

BUTTL0AD

AVRButterfly ISP Programmer

By Dean Camera, 2006
For Buttload V1.3

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 4.2mA at 3V. This figure drops to just .03mA while in sleep mode – thus ButtLoad is very gentle on battery life.

LOADING THE SOFTWARE:

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://www.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 initialise the program, see the "Operation" section of this document.

CONNECTIONS:

Because the on-board dataflash is connected to the SPI interface, the code uses the USI system in three-wire mode to communicate with the slave AVR instead. This means that the two systems can run at different data rates without switching, and is also necessary because the slave AVR does not have a /CS pin.

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

Level shifting circuitry must be employed that can translate the 3.3V Butterfly signals to the target AVR's voltage and vice-versa at sufficient current to prevent damage to the Butterfly. In the connection diagram PDF, this takes the form of two 4.7K ohm resistors. If you wish to program 3V AVR/DataFlash parts, omit the two resistors shown in the diagram.

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) All HEX files must use continuous addresses from 0x0000. Do not try to store and then program a slave AVR with a HEX file whose addresses are non-linear. Direct programming (ie. AVRISP MODE) is 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.

“*WAIT*” will appear on the display; this indicates that the system is busy calibrating the system clock oscillator so that 115200 baud serial communications can be achieved. This process may take several seconds to complete, after which the main menu will appear.

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 available from the Atmel website, application note 061 (available 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 available from http://atmel.com/dyn/products/app_notes.asp?family_id=607).

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. 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.

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 synchronise 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:

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.

Once the programming cycle completes successfully, 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 regardless of if the other preset data types were programmed successfully.

DATAFLASH PRGM MODE:

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 accessible via a computer. Once this mode is selected the AVR programming dialogue can be opened in the same way as 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 respectively. Other functions will return all nulls (0xFF) or will have no effect other than returning a CMD_OK acknowledge message.

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 successfully 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 SPI SPEED:

If you want to manually change the ISP programming frequency, use this option. Pushing 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.

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.

AUTO CALIBRATE:

This function will automatically recalibrate the internal oscillator. This may be necessary if the temperature of the MEGA169 microcontroller changes significantly from the startup temperature.

MANUAL CALIBRATION:

If you are unable to connect to the ButLoad system, or you experience transmission errors with ButLoad, you can use this function to manually set the calibration factor for the internal system clock.

Push the joystick up or down to increase or decrease the system clock OSCCAL value. After each change, ButLoad will send the text "BUTTLOAD" through its serial port at 115200 baud, no parity, 8 data bits and 1 stop bit. Set a terminal application to the identical settings to aid calibration. ButLoad will also echo any characters sent to it back through the USART.

Depressing or pushing right on the joystick will also send out the "BUTTLOAD" text. When you are finished, pushing the joystick left will exit the function and return to the main menu.

JUMP TO BOOTLOADER:

This function will re-enable the JTAG interface momentarily and, assuming the BOOTRST fuse is programmed, jump to the bootloader (if no bootloader is present ButLoad will simply restart). The jump is executed AFTER the joystick is released; if no bootloader is present and 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.

SLEEP MODE:

This function will place the Butterfly in sleep mode. When activated the LCD controller and much of the peripherals will be turned off 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. Upon waking, the auto clock calibration routine will execute before returning to the main menu.

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 successful 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 OVERFLOW: Internal error. Please send a report detailing what occurred to show this message to my email address. Serial data has been corrupted; you will need to exit to the main menu and re-enter the current function.

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

SYNC ERROR: ButtLoad cannot synchronise it's 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.

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 no more
    than 20 characters in length.
*/

#ifndef BLTAG_H
#define BLTAG_H

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

struct ButtLoadData
{
    uint8_t BUTTLOAD_MAGICSTRING[4];
    uint8_t BUTTLOAD_TAGDATA[];
};

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

#endif
```

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 available for your use.

The syntax for the BUTTLOADTAG macro is:

BUTTLOADTAG(*Name*, *TagData*)

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 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, etc. If a ButtTag is over 20 characters in length, the superfluous characters will be ignored when read.

THANKS TO:

I'm very grateful to many people who helped make this project possible. First and foremost, thanks to the members of AVRfreaks.net for their wonderful input and encouragement during the project's development.

Special thanks to Barry (AVRfreaks username Bpar) for donating a significant amount of his time over the development period, remotely testing and debugging the code. 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.

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

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 legitimate emails and take the care to answer every single one. Whether it be a bug report, feedback, AVR-related anecdote, an "attaboy!", coherent letter of abuse or anything else, please don't hesitate to congest the information highway. My email (obfuscated in case a spambot ever reads this) is [dean_camera \(AT\) hotmail \(DOT\) com](mailto:dean_camera(AT)hotmail(DOT)com).