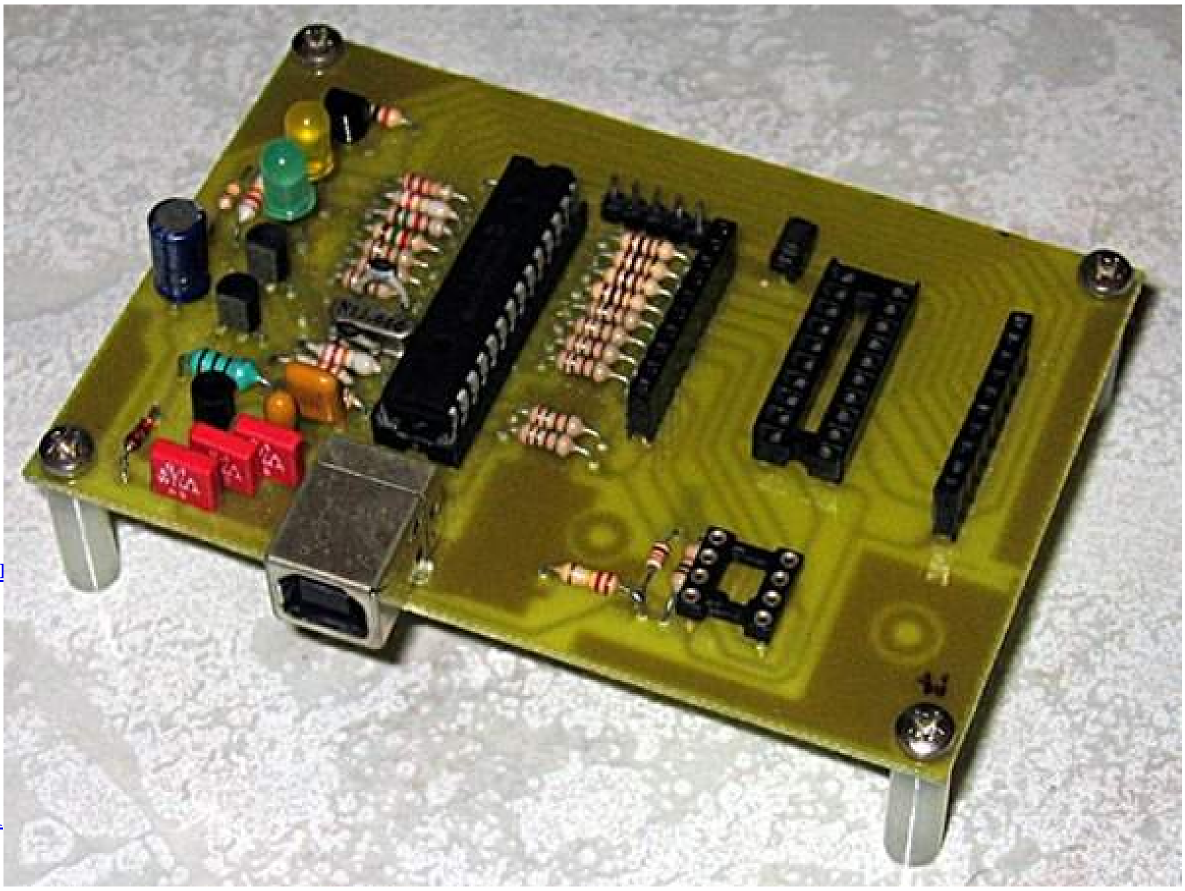
Open Programmer v0.10.0

An open source USB programmer for PIC micros, ATMEL micros, I2C-SPI-MicroWire-OneWire-UNIO EEPROMs, generic I2C/SPI devices and (soon) other devices

Quick facts

- Completely free and Open Source (including firmware)
- Programs PIC10-12-16-18-24, dsPIC30-33, ATMEL AVR (serial and HV serial programming), serial EEPROMs type 24xxxx (I2C), 25xxx (SPI), 93xx6 (MicroWire), DS24xx (OneWire), 11xxx (UNIO), communicates with generic I2C & SPI devices (see[supported devices](#))
- Can work as [ICD debugger](#)
- USB 2.0 Full Speed interface, HID class (same as keyboards, mice, etc.)
- Self powered
- Doesn't need drivers
- Built from easy to find components (estimated cost ~10€)
- Hardware generated timings for maximum speed and reliability (writes a 18F2550 in 15s)
- Doesn't saturate your CPU and doesn't suffer when other programs are running
- Open source control programs for Linux and Windows
- It's not another PicKit clone

Picture of a prototype:



Another programmer?

In the last few years, as serial and parallel interfaces have almost disappeared, electronics enthusiasts find even more difficult to program microcontrollers; old time programmers don't work any more; common solutions include using USB to serial adapters (which can't accept direct access but only slow API calls), or add-on interface chips, like FTDIxxxx, which appear substantially as serial interfaces and require custom or proprietary drivers.
So why not use PIC controllers and their native USB interface?
After searching a while I couldn't find an USB programmer which was at the same time functional, free, and open source, so I decided to design one.
Open source means that all sources and schematics are given free of charge with the rights to modify and release them.

USB & HID firmware (v0.10.0)

In order to use the USB interface included in some PIC devices we need a firmware that implements one of the classes defined by the USB consortium or a new one; I opted for the HID class, which is supported natively by all operating systems and so doesn't need any driver. Maximum allowed speed is 64KB/s, although with my application I measured something in the range 20-40 KB/s, certainly enough to program devices with memory of 100KB at most.
Like all USB devices this one too has a vid and a pid; these are usually obtained under payment; I got a combination for free from pid.codes: 0x1209&0x5432; anyways it's possible to

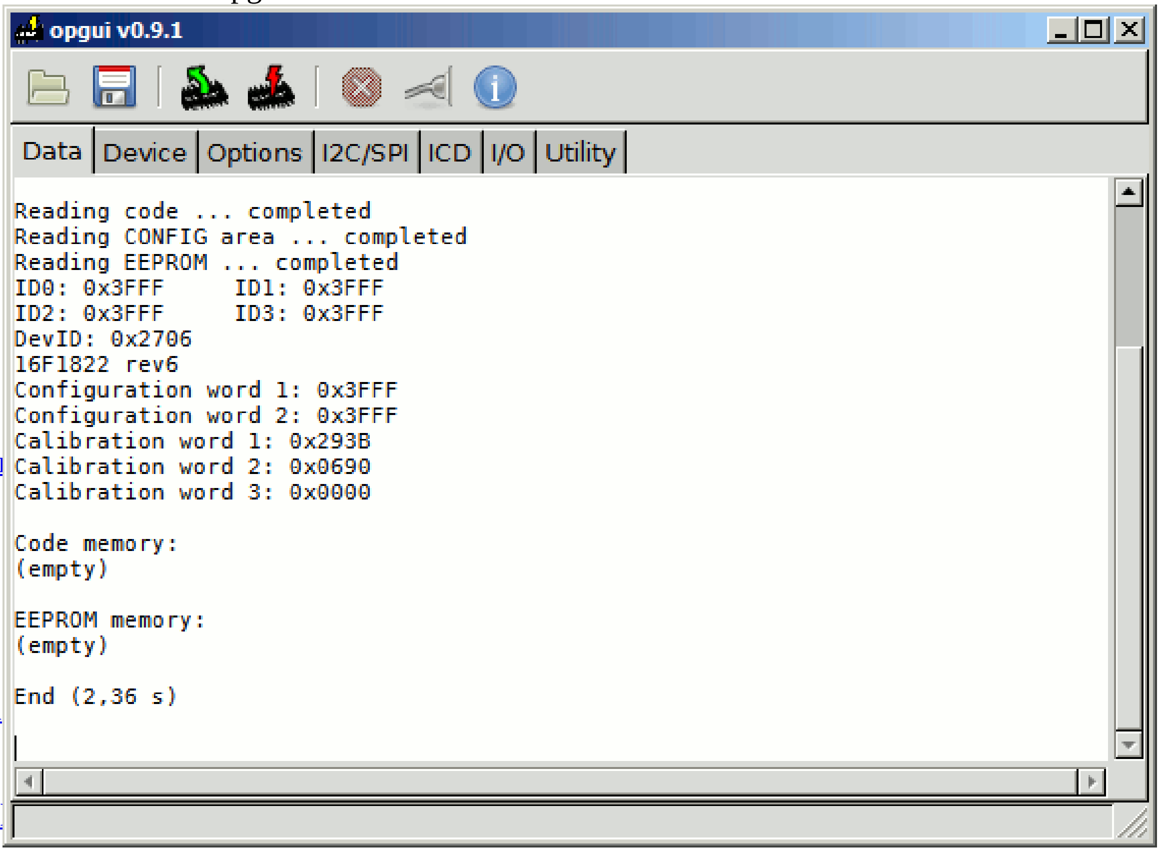
configure both, so I leave the choice to the user.
The programmer appears to the system as a HID device that exchanges 64 bytes packets every 1 ms.
The USB firmware comes from a nearly unknown open source project, written by Alexander Enzmann, which I modified and adapted to the MCC18 compiler.
I wrote a brief guide on how to use it; to my knowledge this is the only open source firmware with HID support and GPL license.
My programmer code simply adds a command interpreter that drives the microcontroller's outputs according to a set of instructions.
The main control cycle waits for a packet from USB, then executes commands in sequence while managing communication tasks; at the same time a control function is called periodically by a timer interrupt and keeps the DCDC regulator output voltage constant.
Building the project requires only free programs: MPLAB and MCC18 student version, which are unfortunately only available for the windows (in)operating system.
It's certainly possible to compile with SDCC, but some changes are needed to the source code.
Everything is given under the GPL2 license.
Here is the complete MPLAB project, here the hex file only.
Here a version (0.8.0) for 18F2450 (with reduced functionality, see the circuit).

Control programs

I initially thought of modifying an existing software, for example winpic or picprog, but I found it would be too difficult because I use packetized communications instead of serial; so I had to write one (two) from scratch.
Unfortunately, or fortunately, since I'm not a professional programmer I kept features at minimum; the result are very small but fast programs that don't use your CPU for nothing.
For most devices the code is verified while programming; for the others immediately following the writing phase.
Ideally you should have the same version number for both software and firmware, except for the last number which indicates minor changes and bug fixes; however I tried to keep the same protocol with each release, so that apart from new features it is often possible to use new software with older firmware and vice versa.
In case you wonder, the reason why it's not possible to program directly from MPLAB is not technical: Microchip does not release specifications of how to interface with its program; if you want them you have to be a commercial manufacturer and sign a non disclosure agreement, which is clearly impossible for a GPL2 open source project.
On the contrary, integration with Piklab is possible and I hope will be done soon; right now the custom programmer interface lacks some essential parameters, but whoever has the ability and time can fix it for sure.

GTK graphical interface for Windows and Linux (v0.10.0)

OPGUI uses the GTK libraries so under Windows it's necessary to install the GTK Runtime Environment.
A screenshot of Opgui:



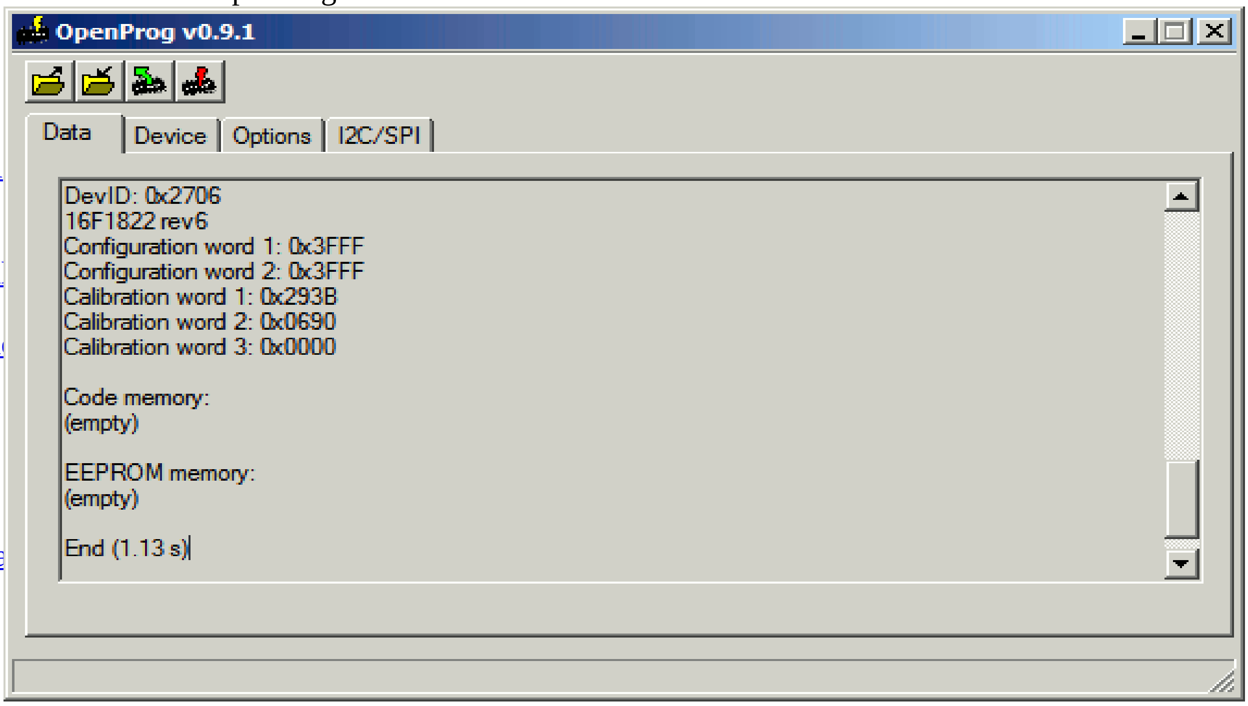
A quick guide: buttons to read, write, load and save files are on the toolbar.
The "Data" tab shows what the programmer is doing.
On the "Device" tab it's possible to choose the device and modify some programming options, such as writing ID and calibration words, using the eeprom etc.; only settings compatible with the current device are considered.
Under "Options" are various general settings: USB connection, errors, log file, expansion boards; using the "Hardware Test" function and a voltmeter is possible to check that the circuit is working.
The "I2C/SPI" tab is useful for communicating with generic I2C and SPI devices; in case of I2C it's always necessary to specify the control byte (and address, if not zero); RW bit is handled automatically.
For example, to write manually 3 bytes on a 24xx16 at address 64 write: A0 40 1 2 3
From version 0.7.10 it is included an ICD debugger, working more or less like pdb; in addition it supports coff files.
The "I/O" tab allows to control individual I/O lines and the power supplies.
Under "Utility" there are functions to convert a single hex line to data and vice versa.
There is no installer since there aren't any libraries and the executable is very small.
The program accepts hex8 and hex32 files, and also binary files in case of serial memories.
Supported languages are currently English and Italian; to add other languages it's necessary to generate the languages.rc file (-langfile option) and to modify it; the language id is before the respective strings, enclosed in square brackets [].
The language is chosen at startup by matching the system

