen
Microchip Technology Consulting (Shanghai) Co., Ltd., Shenzhen Liaison Office
Rm. 1812, 18/F, Building A, United Plaza
No. 5022 Binhe Road, Futian District
Shenzhen 518033, China
Tel: 86-755-82901380 Fax: 86-755-8295-1393

China - Qingdao
Rm. B505A, Fullhope Plaza,
No. 12 Hong Kong Central Rd.
Qingdao 266071, China
Tel: 86-532-5027355 Fax: 86-532-5027205

India
Microchip Technology Inc.
India Liaison Office
Marketing Support Division
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Microchip Technology Japan K.K.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore, 188980
Tel: 65-6334-8870 Fax: 65-6334-8850

Taiwan
Microchip Technology (Barbados) Inc.,
Taiwan Branch
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Austria
Microchip Technology Austria GmbH
Durisolstrasse 2
A-4600 Wels
Austria
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

Denmark
Microchip Technology Nordic ApS
Regus Business Centre
Lautrup hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45-4420-9895 Fax: 45-4420-9910

France
Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Microchip Technology GmbH
Steinheilstrasse 10
D-85737 Ismaning, Germany
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy
Microchip Technology SRL
Via Quasimodo, 12
20025 Legnano (MI)
Milan, Italy
Tel: 39-0331-742611 Fax: 39-0331-466781

United Kingdom
Microchip Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44-118-921-5869 Fax: 44-118-921-5820

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