BUTTLOAD
AVRButterfly ISP Programmer

By Dean Camera, 2006
For Buttload V1.4

SYNOPSIS:

The ButtLoad firmware allows you to transform a cheap, widely available "AVRButterfly" demonstration and development board from Atmel into a fully-fledged ISP programmer for all AVRStudio compatible devices. Using the pre-existing Butterfly bootloader, the programmer itself can have its firmware loaded quickly via a RS-232 (serial) interface. This feature allows the construction of the programmer without the need for a bootstrap cable or pre-existing programmer – thus the ButtLoad system does not suffer the "chicken and egg" dilemma of other homebrew programmers.

The AVRButterfly's extremely small price tag and host of onboard features makes it ideal for this purpose. Compatible with the V2 protocol used in AVRStudio 4.x and the ATAVRISP, ButtLoad takes the place of the latter system. Not only cheaper, the ButtLoad system has the unique ability to store a program (including flash and EEPROM memory as well as the fuse and lock bytes for the device) on its onboard non-volatile dataflash. With this feature, the ButtLoad system can be used to perform complete upgrades or programs in the field without the use of a computer.

ButtLoad can also program and read a wide selection of Atmel Dataflash memory chips directly.

The construction of the ButtLoad system is easy; all that is required component-wise is the level-shifting circuitry for the USI port and the optional bicolour status LED. This can just be a pair of resistors, as shown in "Connection Diagram.pdf".

Current consumption in AVRISP mode with no status LEDs attached is less than 5mA at 3V. This figure drops to less than .1mA while in sleep mode – ButtLoad is very gentle on battery life.

LOADING THE FIRMWARE:

The following instructions assume you are using a Butterfly running the default bootloader. If you have programmed in a different bootloader (or if you have removed the bootloader) you will need to find alternate directions for loading the BUTTLOAD.HEX file into the Butterfly's MEGA169. Note, if not using the bootloader, the BOOTRST fuse bit should be unprogrammed.

1) Compile the project with WinAVR (AVR-GCC). WinAVR is a free collection of C tools, plus an excellent compiler for the Windows platform. You can download the latest package from http://sourceforge.net/projects/winavr/.

2) After compiling, a new file named BUTTLOAD.HEX should be present in the ButtLoad project folder. Start AVRStudio4.

3) Connect your Butterfly to your computer's serial port, and remove all power to the board.

4) Reconnect the Butterfly's power source. Although no activity is present, the system is now in Bootloader mode.

5) Push the Butterfly's joystick inwards, and hold it down. Next, open AVRPROG from the Tools menu.

6) Select the BUTTLOAD.HEX file from the ButtLoad project directory. To program the Butterfly, click the Program button.

7) After the erase, program and verify cycles are complete, release the joystick, close AVRPROG and cycle power to the Butterfly.

Once these simple steps have been followed, ButtLoad is ready to be used. To intitialise the program, see the "Operation" section of this document.

> *If you are using the default Butterfly bootloader and receive programming errors at the flash address 0x940c, then please visit the AVRFreaks thread at http://tinyurl.com/oudt6 for an explanation of the problem and possible solutions.*

CONFIGURING AVRSTUDIO:

The AVRButterfly hardware is not very well suited for the very high speed communications normally used for the official AVR tools (STK500 and AVRISP-MKI). Because of this, ButtLoad uses the slower connection speed of 57600 rather than the normal 115200 baud. To instruct AVRStudio to connect at this slower speed, you will need to run the file *ButtLoadRegPatch.reg* located in the Buttload Support directory.

CONNECTIONS:

USI Interface:

Pin 1 (SCK) - Slave AVR SCK
Pin 2 (DI) - Slave AVR MISO
Pin 3 (DO) - Slave AVR MOSI
Pin 4 (GND) - Slave AVR GND

PORTF (As viewed from the TOP of the board):

Pin 1 (PF4) - Green (active-high) lead of a Bicolour LED (optional)
Pin 5 (PF5) - Red (active-high) lead of a Bicolour LED (optional)
Pin 3 (PF6) - /RESET line of slave AVR or /CS line of slave Dataflash
Pin 10 (GND) - Status LED ground if used (optional)

USART Interface:

Pin 1 – Receive relative to Butterfly
Pin 2 – Transmit relative to Butterfly
Pin 3 – Ground

If you wish to program 3V AVR/DataFlash parts, omit the two protection resistors shown in the schematics.