language (it can also be forced with -lang).
To enable access to the programmer under Linux see chapterCommand line interface.
You can find more info on the OpenProg and Opgui user's guide or in the source code guide.
To compile the program from source (optional) you need to install the GTK libraries, GCC and the maketools (MinGW/MSYS in Windows); then write:
> make
To install it under Linux(if you wish):
> make install
Download the compiled program ... or the sources.

Top
Quick facts
Another programmer
USB & HID firmware
Control programs
GTK graphical interface
MFC Graphical interface
Command line interface
How to ...
Supported devices
Communication protocol
The circuit
Voltage regulator
How to contribute
Download
History
Links
Contacts

Graphical interface for Windows (v0.9.1)

OpenProg is a C++ application written with Visual C++ 6 and MFC.
A screenshot of OpenProg:



Only the basic programming functions are implemented; it was the fist GUI of the project, but currently development continues on OPGUI, so it may be dismissed in the future.
It has the advantage of working without any additional library.
Usage is the same as OPGUI; works with XP, VISTA, 7, 8.
Command-line options are:
-d <device> , selects a target
-r <file name> , reads the target and writes to file
-w <file name> , writes a file to the target
-gui , do not exit after writing or reading (only if -w or -r are specified)
You can find more info on the OpenProg and Opgui user's guide or in the source code guide.
It may be of interest the fact that the DDK (driver development kit) is not required for compilation; I link explicitly to the system library hid.dll and manually load the functions needed.
Download application ... or sources (Visual Studio 6 workspace)

Command-line utility (Linux and Windows, v0.10.0)

Top
Quick facts
Another programmer?
USB & HID firmware
Control programs
GTK graphical interface
MFC Graphical interface
Command-line interface
How to ...
Supported devices
Communication protocol
The circuit
Voltage regulator
How to contribute
Download
History
Links
Contacts

OP is a command-line executable; the Windows version doesn't need installation;
the Linux version searches the programmer between devices /dev/usb/hiddevX (or the one specified as parameter) and needs reading rights for it.
eg. >sudo chmod a+r /dev/usb/hiddev0
To permanently enable a user do the following (on Ubuntu and other Debian based distributions, check for others):
as root create a file /etc/udev/rules.d/10-openprogrammer.rules
if you want to enable a user group write:
KERNEL=="hiddev[0-9]", ATTRS{idProduct}=="5432", ATTRS{idVendor}=="1209", GROUP="<group>", SYMLINK+="openprogrammer"
where <group> is one of the user groups (to get a list type "groups"); select a suitable group and if your user desn't belong to it execute "addgroup <user> <group>"
or, if you want to enable all users, change reading permissions:
KERNEL=="hiddev[0-9]", ATTRS{idProduct}=="5432", ATTRS{idVendor}=="1209", MODE="0664", SYMLINK+="openprogrammer"
restart udev to apply changes:
> udevadm control --reload-rules
> udevadm trigger
Now, every time the system detects the programmer, the corresponding /dev/usb/hiddevX has the correct permissions and also the link /dev/openprogrammer is created.

If after plugging the device /dev/usb/hiddevX is inexistent (and LED2 doesn't blink at 1 Hz), it's sufficient to execute a few times lsusb to force enumeration, or unplug and replug the cable.

If not otherwise specified OP looks for an USB device with vid&pid=0x1209:0x100.
It supports hex8 and hex32 files, and also binary files in case of serial memories.
Using the --HWtest option and a voltmeter is possible to check that the circuit is working.
It is possible to communicate with generic I2C/SPI devices; in case of SPI it's always necessary to specify control byte and address (or addresses); the RW bit is handled automatically.
In case of problems or just for curiosity it's possible to save all data exchanged with the programmer with option -l; its optional parameter must be specified with -l=<file> (who knows why? It may be a bug of getopt).
Supported languages are currently English and Italian; more languages can be added by generating and modifying the file languages.rc.

Options:

-BKosccal	load BKosccal from file
-calib	load calibration from file
-command <message>	send <message> to the programmer and exit
-cwX <cw>	force config word X
-d, device <dev.>	device
-ee	use eeprom
-err <max>	max errors during writing
-fuse <val>	write fuse low byte (Atmel only)
-fuseh <val>	write fuse high byte (Atmel only)

-fusex <val>	write extended fuse byte (Atmel only)
-h, help	help
-HWtest	hardware test
-i, info	informations about programmer
-i2c_r <N Ctr Addr>	read N bytes from I2C bus
-i2c_r2 <N Ctr Addr(2)>	read N bytes from I2C bus (16b address)
-i2c_w <N Ctr Addr Data>	write N bytes to I2C bus
-i2c_w2 <N Ctr Addr(2) Data>	write N bytes to I2C bus (16b address)
-i2cspeed <speed>	set I2C speed: 0=100k,1=200k,2=400k,3=800k"
-icd <val>	enable ICD (goto address)
-id	use ID
-l, log [=file]	save log
-lang <language>	load <language> strings
-langfile	write all strings to file
-lock <val>	write lock byte (Atmel only)
-mode <mode>	SPI mode: 00,01,10,11
-osccal	loads osccal from file instead of using the value saved before erase
-p, path <path>	programmer path [/dev/usb/hiddev0]
-pid <pid>	programmer pid [0x5432]
-r, reserved	read reserved area
-rep <n>	report size [64]
-s1, S1	Multiple programming triggered by S1
-s, save <file>	save Ihex file
-se, saveEE <file>	save EEPROM on Ihex file (ATxxxx only)
-spi_r <N>	read N bytes from SPI bus
-spi_w <N Data>	write N bytes to SPI bus
-spispeed <speed>	set SPI speed: 0=100k,1=200k,2=300k,3=500k" NL
-support	supported devices
-use_BKosccal	copy BKosccal to osccal
-v, version	version
-vid <vid>	programmer vid [0x1209]
-w, write <file>	write Ihex file
-we, writeEE <file>	write EEPROM on Ihex file (ATxxxx only)

Top
Quick facts
Another programmer?
USB & HID firmware
Control programs
GTK graphical interface
MFC Graphical interface
Command-line interface
How to ...
Supported devices
Communication protocol
The circuit
Voltage regulator
How to contribute
Download
History
Links
Contacts

Examples:

```
> op -h                                #help
> op -d 18F2550 -ee -s read.hex        #reads code and EEPROM and saves to file
> op -d 16F628 -ee -w write.hex        #writes
> op -i2c_r 8 A0 0                     #reads 8 bytes from I2C bus, control byte A0, address 0
```

A frequent error is to write the device name with lowercase letters instead of uppercase:
write 16**F**628, not 16**f**628

A makefile is included, so to build the application you need GCC and the maketools (MinGW/MSYS on Windows); write:
\> make
Then to install it (if you wish):
\> make install

You can find more info in the source code guide.
Also included is Hid_test, an utility to send and receive a single 64 bit packet; it can be useful for experimenting with the hardware; in theory one could even write a complete programming script using it.

Download

How to ...

Erase a device: every device is erased before being programmed; however if you still need to erase it it's sufficient to write a hex file with valid data (i.e. <0xFF) beyond the implemented memory.
For example, for PIC12-16:
:020000040000FA
:0144010000BA
:00000001FF
And for PIC18:
:020000040002F8
:020000000000FE
:00000001FF

Change Configuration Word: Config words are usually specified in the hex file, but can be forced for PIC 10-12-16-18 using the related device options (or via command line).
It's also possible to recompile sources, otherwise to change the hex file directly; in case of most PIC16 the config word is at address 0x2007, which is stored at 0x400E; the last byte of the line is a checksum, which can be calculated as the two's complement of the sum of all bytes in the line.
For example:
:02400E00xxxxCC , where xxxx is the new value and CC the checksum

Change configuration of Atmel AVR: unlike PICs, these devices do not map their configuration words in the main memory area (so the hex files don't specify any configuration) and it's necessary to write the desired Fuse/Lock bytes in the device options; don't write anything in case the default value is fine for the application.

Solve the "Synchronization error" with AVR devices: A possible cause is that the SPI speed is too high in relation to the CPU speed; the latter has to be > 4 x SPI speed.
There are many possible CPU speed configurations, so the (new) algorithm varies the SPI speed automatically in order to enter Program Mode.
Obviously the lower the speed the longer it takes to read/write the device; in order to speed up operations you could write an empty file with a fast CPU configuration, then write the final file and configuration at high speed.
Some devices include an extremely low speed setting (16 kHz), which is too low even for the adaptive algorithm; in this case use "write Fuse Low @ 3 kHz" to change Fuse Low to a higher speed setting, then write in the usual way.
Another cause could be that the serial programming is disabled: this can be done only using a parallel programmer, and the same is necessary to enable it again.
The third possibility is that the device is configured for external resonator but X2 cannot move; in case you use the AVR expansion board make sure X2 is not tied to GND.

Check that a device is blank: read it and look at displayed data; only lines with valid data are displayed, so if there are none the device is blank.

Verify that a write was successful: all write algorithms implement write verification, either during write or immediately after; if the program reports 0 errors it means that the code was succesfully verified.
If you want to check again you can read the device and compare with the original data; keep in mind that frequently not all bits are implemented; for example in PIC16 a data word is 14 bits long, so even if the source data is 0xFFFF it will be written as 0x3FFF; also the Config Words usually have some bits fixed at 0, which are not checked.

Read the reserved memory area: most PIC devices have a reserved area above the Config Words which is used for test or calibration purposes; to see it use the relative option before read; on PIC24-30-33 the executive memory is read as well.

Correctly use OscCal and other calibration words: some devices (eg. 12F5xx) store the internal oscillator calibration value in the last address of program memory and in a backup location past the ID words; after erasing all memory the control programs restore the calibration value taking it from the backup location, unless specified otherwise; other options are: use the old value (which should be the same as the backup, if none was changed before), use what is specified in the .hex file.
Similarly it's possible to overwrite the backup value with the content of the .hex file, using option "write ID and BKosccal"; in this case the ID locations will be written as well, if specified in the .hex file.
To overwrite the other calibration values use option "write Calib1 and 2".

Supported devices

I tried this programmer with a small number of devices (those I own plus some tested by other users) indicated in **bold**; the other devices are supported but not tested; however, considering that for every device family at least one has been verified, all of them should work without problems.
Please let me know if you verify operation with the untested devices.
Also contact me if you need other algorithms or code new ones by yourself.
Take notice:
LF series PICs are used exactly as the F ones;
Atmel AVR devices with varius suffixes are grouped together whenever the programming algorithm is exactly the same, eg. ATmega8 and ATmega8A;
EEPROM memories comprise all versions with VDDmax=5V, eg. 242LC56, 24AA256, etc.;
93x memories use 2 different algorithms, for the 93S series and for all the others, indicated with 93x (93xA have 8 bit organization);
SPI Flash memories need a low voltage adapter (see theschematic diagrams).

Devices supported for read and write:
10F200, 10F202, 10F204, **10F206, 10F220, 10F222,** 10F320, 10F322,
12C508, 12C508A,12C509, 12C509A, 12F508, 12F509, 12F510, 12F519,
12F609, 12F615, 12F617, 12F629, 12F635, 12F675, 12F683, 12F752, 12F529T39, 12F529T48,
12F1501, 12F1571, 12F1572, **12F1612, 12F1822**, 12F1840,
16F505, 16F506, 16F526, 16F527, **16F54**, 16F57, 16F570, 16F59,
16F610, 16F616, 16F627, 16F627A, **16F628, 16F628A**, 16F630, **16F631, 16F636**, 16F639, **16F648A, 16F676, 16F677, 16F684**, 16F685, **16F687**, 16F688, **16F689, 16F690**, 16F707, **16F716**, 16F72, 16F720, 16F721, **16F722**, 16F722A, 16F723, 16F723A, 16F724, **16F726**, 16F727, **16F73, 16F737**, 16F74, **16F747**, 16F753, 16F76, 16F767, 16F77, 16F777,**16F785**,
16F818, 16F819, 16C83, 16F83, 16F83A, 16C84, **16F84**,**16F84A**, **16F87**, 16F870, 16F871, 16F872, **16F873, 16F873A**, 16F874, 16F874A, **16F876, 16F876A**, 16F877, **16F877A, 16F88, 16F882**, 16F883, 16F884, 16F886, **16F887**,
16F913, 16F914, 16F916, 16F917, 16F946,
16F1454, **16F1455**, 16F1459, 16F1503, **16F1507**, 16F1508, 16F1509, 16F1512, 16F1513, 16F1516, 16F1517, 16F1518, 16F1519, 16F1526, 16F1527, 16LF1554, 16LF1559, 16F1574, 16F1575, 16F1578, 16F1579, 16F1613, 16F1614, 16F1615, 16F1618, 16F1619, 16F1703, 16F1704, 16F1705, 16F1707, 16F1708, 16F1709, 16F1713, 16F1716, 16F1717, **16F1718**, 16F1719, 16F1782, 16F1783, 16F1784, 16F1786, 16F1787, 16F1788, 16F1789, **16F1823**, 16F1824, 16F1825, **16F1826**, 16F1827, 16F1828, 16F1829, 16F1847, 16LF1902, 16LF1903, 16LF1904, 16LF1906, 16LF1907, 16F1933, **16F1934, 16F1936**, 16F1937, 16F1938, 16F1939, 16F1946, 16F1947,
16F18313, 16F18323, 16F18324, 16F18325, 16F18326,**16F18344**, 16F18345, 16F18346,
18F242, 18F248, **18F252, 18F258**, 18F442, 18F448, 18F452,**18F458, 18F1220**, 18F1230, **18F1320, 18F1330**, 18F13K22,**18F13K50**, 18F14K22, **18F14K50**, 18F2220, **18F2221**, 18F2320, **18F23K20**, 18F23K22, 18F2321, 18F2331, 18F2410, **18F24J10**, 18F24J11, 18F2420, **18F24K20**, 18F24K22, 18F2423, 18F2431, 18F2439, **18F2450, 18F24J50**, 18F24K50, **18F2455**, 18F2458, 18F2480, 18F2510, **18F25J10**, 18F25J11, 18F2515, **18F2520, 18F25K20**, 18F25K22, 18F2523, 18F2525, 18F2539,**18F2550, 18F25J50, 18F25K50, 18F2553**, 18F2580, 18F25K80, 18F2585, 18F2610, **18F26J11**, 18F26J13, 18F2620, 18F26K20, 18F26K22, 18F26J50, 18F26K50, 18F26J53, **18F2680**, 18F26K80, 18F2682, **18F2685, 18F27J13**, 18F27J53, 18F4220, 18F4221, 18F4320, 18F43K20, 18F43K22, 18F4321, 18F4331, 18F4410, 18F44J10, 18F44J11, 18F4420, 18F44K20, 18F44K22, 18F4423, 18F4431, 18F4439, 18F4450, 18F44J50, 18F4455, 18F4458, 18F4480, 18F4510, 18F45J10, 18F45J11, 18F4515,**18F4520**, 18F45K20, 18F45K22, 18F4523, 18F4525, 18F4539, **18F4550**, 18F45J50, 18F45K50, 18F4553, 18F4580, 18F45K80, **18F4585**, 18F4610, 18F46J11, 18F46J13, 18F4620, **18F46K20**, 18F46K22, 18F46J50, 18F46K50, 18F46J53, **18F4680**, 18F46K80, 18F4682, **18F4685**,

18F47J13, 18F47J53, 18F63J11, 18F63J90, 18F64J11, 18F64J90, 18F65J10, 18F65J11, 18F65J15, 18F65J50, 18F65J90, 18F65K80, 18F66J10, 18F66J11, 18F66J15, 18F66J16, 18F66J50, 18F66J55, 18F66J60, 18F66J65, 18F66J90, 18F66J93, 18F67J10, 18F67J11, 18F67J50, 18F67J60, 18F66K80, 18F67J90, 18F67J93, 18F83J11, 18F83J90, 18F84J11, 18F84J90, 18F85J10, 18F85J11, 18F85J15, 18F85J50, 18F85J90, **18F8520**, 18F86J10, 18F86J11, 18F86J15, 18F86J16, 18F86J50, 18F86J55, 18F86J60, 18F86J65, 18F86J72, 18F86J90, 18F86J93, 18F8722, 18F87J10, 18F87J11, 18F87J50, 18F87J60, 18F87J72, 18F87J90, 18F87J93, 18F96J60, 18F96J65,**18F97J60**,

24F04KA200, 24F04KA201, **24F08KA101**, 24F08KA102, 24F16KA101, 24F16KA102, **24FJ16GA002**, 24FJ16GA004, 24FJ32GA002, 24FJ32GA004, 24FJ32GA102, 24FJ32GA104, 24FJ32GB002, 24FJ32GB004, 24FJ48GA002, 24FJ48GA004, 24FJ64GA002, 24FJ64GA004, 24FJ64GA006, 24FJ64GA008, 24FJ64GA010, 24FJ64GA102, 24FJ64GA104, 24FJ64GA306, 24FJ64GA308, 24FJ64GA310, **24FJ64GB002**, 24FJ64GB004, 24FJ64GB106, 24FJ64GB108, 24FJ64GB110, 24FJ64GC006, 24FJ64GC008, 24FJ64GC010, 24FJ96GA006, 24FJ96GA008, 24FJ96GA010, 24FJ128GA006, 24FJ128GA008, 24FJ128GA010, 24FJ128GA106, 24FJ128GA108, 24FJ128GA110, 24FJ128GA306, 24FJ128GA308, 24FJ128GA310, 24FJ128GB106, 24FJ128GB108, 24FJ128GB110, 24FJ128GB206, 24FJ128GB210, 24FJ128GC006, 24FJ128GC008, 24FJ128GC010, 24FJ128DA106, 24FJ128DA110, 24FJ128DA206, 24FJ128DA210, 24FJ192GA106, 24FJ192GA108, 24FJ192GA110, 24FJ192GB106, 24FJ192GB108, 24FJ192GB110, 24FJ256GA106, 24FJ256GA108, 24FJ256GA110, 24FJ256GB106, 24FJ256GB108, 24FJ256GB110, 24FJ256GB206, 24FJ256GB210, 24FJ256DA106, 24FJ256DA110, 24FJ256DA206, 24FJ256DA210,

24EP32GP202, 24EP32GP203, 24EP32GP204, 24EP32MC202, 24EP32MC203, 24EP32MC204,**24EP64GP202**, 24EP64GP203, 24EP64GP204, 24EP64GP206, 24EP64MC202, 24EP64MC203, 24EP64MC204, 24EP64MC206, 24EP128GP202, 24EP128GP204, 24EP128GP206, 24EP128MC202, 24EP128MC204, 24EP128MC206, 24EP256GP202, 24EP256GP204, 24EP256GP206, 24EP256MC202, 24EP256MC204, 24EP256MC206, 24EP512GP202, 24EP512GP204, 24EP512GP206, 24EP512MC202, 24EP512MC204, 24EP512MC206,

24HJ12GP201, **24HJ12GP202**, 24HJ16GP304, 24HJ32GP202, 24HJ32GP204, 24HJ32GP302, 24HJ32GP304,**24HJ64GP202**, 24HJ64GP204, 24HJ64GP206, 24HJ64GP210, 24HJ64GP502, 24HJ64GP504, 24HJ64GP506, 24HJ64GP510, 24HJ128GP202, 24HJ128GP204, 24HJ128GP206, 24HJ128GP210, 24HJ128GP306, 24HJ128GP310, 24HJ128GP502, 24HJ128GP504, 24HJ128GP506, 24HJ128GP510, 24HJ256GP206, 24HJ256GP210, 24HJ256GP610,

30F1010, 30F2010, **30F2011**, 30F2012, **30F2020**, 30F2023, 30F3010, 30F3011, 30F3012, 30F3013, 30F3014, 30F4011,**30F4012**, 30F4013, 30F5011, 30F5013, 30F5015,

[Top](#)
[Quick facts](#)
[Another programmer?](#)
[USB & HID firmware](#)
[Control programs](#)
  [GTK graphical interface](#)
  [MFC Graphical interface](#)
  [Command-line interface](#)
[How to ...](#)
[Supported devices](#)
[Communication protocol](#)
[The circuit](#)
[Voltage regulator](#)
[How to contribute](#)
[Download](#)
[History](#)
[Links](#)
[Contacts](#)

30F5016, 30F6010, 30F6011, 30F6012, 30F6013, 30F6014, 30F6015,
33FJ06GS101, 33FJ06GS102, 33FJ06GS202, 33FJ12GP201,**33FJ12GP202**, 33FJ12MC201, 33FJ12MC202, 33FJ16GP304, 33FJ16GS402, 33FJ16GS404, 33FJ16GS502, 33FJ16GS504, 33FJ16MC304, 33FJ32GP202, 33FJ32GP204, 33FJ32GP302, 33FJ32GP304, 33FJ32GS406, 33FJ32GS606, 33FJ32GS608, 33FJ32GS610, 33FJ32MC202, 33FJ32MC204, 33FJ32MC302, 33FJ32MC304, 33FJ64GP202, 33FJ64GP204, 33FJ64GP206, 33FJ64GP306, 33FJ64GP310, 33FJ64GP706, 33FJ64GP708, 33FJ64GP710, 33FJ64GP802, 33FJ64GP804, 33FJ64GS406, 33FJ64GS606, 33FJ64GS608, 33FJ64GS610, 33FJ64MC202, 33FJ64MC204, 33FJ64MC506, 33FJ64MC508, 33FJ64MC510, 33FJ64MC706, 33FJ64MC710, 33FJ64MC802, 33FJ64MC804, 33FJ128GP202, 33FJ128GP204, 33FJ128GP206, 33FJ128GP306, 33FJ128GP310, 33FJ128GP706, 33FJ128GP708, 33FJ128GP710, **33FJ128GP802**, 33FJ128GP804, 33FJ128MC202, 33FJ128MC204, 33FJ128MC506, 33FJ128MC510, 33FJ128MC706, 33FJ128MC708, 33FJ128MC710, 33FJ128MC802, 33FJ128MC804, 33FJ256GP506, 33FJ256GP510, 33FJ256GP710, 33FJ256MC510, 33FJ256MC710,
33EP32GP502, 33EP32GP503, 33EP32GP504, 33EP32MC202, 33EP32MC203, 33EP32MC204, 33EP32MC502, 33EP32MC503, 33EP32MC504, 33EP64GP502, 33EP64GP503, 33EP64GP504, 33EP64GP506, 33EP64MC202, 33EP64MC203, 33EP64MC204, 33EP64MC206, 33EP64MC502, 33EP64MC503, 33EP64MC504, 33EP64MC506, 33EP128GP502, 33EP128GP504, 33EP128GP506, 33EP128MC202, 33EP128MC204, 33EP128MC206, 33EP128MC502, 33EP128MC504, 33EP128MC506, 33EP256GP502, 33EP256GP504, 33EP256GP506, 33EP256MC202, 33EP256MC204, 33EP256MC206, 33EP256MC502, 33EP256MC504, 33EP256MC506, 33EP512GP502, 33EP512GP504, 33EP512GP506, 33EP512MC202, 33EP512MC204, 33EP512MC206, 33EP512MC502, 33EP512MC504, 33EP512MC506,
AT90S1200, AT90S2313, **AT90S8515, AT90S8535, ATmega48, ATmega8, ATmega88**, ATmega8515, ATmega8535, **ATmega16**, ATmega164, **ATmega168, ATmega32, ATmega324, ATmega328**, ATmega64,**ATmega644, ATmega1284**,
ATtiny11, **ATtiny12, ATtiny13**, **ATtiny2313**, ATtiny24, ATtiny25, **ATtiny26**, ATtiny261, ATtiny4313, **ATtiny44**, ATtiny45, **ATtiny461**, ATtiny48, **ATtiny84**, ATtiny85, ATtiny88, ATtiny861,
2400, 2401, 2402, 2404, 2408, 2416, 2432, 2464, 24128, 24256, 24512, 241024, **241025**,
25010, 25020, 25040, 25080, 25160, 25320, 25640, 25128, 25256, 25512, **251024**,
95010, 95020, 95040, 95080, 95160, **95320**, 95640, 95128, 95256, 95512, 95M01, 95M02,
251005, 252005, 254005, 258005, **251605**, 25X05, 25X10, 25X20, **25X40**, 25X80, 25X16, 25X32, 25X64, 25X128, 25Q40,
93S46, **93x46**, 93x46A, **93S56, 93x56, 93x56A**, 93S66, **93x66, 93x66A, 93x76, 93x76A, 93x86, 93x86A**,

DS2430, DS2431, DS2433, DS28EC20, **DS1820**,
11010, 11020, 11040, 11080, 11160

devices supported for read only:
12C671, 12C672, **12CE673**, 12CE674

Important!! Don't use 3.3V devices without the 3.3V expansion boards, otherwise permanent damage may occur; the software verifies that such adapters are present before starting to program, but obviously you need to select the proper device; the 3.3V devices are:
12F1xxx,16F1xxx,18FxxJxx,18FxxKxx,24Fxxx,24Hxxx,33Fxxx.
Some of them have 5V variants; if you need to program at 5V you can select the option "Don't require LV boards". Also don't put any 24F-33F on the 30F socket, which works at 5V.