KNOWN ISSUES:

1) The maximum speed of ButtLoad's USI system in SPI mode is 210.651 KHz.

2) A maximum of 10 fuse bytes and 10 lock bytes can be stored in memory at any one time (writing the same fuse overwrites the existing value). If it is attempted to write more than this maximum, the extra bytes will be ignored.

3) HEX files containing addresses which are non-consecutive (eg. use of .ORG command in assembler other than .*ORG 0*) cannot be stored into ButtLoad's non-volatile memory in STORAGE MODE. Other modes are not affected by this issue.

OPERATION:

Initialising the system:

Once the firmware has been loaded using the bootloader, the power must be cycled to the device in order to reset it. To initiate the new firmware using the Atmel bootloader, push the joystick upwards briefly; this will cause the main menu to show.

Interfacing with ButtLoad:

ButtLoad communicates with AVRStudio in the exact same manner as the AVRISP. Details on the STK500 communication protocol (a subset of which is the AVRISP communication protocol) is avaliable from the Atmel website, application note 061 (avaliable from http://atmel.com/dyn/products/app_notes.asp?family_id=607). Details on the actual programming method can be found in application note 910 (also avaliable from http://atmel.com/dyn/products/app_notes.asp?family_id=607).

Due to hardware constraints, ButtLoad cannot achieve the high programming speeds of the official Atmel tools. The correct SPI programming speeds are shown inside the "SET SPI SPEED" option in the settings submenu, however the speed values shown in AVRStudio are fixed and cannot be changed. If you wish to set the programming speed of ButtLoad via the AVRStudio programming window, the table below shows the expected speed (as shown in the programming speed combobox in AVRStudio) and the actual ButtLoad speed.

AVRStudio Speed	*ButtLoad Speed*
28,800Hz	57,153Hz
57,600Hz	86,738Hz
230,400Hz	113,427Hz
921,600Hz	210,651Hz

Status LEDs:

Adding the bicolour status LED to ButtLoad is optional, but can serve as a quick indication of the system status when the user is not in a position to easily read the LCD display. The status LEDs can show one of three colours:

RED	Programming
ORANGE	Busy
GREEN	Ready

The main menu:

The default function in the main menu is "AVRISP MODE". To scroll through the available menu items, push the joystick up or down. To select a function, press the joystick inwards briefly. You can access program info by pushing the joystick right (then push up or down to scroll and left to return).

When ButtLoad starts it is in the main menu only, NOT in the AVRISP mode. You will need to enter a function via clicking the joystick on the desired function name before use.

Before any function which requires the use of the USART ButtLoad will calibrate the internal RC osccilator. This process should take no longer than one second to complete.

AVRISP MODE:

This mode will cause the Butterfly to emulate an AVRISP, as its name suggests. While "*AVRISP MODE*" scrolls across the display, you can connect to the ButtLoad system using the AVRStudio programmer as if it was a normal ATAVRISP and perform tasks on a connected AVR. To interact with ButtLoad in this mode, select *Tools->Program AVR->Connect...* from AVRStudio, select the AVRISP option and click OK.

When entering programming mode, ButtLoad will attempt to syncronise with the attached AVR. If this fails, "SYNC ERROR" will show on the display briefly and the AVRStudio programmer will show an error message.

To exit the function, push the joystick left. For safety reasons, the function can only be exited while not in programming mode or during the reception of a data packet from the computer.

STORE PRGM:

This mode behaves in exactly the same manner as AVRISP MODE, except "*STORAGE MODE*" will scroll across the display, and the target will be the internal memory rather than an attached AVR. You can read or write to the non-volatile memory as if it was an attached AVR, including setting the fuses, lockbytes, EEPROM and FLASH contents. To interact with ButtLoad in this mode, select *Tools->Program AVR->Connect...* from AVRStudio, select the AVRISP option and click OK.

In this mode the signature bytes will always read back as 0x01 0x01 0x01.

To exit the function, push the joystick left. For safety reasons, the function can only be exited while not in programming mode or during the reception of a data packet from the computer.

PROGRAM AVR:

Once data has been loaded into ButtLoad, it may be programmed into an attached AVR. This may be EEPROM, FLASH, Fuse Bytes, Lock Bytes or a combination.

When selected, a new list will appear. To select an option, depress the joystick. To cancel, push the joystick left. The options available are:

PRGM ALL
DATA ONLY
EEPROM ONLY
DATA AND EEPROM
FUSE BYTES ONLY
LOCK BYTES ONLY
FUSE AND LOCK BYTES
ERASE ONLY

If the selected item is not present in memory (for instance, you have elected to program the stored fuse bytes into the target AVR, but no fuse bytes have been loaded into memory) the system will show a "NO x" error – where x is the item that cannot be programmed.

As the programming commences, the screen will update to show the current task. This takes the form of a "PRG>" prefix followed by on of the following letters:

Letter	Process
C	Target Erase (memory clear)
D	Target Flash programming
E	Target EEPROM programming
F	Target Fusebytes programming
L	Target Lockbytes programming

Once the programming cycle completes sucessfully, the display will show "PROGRAMMING DONE" for a short period before returning to the main menu. If an error occurred during the programming (such as a data type missing) then "PROGRAMMING FAIL" will appear. This will show even if the other chosen data types were programmed sucessfully.

DATAFLASH PRGM:
ButtLoad can directly read and program Atmel dataflash memory. After connecting your dataflash to the USI interface and dataflash /CS pin (PortF.6), the device is accessable via a computer. Once this mode is selected the AVR programming dialogue can be opened in the same way as with the AVRISP mode.

Once open, the only responsive commands are the EEPROM read, write and verify. These correspond directly with Dataflash read, write and verify respectivly. Other functions will return all nulls (0xFF) or will have no effect other than returning a CMD_OK acknowlege message.

The erase command, due to the time required to perform it, is executed *after* the CMD_OK is sent back to the computer. While the erase is taking place

"*WAIT*" will display and ButtLoad will become unresponsive to both joystick and computer messages. Do not attempt to send any commands to the device while ButtLoad is erasing a dataflash.

To interact with ButtLoad in this mode, select *Tools->Program AVR->Connect...* from AVRStudio, select the AVRISP option and click OK.

In this mode the signature bytes will always read as 0x02 0x02 0x02.

If the attached dataflash is missing, unrecognised or damaged, the LCD will show DATAFLASH ERROR. This will remain until a dataflash is sucessfully connected or the function is exited.

To exit the function, push the joystick left. For safety reasons, the function can only be exited while not in programming mode or during the reception of a data packet from the computer.

DATASTORE INFO:
This function contains a submenu, with options for viewing different aspects of the data (if any) stored in ButtLoad's onboard non-volatile memory via the STORAGE MODE function.

STORAGE SIZES:
This function shows the size (in bytes) of the stored types of data. Pushing up or down in this function will scroll between the program data, eeprom data, total fuse bytes and total lock bytes.

To return to the DATASTORE INFO submenu, push the joystick left.

VIEW DATA TAGS:
To help identify characteristics about the a program stored in the dataflash, ButtLoad can display "ButtTag" data embedded in the program as strings. To learn how to place your own custom ButtTags in your program, see the "ButtTag" section.

When entered, this mode will scan the stored program data for tags. Once encountered, the first tag data will be displayed onto the LCD. Pressing down advances to the next tag (if present) – pushing the joystick upwards has no effect. To exit this mode and return to the main menu, push the joystick left.

SETTINGS:
This function will allow you to change ButtLoad's settings. If selected, the available settings will appear in a new menu. This submenu functions in the same manner as the main menu; pushing the joystick left will exit the settings menu and return to the main menu.

SET CONTRAST:

To preserve ButtLoad battery life, or for aesthetic reasons, the ButtLoad display's contrast can be set. This value is saved into non-volatile memory and thus the contrast value will be retained on power-off. To change the contrast, push the joystick up (to darken) and down (to lighten) - the contrast range can vary from 1 (very light) to 15 (very dark). To exit the SET CONTRAST mode and save the new value into memory, push the joystick left.

SET ISP SPEED:

If you want to manually change the ISP programming frequency, use this option. Pushung the joystick up or down will cycle through the preset speeds (shown in Hz). To save the current speed and return back to the main menu, push the joystick left.