Top
Quick facts
Another programmer?
USB & HID firmware
Control programs
GTK graphical interface
MFC Graphical interface
Command line interface
How to ...
Supported devices
Communication protocol
The circuit
Voltage regulator
How to contribute
Download
History
Links
Contacts

Communication protocol

To design a communication protocol we must take into account some often contrasting requirements:
transfer speed and efficiency, code size, adaptability and expandability.
Differently from serial links, USB is packet based; a packet is received altogether, but HID devices can only exchange them every ms, so it is out of question to manage timings directly as with serial ports.
It's necessary to introduce synthetic commands that the microcontroller can use to recreate the proper waveforms.
Furthermore, one objective of a reliable programmer is to be independent from the host speed and CPU occupation, so the task of generating waveforms would anyways be given to the microcontroller.
In general we can find two types of programmers: simple serial programmers only take commands to change voltage levels; host software manages both timings and programming algorithms but needs all the CPU time and is dramatically affected by other processes running on the system.
At the other extreme are "smart" programmers, which autonomously manage timings and algorithms, but must be updated to support new devices and tend to require much memory to store code.
I chose a combination of both: ICSP (In Circuit Serial Programming) commands are implemented in firmware, but the host software manages the algorithms.
In order to increase speed and efficiency some instructions correspond to sequences of frequently repeated commands, such as sequential reads.
The advantage of this approach is that timings are very precise, while the extreme variety of algorithms does not increase the firmware code size.
Another advantage is that once the basic commands are verified the development of algorithms is done on the PC, without the need for frequent firmware updates.
For example, this is the sequence used to enter program mode for 16F628 and read DevID:

```
SET_PARAMETER    //set delays to be used by other instructions
SET_T1T2         //T1 & T2
```

```
1                   //T1=1us
100                     //T2=100us
EN_VPP_VCC          //Vpp & Vcc = 0
0x0
SET_CK_D            //Clock and Data as output and 0
0x0
EN_VPP_VCC          //Vpp enabled
0x4
NOP                 //small delay
EN_VPP_VCC          //Vdd+Vpp enabled
0x5
NOP                 //small delay
LOAD_CONF           //program counter to 0x2000
0xFF                //fake config
0xFF                //fake config
INC_ADDR_N          //increment address by 6
0x06
READ_DATA_PROG      //read DevID
...
```


In addition to ICSP commands other instructions manage the programmer, control programming voltages, execute precise delays, communicate via I2C or SPI bus.
Every instruction is executed in at least 40 us, due to the interpreter loop execution time.
ICSP commands use T1 or T2 as values for delays; all instructions return an echo, with the exception of FLUSH, which immediately sends the output buffer and stops the execution of current packet.
In case an instruction doesn't have enough parameters it returns an error (0xFE) and the execution of current packet is halted.
The state of USB connection is signaled by LED2: it blinks at 4 Hz during enumeration, at 1 Hz in normal operation.
LED1 shows when there are instructions being executed.
Following is the list of all instructions:

Instruction	Value	Parameters	Answer	Notes
NOP	0x00	none	echo	no operation
PROG_RST	0x01	none	echo + 10B	programmer reset; sends fw version (3B), ID (3B), " RST" string
PROG_ID	0x02	none	echo+ 6B	sends fw version (3B), ID (3B)
CHECK_INS	0x03	1B	echo + 1B	if specified instruction exists returns its code, otherwise returns error (0xFE)
FLUSH	0x04	none	none	flushes output buffer (sends 64B) and stops command interpreter for the current packet.
VREG_EN	0x05	none	echo	turns on the voltage regulator
VREG_DIS	0x06	none	echo	turns off the voltage regulator
				sets internal parameters; byte1:

SET_PARAMETER	0x07	1B	echo	parameter to change, byte 2-3 value: SET_T1T2 (=0): T1 & T2 SET_T3 (=1): T3(H,L) SET_timeout (=2): timeout(H,L) SET_MN (=3): M, N
WAIT_T1	0x08	none	echo	waits T1 us (1us default)
WAIT_T2	0x09	none	echo	waits T2 us (100us default)
WAIT_T3	0x0A	none	echo	waits T3 us (2ms default)
WAIT_US	0x0B	1B	echo	waits N us
READ_ADC	0x0C	none	echo +2B	reads regulator voltage (effective 10bits, MSB-LSB); considering the input divider, voltage in V is <value>/1024*5*34/12
SET_VPP	0x0D	1B	echo +1B	sets regulator voltage to <parameter>/10; if error is < 200 mV within 15ms returns <parameter>, otherwise error (0xFE)
EN_VPP_VCC	0x0E	1B	echo	controls Vpp and Vcc on the programmed device; 1 bit for level (0-1), 1bit for impedance (keep at 0); bit 0-1: Vcc, bit 2-3: Vpp
SET_CK_D	0x0F	1B	echo	controls CK, D, PGM on the programmed device; 1 bit for level (0-1), 1bit for impedance (low-high); bit 0-1: D, bit 2-3: CK, bit 4-5: PGM
READ_PINS	0x10	none	echo +1B	reads the state of control lines, 1 bit level (0-1), 1bit impedence (low-high); bit 0-1: D, bit 2-3: CK, bit 4-5: PGM
LOAD_CONF	0x11	2B	echo	ICSP command: Load configuration (000000), T1 us between command and data; 14 bit data (right aligned, MSB-LSB)
				ICSP command: Load

[Top](#)
[Quick facts](#)
[Another programmer?](#)
[USB & HID firmware](#)
[Control programs](#)
- [GTK graphical interface](#)
- [MFC Graphical interface](#)
- [Command-line interface](#)

[How to ...](#)
[Supported devices](#)
[Communication protocol](#)
[The circuit](#)
[Voltage regulator](#)
[How to contribute](#)
[Download](#)
[History](#)
[Links](#)
[Contacts](#)

LOAD_DATA_PROG	0x12	2B	echo	Data in Program Memory (000010), T1 us between command and data; 14 bit data (right aligned, MSB-LSB)
LOAD_DATA_DATA	0x13	1B	echo	ICSP command: Load Data in Data Memory (000011), T1 us between command and data; 8 bit data
READ_DATA_PROG	0x14	none	echo +2B	ICSP command: Read Data from Program Memory (000100), T1 us between command and data; 14 bit data (right aligned, MSB-LSB)
READ_DATA_DATA	0x15	none	echo +1B	ICSP command: Read Data from Data Memory (000101), T1 us between command and data; 8 bit data
INC_ADDR	0x16	none	echo	ICSP command: Increment Address (000110), T1 us delay at the end
INC_ADDR_N	0x17	1B	echo	ICSP command: Increment Address (000110), T1 us delay at the end; repeated N times
BEGIN_PROG	0x18	none	echo	ICSP command: Begin Programming (001000)
BULK_ERASE_PROG	0x19	none	echo	ICSP command: Bulk Erase Program Memory (001001)
END_PROG	0x1A	none	echo	ICSP command: End Programming (001010)
BULK_ERASE_DATA	0x1B	none	echo	ICSP command: Bulk Erase Data Memory (001011)
END_PROG2	0x1C	none	echo	ICSP command: End Programming (001110)
ROW_ERASE_PROG	0x1D	none	echo	ICSP command: Row Erase Program Memory (010001)
BEGIN_PROG2	0x1E	none	echo	ICSP command: Begin Programming (0011000)
				ICSP command

CUST_CMD	0x1F	1B	echo	specified in the parameter
PROG_C	0x20	2B	echo +1B	Programs a word following 12Cxxx algorithm: 000010, 001000, 001110, M pulses & N overpulses
CORE_INS	0x21	2B	echo	PIC18 ICSP command: Core instruction (0000); 16 bit data (MSB-LSB)
SHIFT_TABLAT	0x22	none	echo +1B	PIC18 ICSP command: Shift TABLAT (0010); 8 bit data
TABLE_READ	0x23	none	echo +1B	PIC18 ICSP command: Table read (1000); 8 bit data
TBLR_INC_N	0x24	1B	echo+N+NB	PIC18 ICSP command: Table read post-inc (1001); 8 bit data; repeats N times; returns N and NB data
TABLE_WRITE	0x25	2B	echo	PIC18 ICSP command: Table write (1100); 16 bit data (MSB-LSB)
TBLW_INC_N	0x26	(2N+1)B	echo	PIC18 ICSP command: Table write post-inc (1101); 16 bit data (MSB-LSB); repeats N times (N is the first parameter)
TBLW_PROG	0x27	4B	echo	PIC18 ICSP command: Table write and program (1111); 16 bit data (MSB-LSB); also executes a NOP with a delay specified in parameters 3-4 (in us)
TBLW_PROG_INC	0x28	4B	echo	PIC18 ICSP command: Table write and program post-inc (1110); 16 bit data (MSB-LSB); also executes a NOP with a delay specified in parameters 3-4 (in us)
SEND_DATA	0x29	3B	echo	PIC18 ICSP command specified in byte 1; sends 16 bit data (MSB-LSB)
				PIC18 ICSP command

READ_DATA	0x2A	1B	echo+1B	specified in byte 1; reads 8 bit data
I2C_INIT	0x2B	1B	echo	Initializes I2C communication: 0xFF disables I2C; bit 6: slew rate control for speed > 100kbps; bit 5:3 speed: 0=100k, 1=200k, 2=400k, 3=800k, 4=1M; attention: use pull-up resistors according to selected speed; bit 2:0: logic level of A2-A1-A0 (on device)
I2C_READ	0x2C	3B	echo+1+NB	Reads <parameter 1> bytes from I2C bus using <parameter 2> as control byte and <parameter 3> as address; forces automatically the RW bit in the control byte. Responds with <parameter 1> + Data or with ACK_ERR (0xFD) in case of acknowledge error (eg. if there are no devices on the bus)
I2C_WRITE	0x2D	3B+NB	echo	Writes <parameter 1> bytes to I2C bus using <parameter 2> as control byte and <parameter 3> as address; forces automatically the RW bit in the control byte. Responds with ACK_ERR (0xFD) in case of acknowledge error (eg. if there are no devices on the bus). For 2 byte addresses just use the 2nd byte of address as the first byte of data.
I2C_READ2	0x2E	4B	echo+1+NB	Reads from I2C bus; identical to I2C_READ, but uses 2 bytes for addressing
SPI_INIT	0x2F	1B	echo	Initializes SPI communication: 0xFF disables SPI bit 1:0 speed: 0=100kbps,

				1=200kbps, 2=300kbps, 3=500kbps bit 2:3 SPI mode
SPI_READ	0x30	1B	echo+1+NB	Reads <parameter 1> bytes from SPI bus. Returns <parameter 1> + Data; If <parameter 1>=0 returns the byte that was last received (during either read or write)
SPI_WRITE	0x31	1B+NB	echo+1B	Writes <parameter 1> bytes to SPI bus.
EXT_PORT	0x32	2B	echo	Forces levels of communication ports: <parameter 1> = <RB7:RB0> <parameter 2> = <RC7,RC6,RA5:RA3> Does not change signal direction.
AT_READ_DATA	0x33	3B	echo+1+2NB	ATMEL command: read program memory (0010H000); reads <parameter 1> words at address <parameter 2> : <parameter 3> via SPI. Returns <parametro 1> + Data
AT_LOAD_DATA	0x34	3B+2N	echo+1B	ATMEL command: load program memory page (0100H000); loads <parameter 1> words at address <parameter 2> : <parameter 3> via SPI. Returns <parameter 1>
CLOCK_GEN	0x35	1B	echo	Generates a clock signal on RB3 (using CCP1-2 and TIMER1) bit 2:0 frequency: 0=100kHz, 1=200kHz, 2=500kHz, 3=1MHz, 4=2MHz, 5=3MHz, 6=6MHz; Disables PWM1 output (DCDC regulator)
SIX	0x36	3B	echo	PIC24 ICSP command: Core instruction (0000); 24 bit data (MSB first)
				PIC24 ICSP

SIX_LONG	0x3E	3B	echo	command: Core instruction (0000); 24 bit data (MSB first); appends 2 ICSP_NOP at the end
SIX_LONG5	0x49	3B	echo	PIC24 ICSP command: Core instruction (0000); 24 bit data (MSB first); appends 5 ICSP_NOP at the end
SIX_N	0x3F	1+3NB	echo	PIC24 ICSP command: Core instruction (0000); N * 24 bit data (MSB first); sends N instructions and adds M ICSP_NOP after each one; N=<parameter1>&0x3F, M=<parameter1> >>6
REGOUT	0x37	none	echo +2B	PIC24 ICSP command: Shift out VISI register (0001); 16 bit data
ICSP_NOP	0x38	none	echo	PIC24 ICSP command: Execute NOP (0000)
TX16	0x39	1+2NB	echo+1B	Transmits 16 bit words over ICSP (MSB first); clock period: 2*(T1-1)+1 us
RX16	0x3A	1B	echo+1+2NB	Receives 16 bit words over ICSP (MSB first); clock period: 2*(T1-1)+1 us
uW_INIT	0x3B	none	echo	Initializes MicroWire communication
uW_TX	0x3C	1B+NB	echo+1B	Writes <parameter 1> bits to MicroWire bus. Data is specified MSB first
uW_RX	0x3D	1B	echo+1+NB	Reads <parameter 1> bits from MicroWire bus. Returns <parameter 1> + Data, MSB first
OW_RESET	0x40	no	echo+1B	OneWire Reset pulse; detects the slave presence pulse: 1=present 0=absent
OW_WRITE	0x41	1B+NB	echo	Writes <parameter 1> bytes on the OneWire bus