SET RESET MODE:

By default ButtLoad tristates it's target reset pin (PF.7) so that it does not intefere with any SPI comminictions when not programming. This consumes more power than using a defined logic state. If you wish to save power OR if you are using an external buffering of the ISP lines which expects defined logic levels at all times, change this setting to LOGIC. To use the default tristating of the reset line when inactive, choose FLOAT. To save the current reset mode and return back to the main menu, push the joystick left.

SET FIRM VERSION:

In a normal AVRISP, AVRStudio determines the firmware version of the attached device and performs an upgrade if nessesary. Because ButtLoad is custom firmware for completely different hardware, such an automated upgrade is not possible or nessesary.

You can change the firmware version returned by ButtLoad to the latest your version of AVRStudio4 supports to prevent the upgrade message from appearing each time you connect to ButtLoad.

The default firmware version returned is V2.4. You can only change the minor version number from 0 to 9.

SET SLEEP TIMEOUT:

ButtLoad will automatically go into sleep mode after a user-settable period of time of no joystick activity. This auto-sleep timer is always active **except** in functions which use the serial port.

To change the timeout duration, push the joystick up or down. To save the selected value and have it take effect immediately push the joystick left.

CLEAR MEMORY:

Selecting this function will immediately clear the internal EEPROM. This will have the effect of removing all references to the program (if any) stored in dataflash, as well as all other non-volatile settings.

Once complete, the function will show a success message and return automatically to the main menu.

JUMP TO BOOTLOADER:

This function will re-enable the JTAG interface momentarity and, assuming the BOOTRST fuse is programmed, jump to the bootloader (if no bootloader is present ButtLoad will simply restart). The jump is executed AFTER the joystick is released; if you are programming via the JTAG interface, connect to the AVR while holding in the joystick to enter the function. While the JTAG interface is enabled, the message "*JTAG ON*" will be displayed.

The auto-sleep timeout is disabled while the JTAG interface is enabled.

SLEEP MODE:

This function will place the Butterfly in sleep mode. When activated the LCD controller and much of the peripherals will be turned of to save power. This mode can be used instead of physically removing device power but keep in mind a very small current draw will still exist.

To wake up the Butterfly and resume normal operation, push the joystick upwards.

Errors:

ButtLoad errors are prefixed with the text "E>". If an error occurs, the error text will continuously scroll across the display until the joystick is pushed inwards. An exception to this is sync errors in AVRISP MODE or dataflash errors in PRGM DATAFLASH MODE; these will clear automatically after a sucessful retry and will not have the "E>" prefix.

ButtLoad can show one of the following error messages:

BADISR: Internal error. Please send a report detailing what occurred to show this message to my email address. You will need to power-cycle your Butterfly to clear this error.

BUFF OVF: Internal error. Please send a report detailing what occurred to show this message to my email address. You will need to power-cycle your Butterfly to clear this error.

DATA OVR: Internal error. Please send a report detailing what occurred to show this message to my email address. You will need to power-cycle your Butterfly to clear this error.

FRAME ERR: Internal error. Please send a report detailing what occurred to show this message to my email address. You will need to power-cycle your Butterfly to clear this error.

DATAFLASH ERROR: Could not recognise either the onboard Butterfly or external dataflash (in DATAFLASH PRGM MODE). It may be of the wrong type, absent or damaged.

SYNC ERROR: ButtLoad cannot syncronise its ISP communications to a connected target AVR. No AVR may be connected, the ISP cable may be attached improperly or the target AVR may be damaged.

NO ERASE CMD: You are trying to program a slave AVR's flash from the stored program data, but no erase command has been saved by ButtLoad. You will need to execute a flash erase while in STORAGE MODE and reload your program data.

NO DATA: No program flash data has been stored in memory, but you are trying to program a slave AVR's flash.

NO EEPROM: See NO DATA error description.

NO FUSE BYTES: See NO DATA error description.

NO LOCK BYTES: See NO DATA error description.

NO STORED PRGM: No program has been stored into the dataflash, and so ButtLoad cannot check for tags.

NO TAGS: No tags were found in the entire stored program data. Either no tags are present, or the tag headers are incorrect/invalid.

Internal errors will cause ButtLoad to freeze up, and will not be prefixed by the standard "E>" error text. The occurance of an internal error will also cause the status LED to flash quickly from orange to red and vice-versa. You will need to reset your Butterfly to clear an internal error.