OW_READ	0x42	1B	echo+1+NB	Reads <parameter 1> bytes from the OneWire bus
UNIO_STBY	0x43	no	echo	UNIO standby pulse
UNIO_COM	0x44	1B+1B+NB	echo+1+NB	Executes a UNIO communication cycle: writes <parameter 1> bytes and reads <parameter 2> bytes; generates a synchronization byte if there are bytes to write
SET_PORT_DIR	0x45	2B	echo	Sets the direction on the IO ports (0=out, 1=in): <parameter 1> = <RB7:RB0> <parameter 2> = <RC7,RC6,RA5:RA3>
READ_B	0x46	no	echo+1B	Reads IO port B
READ_AC	0x47	no	echo+1B	Reads IO ports A and C: <RC7,RC6,RA5:RA3>
AT_HV_RTX	0x48	1B+2NB	echo+1B	Sends 2N*8 bits on RB0/RC7 (PB1/PB0), with CLK on RC6 (PB3) byte N=PB1, byte N+1=PB0 Receives 8 bits from RB1 (PB2) (only the last byte)
READ_RAM	0xF0	2B	echo+3B	Reads from host memory; 16 bit address, 8 bit data; echoes address
WRITE_RAM	0xF1	3B	echo+3B	Writes to host memory; 16 bit address, 8 bit data; echoes address and data
LOOP	0xF2	none	none	Resets instruction pointer and executes all instructions again. For test purposes only.

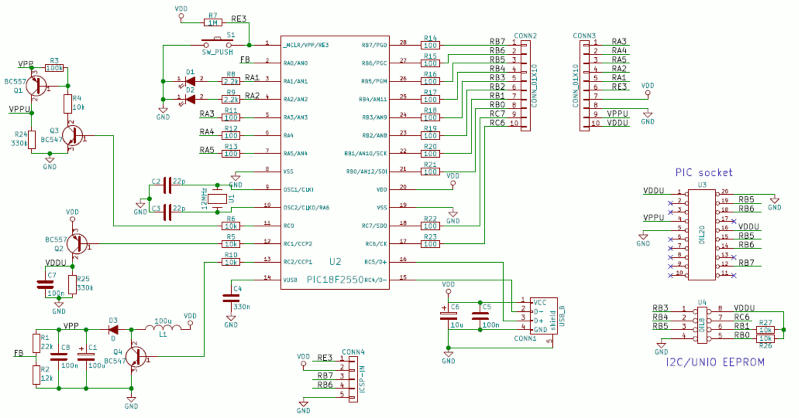
The circuit (v1.7)

The project is based on a 28 pin 18F2550; about 8.5 KWords are used, so it will fit confortably into the smaller 2455.
The 2458 and 2553 have a 12 bit ADC, so only recompilation is required.

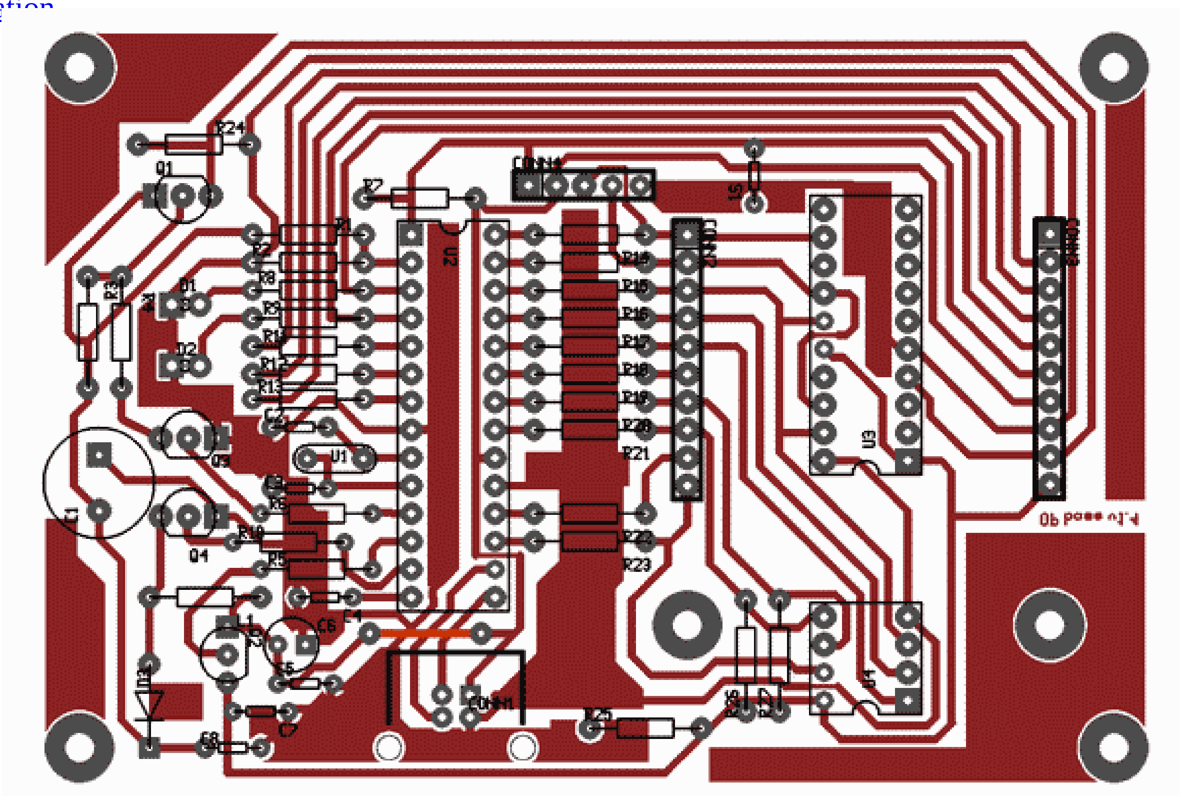
Up to version 0.8.0 I adapted the code to the 2450; since this model lacks the MSSP module I used a software implementation of I2C and SPI; it also lacks the second PWM channel, therefore it can't generate the clock for Atmel chips (for those that are configured with external clock); in this case RB3 can be used to turn on an external oscillator (which would be inserted in a modified Atmel expansion board).
The use of the corresponding 40 pin devices (4450, 4455, 4458, 4550, 4553) requires modification of the PCB.
In order to implement an USB pheripheral with a PIC micro we need very few components: the main microcontroller, a quartz, some capacitors, and a USB type B receptacle, exactly as written in application notes from Microchip.

To be able to program PIC devices we need two digital lines for clock and data and two supply voltages, VCC and VPP, which are controlled using three transistors; VPP comes from a [switching voltage regulator](#) formed by Q4, L1, D3 which is described later.

[Schematic diagram](#) of main module:



PCB of main module:



Many components are optional, are only needed to program

some types of devices or for future applications: expansion connectors CONN2-3, protection resistors R11:23 (considering their cost why not use them?), I2C pull-up resistors R26-27, S1 switch, ICSP-IN CONN4 (right now it's used to program the main microcontroller without extracting it).
The pcb was optimized to fit the solder side, however a few jumpers are needed on the component side; if you want you can avoid that by using a double side pcb.
Pay attention to the orientation of transistors: Q1's emitter to the left, Q2 up, Q3 and Q4 right.
Once connected to the PC, a working circuit blinks D2 at 4Hz until the enumeration is completed, then at 1Hz.
To verify that everything is working correctly use the "Hardware Test" function in the control program: in this mode, to be executed without target devices, all the outputs (CK, D, PGM, VDDU, VPPU, which can be reached on pins 14-15-12-1-4 of U3, with respect to GND, pin 5) are activated in various combinations; if the measured voltages correspond to what is presented on screen then the hardware is correctly assembled.
VPP voltage could be different from the set value by up to 1V; this is due to the fact that the DCDC converter takes VCC as reference voltage; the latter comes from the USB cable and can vary from 4.75V to 5.25V; in addition the feedback voltage divider (R1-R2) can introduce another 5% of error.
The most common causes of malfunction are:
incorrect orientation of transistors,
incorrect inductor value,
pcb defects like shorts or opens,
unsoldered capacitors,
main microcontrollorer not programmed or incorrectly programmed (with LVP option).

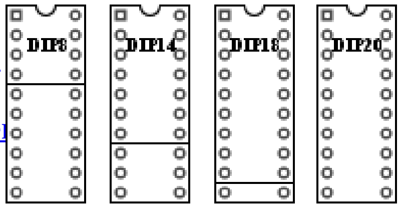
Top
Quick facts
Another programmer?
USB & HID firmware
Control programs
GTK graphical interface
MFC Graphical interface
Command-line interface
How to ...
Supported devices
Communication protocol
The circuit
Voltage regulator
How to contribute
Download
History
Links
Contacts

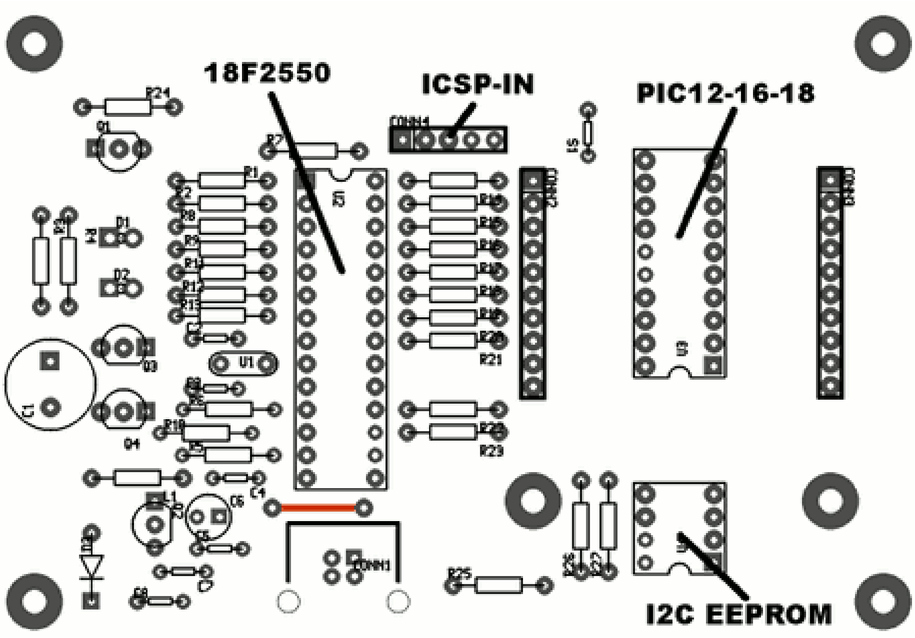
Component list:
U1 12Mhz quartz (also 4, 8, 16, 20; reconfiguration of input divider options is required)
U2 18F2550 (also 2450,2455,2458,2553,4450,4455,4458,4550,4553)
U3 20p socket.
U4 8p socket.
Q1-2 BC557 (or any PNP, pay attention to polarity)
Q3-4 BC547 (or any NPN, pay attention to polarity)
D1-2 LED
D3 1N4148 (or any diode, better if Shottky)
L1 100uH resistor type or other
R1 22K
R2 12K
R3 100K
R4:6 10K
R7 1M
R8-9 2.2K
R10 10K
R11:23 100
R24-25 330K
R26-27 10K
C1 22-100uF 25V
C2-3 22pF
C4 >= 220nF
C5 100nF
C6 10uF

C7-8 100nF
CONN1 USB type B
CONN2-3 10 pin female stripline
CONN4 5 pin stripline

How to use

The basic circuit can host PIC devices with 8, 14, 18, and 20 pins (except 10Fxxx); they should be inserted in U3 with alignment to pin1:

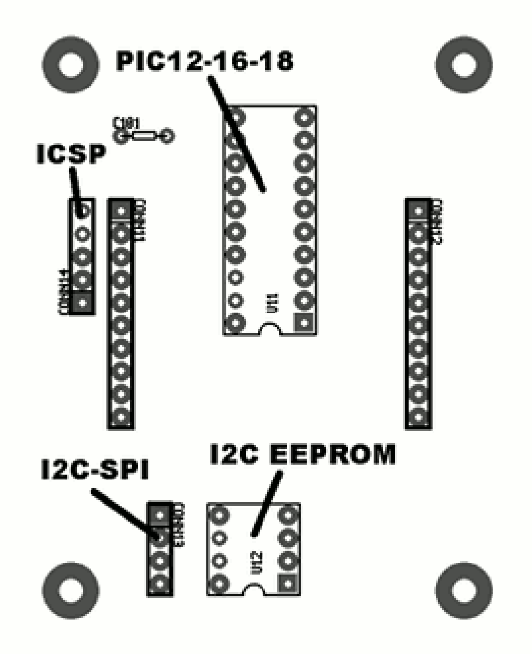


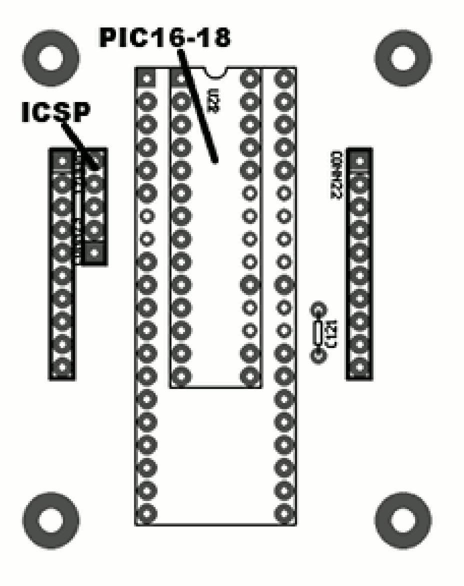


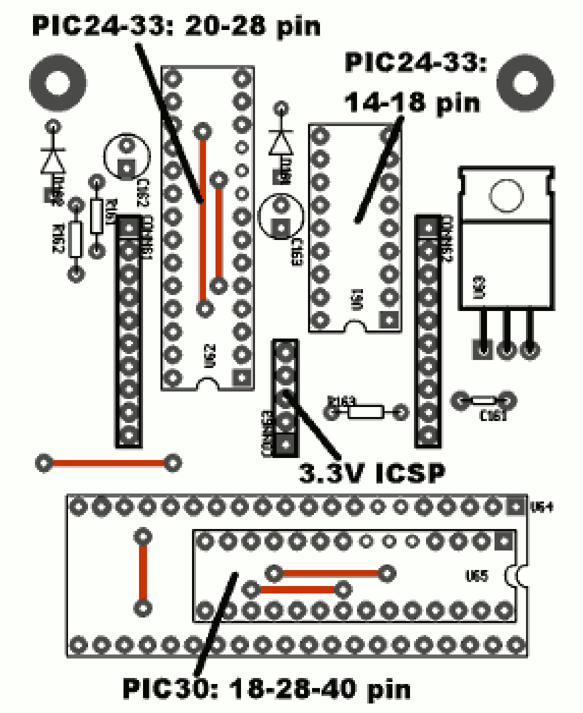
I2C and UNIO memories go in U4.
One-Wire devices in TO92 package can also be connected on U4: GND lead goes to RB1 (pin 6), IO lead to RB0 (pin 5).
I plan to make an adapter for 10Fxxx with 6 or 8 pins; in the meantime it's possible to get by using wires.
Other devices can be programmed using expansion boards plugged to connectors CONN2-3 (but they're not required for basic operation):

- 28-40 pin PICs + ICSP connector
- 8-20 pin PICs (same as main board, but there's more space for a ZIF socket) + ICSP conn.
- 3.3V PIC16-18 + ICSP conn. (this board has also a 3.3V regulator)
- PIC24-30-33 + ICSP conn. (this board has also a 3.3V regulator)
- I2C, SPI, uW memories and I2C-SPI conn.
- 3.3V SPI memories (this board has also a 3.3V regulator)
- 8-14-20-28-40 pin ATMEL micros and I2C-SPI conn

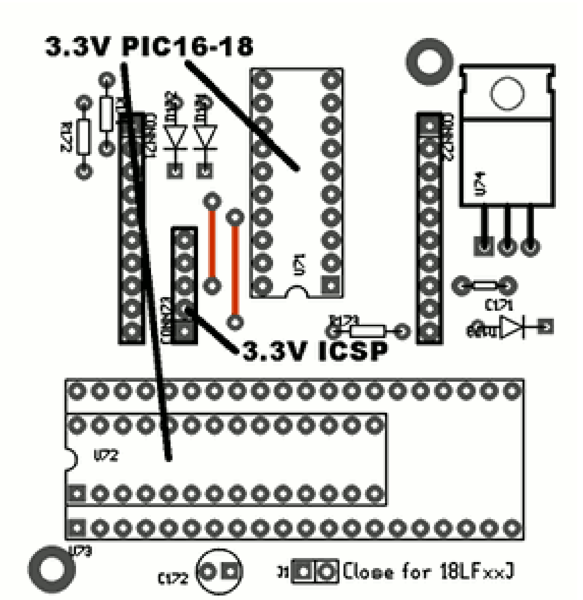
Components for the expansion boards are indicated in theschematic diagram; diodes can be of any kind; TBD resistors should not be mounted.
In assembling the adapters I suggest to insert the expansion connectors from the component side, and keep their plastic spacer on that side; this improves the solder strength, especially during extraction.
In case of 3.3V devices, the presence of a 3.3V adapter (which has RB1 and RB0 shorted) is checked by the software in order to avoid irreversible damage.
The 16F1xxx could be programmed also without such adapter (only the 16LF1xxx need it), but the check is present for both so there is no chance of confusion.
Due to the impossibility of erasing dsPIC30 protection registers at 3.3V, these devices are now powered at 5V; who already made the adapter (prior to v. 1.7) can easily modify it.
The following images show how to insert various target devices in the expansion boards:



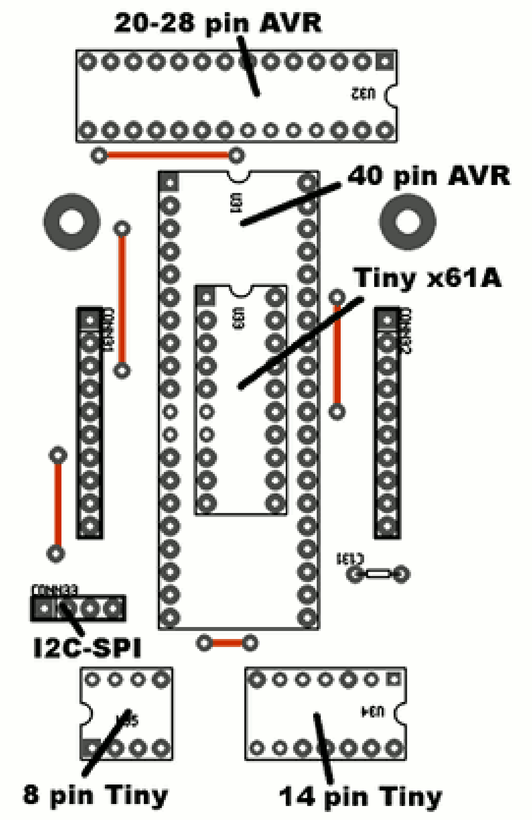


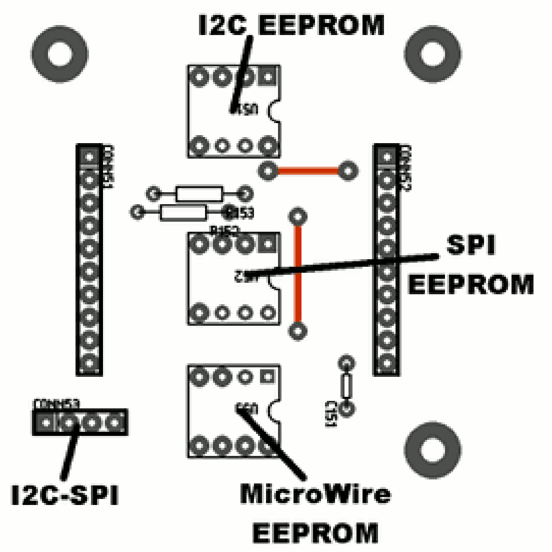


PIC24-33: 20-28 pin
PIC24-33: 14-18 pin
3.3V ICSP
PIC30: 18-28-40 pin



3.3V PIC16-18
3.3V ICSP
Close for 18LFxxJ



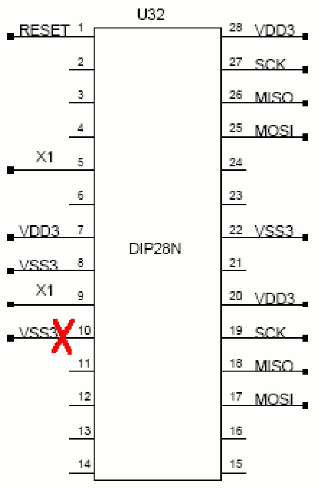


Smaller devices have to be aligned to pin 1 of the respective socket, for example 8 pin PICs in the 20p. socket, or the ATTiny2313 in the 28p. socket.
Target chips can also be programmed in circuit by routing ICSP signals (VPPU,VDDU,ICD,ICK,GND) to the application board; these signals are present in the main module expansion connectors or in some expansion boards as a discrete connector; note that low voltage devices require ICSP signals from a low voltage expansion board.
The ICSP-IN connector is used to program the main micro without extracting it, by means of another programmer.

ATTENTION: the ATMEL AVR board up to version 1.7 has a bug that prevents 28 pin devices (eg. ATMega8) from entering program mode when they are **not** configured with the internal oscillator.
In order to share the same socket with 20 pin devices (eg.

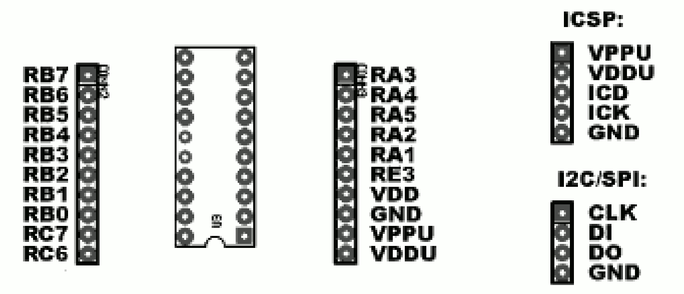
[Top](#)
[Quick facts](#)
[Another programmer](#)
[USB & HID firmware](#)
[Control programs](#)
[GTK graphical interface](#)
[MFC Graphical interface](#)
[Command line interface](#)
[How to ...](#)
[Supported devices](#)
[Communication protocol](#)
[The circuit](#)
[Voltage regulator](#)
[How to contribute](#)
[Download](#)
[History](#)
[Links](#)
[Contacts](#)

ATTiny2313), pin 10 is forced to VSS; but this pin corresponds to X2 in the bigger devices, and has to be floating when the oscillator is external.
To fix the bug it's sufficient to keep X2 floating, in one of the following ways:
a) bend pin 10 outwards on the target device so that it stays out of the socket.
b) cut the trace between pin 10 and VSS, but reconnect it when using 20 pin devices.



Version 1.8 includes a jumper to short pin 10 to VSS; unfortunately the pcb is not yet updated.

Pin mapping of various connectors in the main and expansion boards:



Map of resources used:

Pin	Various functions	ICSP	I2C-EEPROM	SPI-EEPROM	SPI-ATMEL	uW-EEPROM	OneWire/UNIO
RB7		PGM					
RB6		ICSP clock					
RB5		ICSP data	A2			W (6)	
RB4			A1	HLD		S (1)	
RB3			A0	CS	Device clock	PRE (7)	
RB2	expansion						
RB1			Clock	Clock	SPI Clock	Clock	
RB0			Data	Data out (MISO)	Data out (MISO)	Data out	Data IO

RC7				Data in (MOSI)	Data in (MOSI)	Data in	
RC6			WP	WP	RESET		
RC5	USB D+						
RC4	USB D-						
RC2	DCDC PWM						
RC1	controls VDD						
RC0	controls VPP						
RA5	expansion						
RA4	expansion						
RA3	expansion						
RA2	LED 2						
RA1	LED 1						
RA0	ADC for regulator						
RE3	S1 switch						

The schematic diagram was drawn with KiCad (it was originally created with Gschem, an open source program that comes with GEDA suite).
PCBs were drawn with PCB; I will eventually convert this to KiCad as well.
With a little effort the circuit can also be mounted on experimental boards, without pcb.