If you experience an internal error, please email me a bug report.

BUTTTAGS:

ButtTag.h contents:

This file should be included in your source files which contain ButtTags.

```
/*
            BUTTLOAD - Butterfly ISP Programmer

             Copyright (C) Dean Camera, 2006.
```

```
                    dean_camera@hotmail.com
*/

/*
   ButtTag.H: This file can be included in user projects to
   allow the embedding of "ButtTags", small strings of text
   which may be read by ButtLoad (if the program is stored in
   ButtLoad's non-volatile memory) or by other C management
   programs. Each ButtTag must have a unique name and be less
   that 20 characters in length.
*/

#ifndef BLTAG_H
#define BLTAG_H

#include <avr/io.h>
#include <avr/pgmspace.h>

struct ButtLoadData
{
      uint8_t MagicString[4];
      uint8_t TagData[];
};

#define BT_TAGHEADER          {'@','(','#',')'}
#define BUTTLOADTAG(id, data) const struct ButtLoadData BUTTTAG_##id
PROGMEM = {BT_TAGHEADER, data}

#endif
```

The ButtTag header file must be included in your project before any tags or you will receive compiler errors. The header file should be included in every file in your project which includes ButtTags.

The header file is protected against multiple-inclusion errors or compiler loops.

Placing ButtTags in your program:

To place ButtTags in your program, first you must place the above code into a new header file, and include that into your program. Once included, the new macro "BUTTLOADTAG" becomes avaliable for your use.

The syntax for the BUTTLOADTAG macro is:
   BUTTLOADTAG(*Name***, ***TagDataInQuotes***)**

All ButtTags must be given a unique name, due to C language constraints. These names are not stored in the resulting binary, and thus no extra restrictions except normal C language constraints are present.

TagData can be any null-terminated string equal to or less than 20 characters in length. Tags are read out from the program binary sequentially. You may use ButtTags to store copyright information, the name of the program, its version or anything else alpha-numeric which can be displayed onto the Butterfly's LCD. If a

ButtTag is over 20 characters in length, the superflous characters will be stored in the resulting binary but ignored by ButtLoad when read.

THANKS TO:

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Also thanks to Tom (AVRFreaks username ZoomCityZoom) for the lending of his JTAG ICE and a Butterfly, and "Smokey" (www.smileymicros.com) for his donation of a pair of Butterflies for the cause after I damaged my own Butterfly. If you're new to C or want a cheap Butterfly, he is your man at $20 a pop and he's written a fantastic introduction to the C language – based around the Butterfly board and the free GCC compiler – which have read and I highly recommend.

Eternal thanks to the members of the AVR-GCC project for their wonderful and free C compiler which is avaliable for everyone in a convienient toolset for Windows made by Eric of AvrFreaks.net (winavr.sourceforge.net).

My grattitude is also extended to both David Bourgeois and Scott Coppersmith, who gratiously gave their time and input to test the alpha versions of ButtLoad 1.4, helping me fix problems which arose along with my significant changes from the previous version.

Final thanks to Sylvian for his connection diagram for ButtLoad, and Collin O'Flynn for his OSCCAL calibration example code. Both are also active members of AVRFreaks.net.

CONTACT:

I'm always happy to receive legitemate emails and take the care to answer every single one. Whether it be a bug report, feedback, AVR-related anecdote, an "attaboy!", cohherant letter of abuse, picture of your mounted ButtLoad ISP programmer or anything else, please don't hesitate to congest the information highway. My email address is dean_camera@hotmail.com. I am also avaliable via PM at www.AVRFreaks.net under the username "abcminiuser".

If you wish to browse my personal webpage (listing my main past projects), the address is http://home.pacific.net.au/~sthelena.

DISCUSS:

ButtLoad development is currently being discussed in the ButtLoad AVRFreaks Academy thread, avaliable at http://tinyurl.com/cco7k. You can post suggestions, bug reports and the like there as an alternative to contacting me directly.

UPDATE:

The latest version of ButtLoad is always avaliable at its AVRFreaks academy project entry, at http://tinyurl.com/afbad.

LICENCE:

ButtLoad is released under the GPL licence (V2). Please see the "GPL Licence.txt" file included with this ButtLoad distribution for information on this licence and its terms.