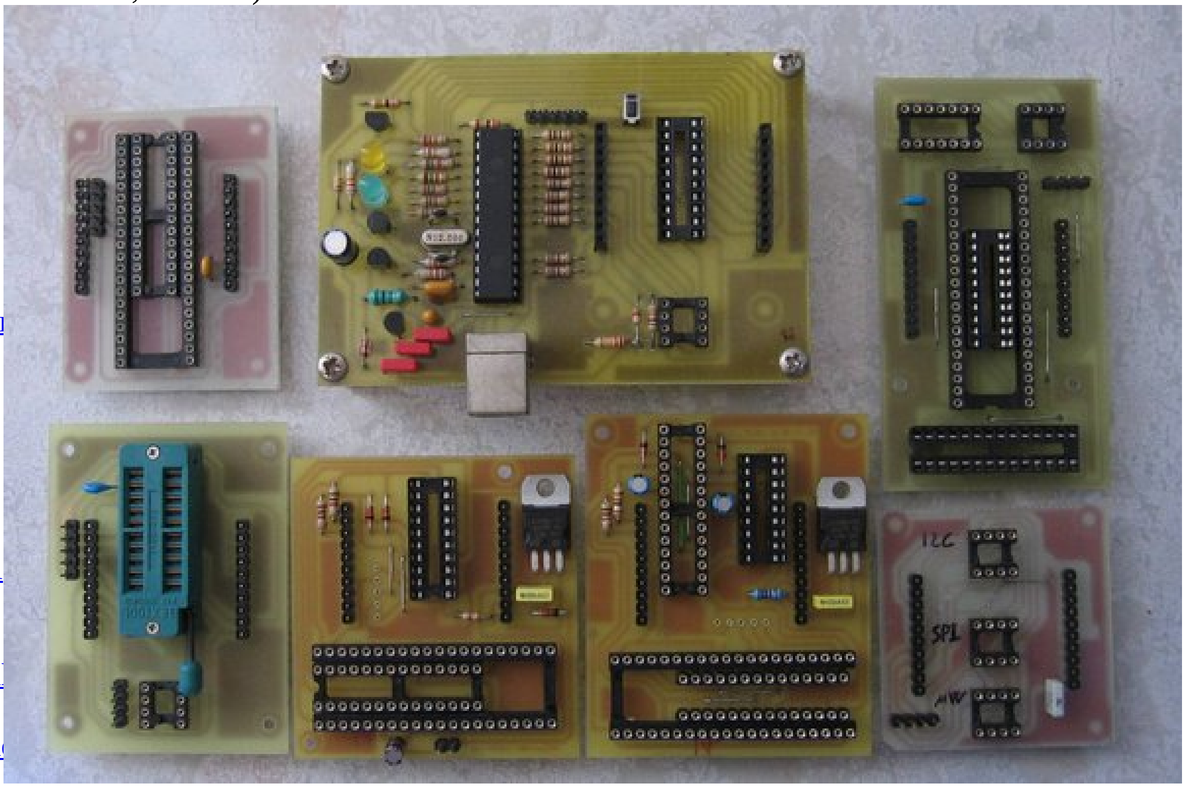
Schematic diagram of base module and expansion boards: Pdf,KiCad, Gschem
Pcb of main module: .pdf, .png; main module + expansion boards: .pdf (also mirrored), .png; everything in PCB format:Oprog.pcb
Complete archive, includes sources, gerber, pdf, png

How to program the main micro the first time?

This is an interesting problem: a new device can't work as programmer, so it must be programmed in some way.
Apart from asking someone else to do it for you, my advice is to build one of those serial programmers, like JDM, to do the job the first time.
It may seem strange to use a programmer to build another one, but there is no way to interface USB without firmware; I think the effort is worth it because serial programmers are not very reliable, are slow, and of course not portable to new computers that lack serial ports.
Make sure you program the device correctly and do not enable the LVP bit (low voltage programming); this reserves RB5 for program mode entry and RB6-RB7 for communication, and the result is a non functioning programmer.

It would also be a good idea to buy a backup micro, in order to program it with updated firmware versions.

The main circuit and some expansion boards (28-40p PIC, 8-20p PIC with ZIF, 3.3V PIC16-18, 3.3V PIC24-30-33, EEPROM, ATMEL):



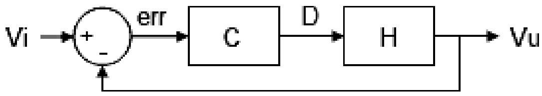
Expansion board connected to the main circuit:

OneWire device in TO92 package:

Switching voltage regulator

In order to generate a voltage higher than 5V we need a boost switching converter.
On the market there are thousands of single chip solutions, but I used instead the microcontroller itself and a few external components.
The width of output pulses will vary to keep the output voltage stable over all operating conditions.
In practice this is a digitally controlled regulator, as shown in

the following diagram:



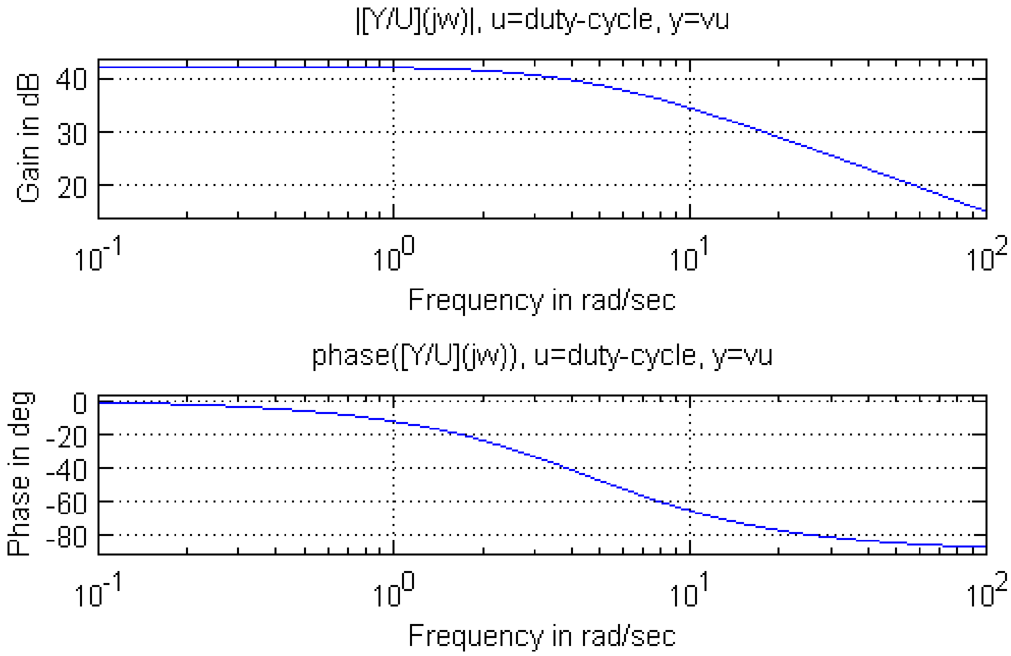
The ADC converter presently uses the 5V supply as a reference, so the output voltage will follow it; it is possible to connect an external reference to RA3 to improve the overall precision.
Switching frequency is 90 kHz, which is well over the cutoff frequency of the output LC filter (~2,3 kHz).
The performance is limited by losses due to the transistor, diode, inductor, but since the load is very low we can use low-cost (even recycled) components; to improve load capability switch to a better transistor, a Shottky diode, a higher rated inductor.
Anyways, in order to design a suitable regulator (block C above) it's necessary to work in s domain and model the converter itself; this has fortunately been done already, some info is available for example here.
With present component values the boost converter operates in dicontinuous mode; critical current is:
Icrit=Vu*T/(16*L)=86 mA
well over expected load, supposed to be 1 mA.
Other parameters:
Vi=5
Vu=12.5
D=(Vu-Vi)/Vo
L=100e-6
C=47e-6
I=1e-3
R=12/I
Rl=1.6 (inductor series resistance)
T=1/90e3

$$\frac{vu}{D} = Gdo \frac{1}{1 + s/wp} \quad \text{where } Gdo = 2 \frac{vu}{D} \frac{M-1}{2M-1}, \; M = \frac{Vu}{Vi}, \; wp = \frac{2M-1}{(M-1)\,RC}$$

Transfer function results to be:

$$\frac{vu}{D} = \frac{127.58}{0.22031\ s + 1}$$

Which has the following Bode diagram:



Top
Quick facts
Another programmer
USB & HID firmware
Control programs
GTK graphical interface
MFC Graphical interface
Command-line interface
How to ...
Supported devices
Communication protocol
The circuit
Voltage regulator
How to contribute
Download
History
Links
Contacts

It seems that the system, in closed loop, would be stable even by itself; however it would have a steady state error of 1/DCgain.
It's better to use a controller with a pole on the origin and a zero to stabilize everything, for example the following controller:

$$C = \frac{D}{err} = \frac{0.25\ (s + 50)}{s}$$

Overall transfer function would be:

$$\frac{vu}{vi} = \frac{144.77\ s + 7238.4}{s^2 + 4.539\ s}$$

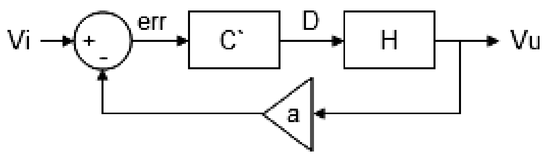
The system is stable, with a phase margin of ~75º.
Since we operate in the digital domain we must choose the sampling frequency.
It can't be too high because of execution speed; if too low it limits the regulator bandwidth; a period of 250 us was a good compromise.
The various transfer functions are converted to z domain using bilinear transformation:

$$\frac{vu}{vi} = \frac{0.018199\ z^2 + 0.00022607\ z - 0.017973}{z^2 - 1.9989\ z + 0.99887}$$

The controller is:

$$C = \frac{D}{err} = \frac{0.25156*z - 0.24844}{z - 1} = \frac{C1 - C2\ z^{-1}}{1 - z^{-1}}$$

Remember that z^{-1} represents a delay of one clock cycle.
Next we must deal with quantization and calculation errors.
A/D converter is 10 bits wide, and is triggered by timer2; at the end of conversion an interrupt calls the regulation routine, which calculates the new duty cycle for the PWM peripheral, also 10 bits wide.
On the feedback path it's necessary to include a voltage divider in order to limit ADC input voltage to [0,5V]; R1 and R2 do this.
So the block diagram is modified as follows:



a=12/34

Vu=C'H(Vi-aVu)

$$\frac{Vu}{Vi} = \frac{C'H}{1+aC'H}$$

To compare with the previous model we can multiply both terms by a; simply remembering to change the set point we can decide that the new input is Vi/a, and equate with the previous expression:

$$\frac{Vu}{Vi/a} = \frac{aC'H}{1+aC'H} = \frac{CH}{1+CH}$$

aC'=C

$$aC' = \frac{aC1' - aC2'\ z^{-1}}{1 - z^{-1}} = C = \frac{C1 - C2\ z^{-1}}{1 - z^{-1}}$$

aC1'=C1
aC2'=C2

Since the hardware works with 10 bit digital data we can go from D/err to pwm/[err]:

[err]=err*1024/5
pwm=D*1024

$$C' = \frac{D}{err} = \frac{pwm/1024}{[err]/1024*5} = \frac{pwm}{[err]*5} = \frac{C1' - C2' z^{-1}}{1 - z^{-1}}$$

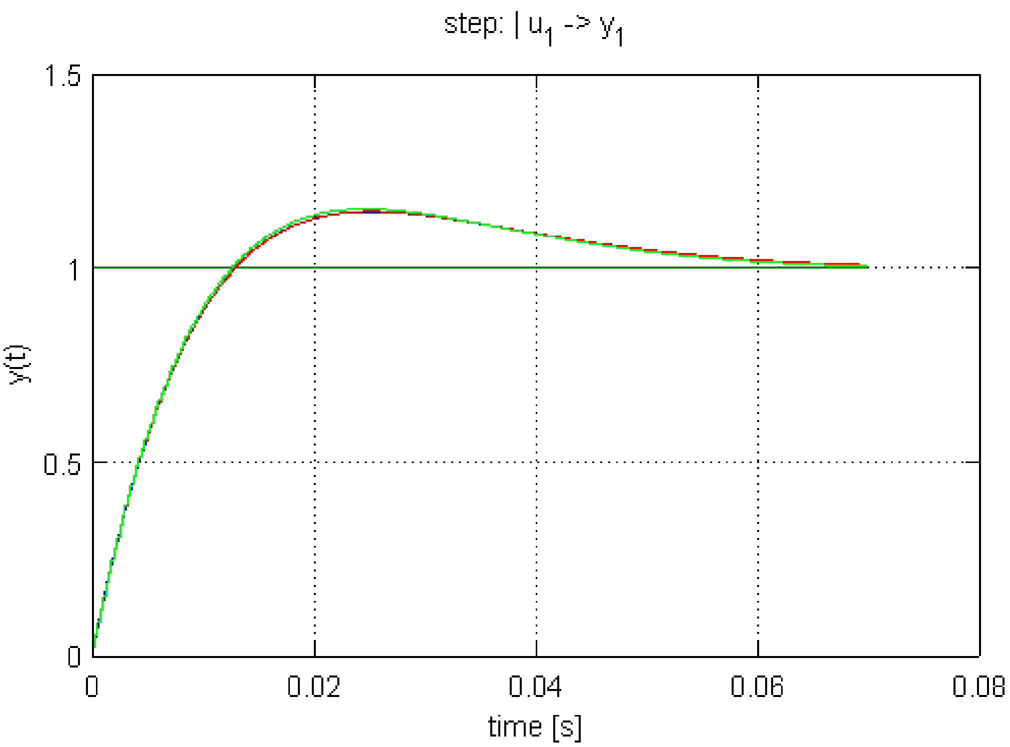
$pwm(1 - z^{-1})=[err](5*C1/a - 5*C2/a\ z^{-1})=[err](3.564 - 3.52\ z^{-1})$

It's clear that integer multiplications can't be used with these coefficients; the easiest solution is to work with fractional values (i.e. divide output by 2^N and multiply coefficients accordingly); considering that pwm output is 10 bits wide and left-aligned, we can easily work with values divided by 64.

$pwm(1 - z^{-1})=[err](k1 - k2\ z^{-1})/64$

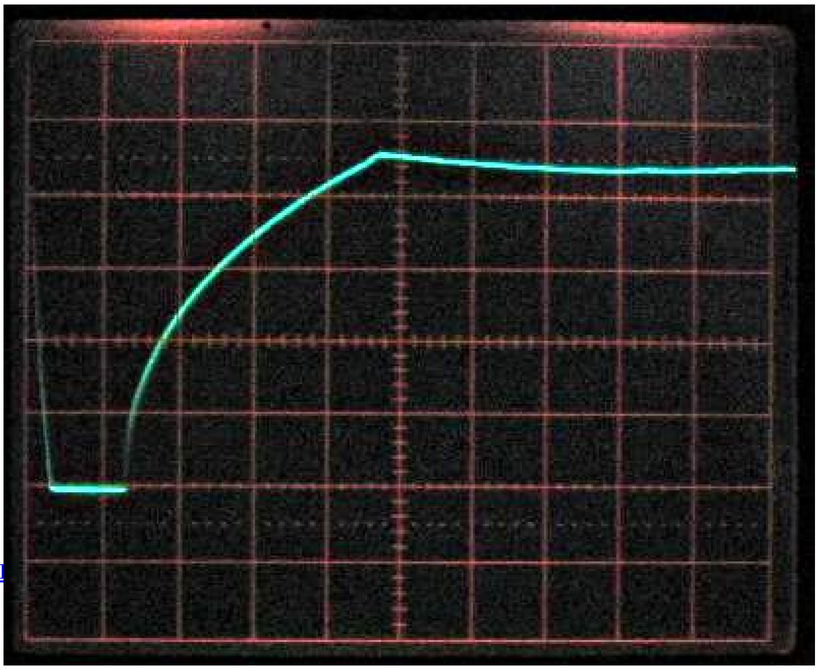
k1=5C1/a*64=228.12 ~ 228
k2=5C2/a*64=225.25 ~ 225

Following are step responses of continuous-time system (blue), discrete-time system (red), discrete-time system with approximate cefficients (green); As you can see they're almost coincident.

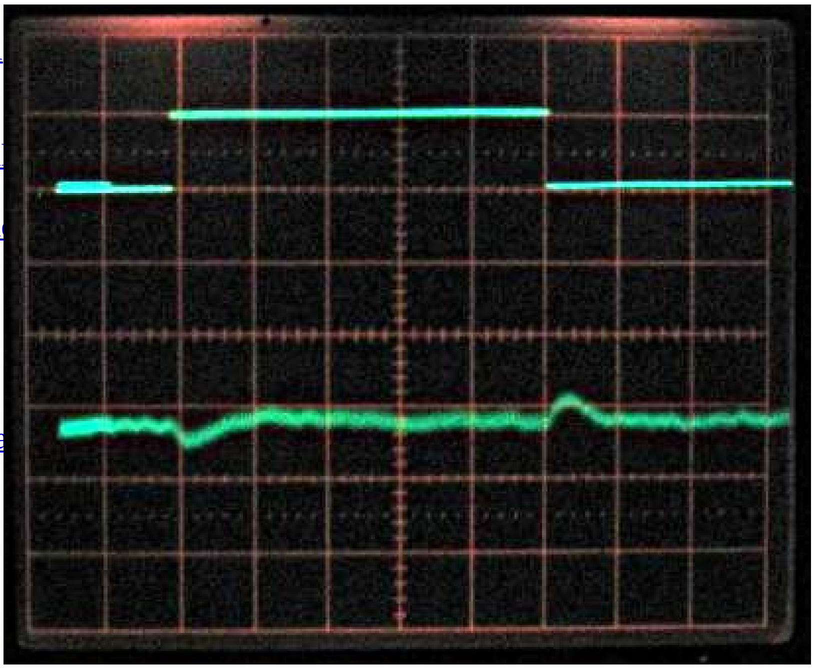


For all calculations I used Octave, an open source mathematical modeling tool; version 3 has just been released, and it can be used also under the famous windows (almost)operating system.
If someone is interested these are the modeling scripts I used.
The real code for the control function was written in assembly; this is necessary for performance reasons.
In fact our C compiler calls a library function to perform multiplications, so it has to save many variables on the stack causing a delay; in this case the resulting execution time had reached 50 us, which is a significant fraction of the sampling period.
Instead, by avoiding function calls and manually coding the 16x8 bit multiplication (see k1 & k2), the execution time is down to 12 us.

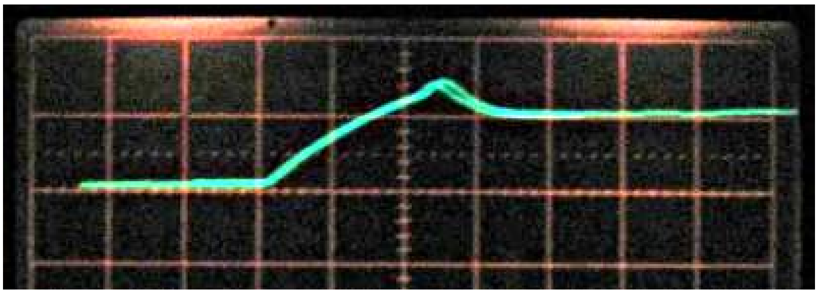
Some real waveforms:



Power-up transient, 50 ms/div



Step response to load change (load on top trace, AC coupled output on bottom tr.), 50ms/div



Step response to set point change (from 11,5 to 12,5 V), 50 ms/div

How to contribute

The best way to contribute to this project is to build it, use it, and report bugs or suggestions.
Also there are still many devices to test; check the list insupported devices.
Whoever has the know-how and patience can also expand support to other devices.
Or if you have a device that is not supported you can send it to me so that I can work on it.
If you find this project useful write me a couple of lines: albertom78@gmail.com, and if you modified it show me your work.
On SourceForge you can find some forums where you can discuss about this project; you could also recommend it or write a (hopefully positive) review.

Downloads

Schematic diagram and pcb: Pdf, KiCad, complete archive.
Firmware: complete MPLAB project or compiled firmware(.hex) or a version for 18F2450 (0.8.0) (with reduced functionality, see the circuit).
opgui (GTK GUI for Linux & Windows): sources orapplication
OpenProg (windows): application only; sources (Visual Studio 6 workspace)
OP (command-line for Linux & Windows)
OpenProg and Opgui user's guide
Octave scripts

History

a long time ago	need for a reliable and free USB programmer
2007	experiments with USB PIC and varionus firmwares; voltage regulator
2008	first prototypes and software
July 2008	documentation and website, released version 0.3
August 2008	version 0.4: added support for I2C EEPROMs
November 2008	version 0.5: I2C & SPI bus, added some ATMEL devices
January 2009	control programs v0.5.1: added some PIC devices, removed some bugs
March 2009	control programs v0.5.2 and v0.5.3: added some PIC an Atmel devices, removed some bugs
April 2009	schematic diagram and pcb v1.4: changed Atmel adapter
June 2009	version 0.6: fully GPL2 USB firmware, added 93Sx6 MicroWire EEPROMs
September 2009	version 0.6.1: solved some SPI bugs, added some Atmel devices and 93Cx6C
October 2009	control programs v0.6.2: bugfix
January	version 0.7.0: added PIC24 and SPI EEPROMs;

[Top](#)
[Quick facts](#)
[Another programmer?](#)
[USB & HID firmware](#)
[Control programs](#)
[GTK graphical interface](#)
[MFC Graphical interface](#)
[Command-line interface](#)
[How to ...](#)
[Supported devices](#)
[Communication protocol](#)
[The circuit](#)
[Voltage regulator](#)
[How to contribute](#)
[Download](#)
[History](#)
[Links](#)
[Contacts](#)

2010	circuits v1.5: expansion board for 3.3V PIC24-30-33
February 2010	control programs v0.7.1: added some PIC18 and Atmel devices; bugfix
March 2010	control programs v0.7.2: added some MicroWire eeproms; bugfix
April 2010	control programs v0.7.3: added PIC16F1xxx; OP works in windows; code rework and bugfix; circuits v1.6: expansion board for 3.3V PIC16-18
May 2010	control programs v0.7.4: added PIC18FxJx, PIC18FxKx, PIC24H, dsPIC30-33, ATtiny2313, 241024; bugfix; circuits v1.7: modified PIC24-30-33 expansion board, PIC30 now at 5V
June 2010	control programs v0.7.5: corrected write bug for 18Fx config, added "goto ICD" write for 16Fx, various minor fixes
July 2010	firmware v0.7.6: modified TX16 and RX16 with variable period for communication with ICD; control programs v0.7.6: byte by byte read with 93xx6 for better compatibility; first release of pdb debugger (v0.1);
August 2010	control programs v0.7.7: added 16F72x, some minor fixes; circuits v1.7.1: reduced value of R173 on the PIC16/18 LV expansion board
April 2011	control programs v0.7.8: updated algorithms for 16F87xA and 16F62xA, 16F1822 becomes 12F1822, added 30F1010, 30F2020, 30F2023, 16F1847, 12F1840 16F1516, 16F1517, 16F1518, 16F1519, 16F1526, 16F1527; greater modularity for source code, corrcted some bugs
June 2011	control programs v0.7.9: added ATtiny11-12-24-26-261-44-48-461-4313-84-88-861, ATmega48-88-164A-168-324A-328-644A-1284, 16LF1902-3-4-6-7, various minor modifications and fixes; new graphical interface based on GTK for Linux and Windows
January 2012	control programs v0.7.10: added 12F617,12F1501,16F1503-7-8-9,16F720-21,16F72,16F707, 18F13K22,18F14K22,18F23K22,18F43K22,18F24K22,18F44K22,18F25K22, 18F45K22,18F26K22,18F46K22,18F8520,18F66J60,18F66J65,18F67J60, 18F86J60,18F86J65,18F87J60,18F96J60,18F96J65,18F97J60, fixed read/write binary files, various corrections, added support for in-circuit debugging in OPGUI
July 2012	firmware v0.8.0: support for One-Wire and UNIO; control programs v0.8.0: added DS2430,DS2431,DS2433,DS28EC20,DS1820; 11010-20-40-80-160; 251005,252005,254005,258005,251605,25X10,25X20,25X40,25X80, 25X16,25X32,25X64; 16F1782-3-4-6-7,12C508-9; corrected write for 24x1024/5 and 251024;
June 2013	control programs v0.8.1: various user interface improvements; fixed EEPROM write when code protection is active (16F83-84,12F629, 12F675,16F627-28,16F630,16F676,16F870-1-2,16F873-74,16F876-77); fixed read of files > 1MB; modified prog mode entry for AVR; fixed write of 93Sx6 with protection;
March 2014	firmware v0.9.0: support for ATMEL HV serial programming; new command for PIC24/33; improved DCDC regulator; control programs v0.9.0: Write16F72x requires only config-word 1; added HV serial programming for ATtiny11-12-13-24-25-44-45-84-85; added 24FJ64GA3xx-GCxx,24FJ128GA3xx-GB2xx-GCxx-DAxx,24FJ256DAxx,24EPx,33EPx; added 95xx SPI EEPROM,25X05 FLASH; added 12F1571-72,16F527,16F753,16F1454-55-59; some code rework & minor improvements;

November 2014	control programs v0.9.1: various user interface improvements; fixed verification of ATTiny11-12; fixed 24FJ128GA3xx-GB2xx-GCxx-DAxx; added: config force for PIC18, IO lines hardware test, AVR auto speed communication, AVR write fuse @ 3kHz; faster write verification for SPI FLASH memories; added 10F320-22,12F529T39A,12F752,12F1612-13-14-15-18-19, 16F1512-13,16F1574-75-78-79,16F1703-04-05-07-08-09-13-16-17-18-19, 16F1788-89,16F570,16LF1554-59, 18F24K50-25K50-26K50-45K50-46K50, 18F25K80-26K80-45K80-46K80-65K80-66K80, 18F63J11-90,18F64J11-90,18F65J10-11-15-50-90, 18F66J10-11-15-16-50-55-90-93,18F67J10-11-50-90-93, 18F83J11-90,18F84J11-90,18F85J10-11-15-50-90, 18F86J10-11-15-16-50-55-90-93,18F87J10-11-50-72-90-93, 25X128,25Q40
June 2016	firmware v0.10.0: added instructions LOAD_PC, LOAD_DATA_INC, READ_DATA_INC, JTAG_SET_MODE, JTAG_SEND_CMD, JTAG_XFER_DATA, JTAG_XFER_F_DATA; new USB VID&PID (0x1209,0x5432); changed some CK timing; reduced CLOCK_GEN startup time; control programs v0.10.0: added 16F18313-23-24-25-26-44-45-46; improved USB communication
the future	increase support for PIC and ATMEL micros; add ST72, JTAG, parallel memories; expand ICD support; compile firmware also with SDCC

Links

Open Programmer on SourceForge
USB 2.0 standard
HID page on USB.org
pdb, a simple ICD debugger for PIC16
Quick guide to a HID firmware
USB Central
USB & PIC
Microchip
Atmel
hiddev documentation
Winpic
ICprog
Octave
KiCad
gEDA-Gschem
PCB
GNU/GPL
Piklab IDE for PIC microcontrollers
USBPicprog, another open source programmer
Cygwin, a linux environment inside windows

Contacts

For informations or comments:
Alberto Maccioni albertom78@gmail.com
You can also post your questions on the forum on sourceforge.

Thanks

I'd like to thank all the people that contributed to the growth of this project, in particular: Anselmo for helping with linux/git, Sandro for the highly professional PCBs, Alessandro for testing many devices, Ken for testing many AVR devices, Luigi for testing OneWire memories, Mihaly for testing SPI Flash memories.