

Arduino Debugger

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Introduction

This documentation describes source level debugger for Arduino based on GNU Debugger (GDB). It uses GDB stub mechanism for implementing the debugger. This means a piece of code (stub) is added to your Arduino program. This code then communicates with the GDB debugger. No external programmer or modification of the Arduino board is required. Eclipse can be used as a graphical frontend for debugging.

Release notes

July 2017

- Added support for writing breakpoints into flash memory – Arduino Uno only. This allows debugging program without the significant drop of execution speed which happens when using breakpoints in RAM.
- Added support for loading new program from the debugger – Arduino Uno only. This allows uploading changed program to the MCU and debugging with single click – no need to upload separately using AVRDude.

January 2017

- Added support for Arduino Mega board with ATmega1280 and ATmega2560 MCUs.
- Example programs reorganized and renamed. The name now contains Arduino variant so that example projects for different variants can be imported into single eclipse workspace.
- Fixed bug for ATmega328 (Uno) - the debugger now works for programs larger than 16 kB.
- Documentation updated to describe also direct serial communication with the debugger (without the TCP-to-COM proxy) which seems to work on Windows 10 and with some boards also on Windows 7.

June 2015

First release. Arduino Uno supported.

Note about this documentation

The January 2017 revision of this document has been updated with information related to the Arduino Mega. Also new information has been added based on current experience with new versions of the tools used. However, the procedures, screenshots etc. were not completely updated.

Abbreviations and terms used in this document

Arduino MCU Framework – the software for the microcontroller (MCU) shipped with Arduino, the core library of Arduino with functions like digitalWrite, etc. Also Arduino software library.

Arduino software library – see Arduino MCU Framework.

Debug driver – the code which communicates with the debugger. This code is added into your project in Eclipse. It is a program library. This driver is located in `avr8-stub.c` and `avr8-stub.h`.

MCU – microcontroller

Introduction: How to use this document

This document should help you use the Arduino debugger. It assumes that you write and debug your programs in Eclipse IDE. Setting up Eclipse and other tools is quite complicated, but currently I am not aware of any easier way to achieve this.

The chapters in this document are organized in a step-by-step order, so you can follow the chapters as they are. You can also skip any of them if you feel confident you do not need this step.

These main steps are covered:

1. Installing and setting up the tools needed to develop and debug your program for Arduino in Eclipse.
2. Building and uploading simple program in C language into the Arduino board, without using the Arduino software library.
3. Enabling the debugger functionality in this program and debugging it.
4. Enabling the Arduino software library functions in your programs in Eclipse.
5. Enabling the debugger functionality in this program and debugging it.

I recommend that you follow these steps including the simple program in C without Arduino software library; this is not a detour but rather a check point. You need to be able to build program in plain C language to be able to build one with the Arduino functions.

Before diving into the step-by-step instructions below, please read the following sections to know what you are doing.

Basic information about the tools

For a typical Arduino user, only one tool is needed – the Arduino IDE.

But you cannot debug your program in the Arduino IDE; it does not provide such functionality. You need an IDE with graphical interface for debugging. The most popular alternatives for Arduino development are probably the Eclipse and Atmel Studio.

I do not think Atmel Studio can be used with the debugger presented here. At least I was not able to set up the GDB debugger in Atmel Studio. It seems there is no access to the settings needed to make this work. This leaves us with the Eclipse as the only option. Or the command line use of GDB, if you prefer. But I will not describe this case here.

So, we need to write, build, upload and debug our programs for Arduino in Eclipse.

Unfortunately, there is no direct support for Arduino in Eclipse. Eclipse is not a “single purpose” IDE; it can be used for all kinds of projects in several languages etc. So you cannot just download Eclipse

and start coding for the Arduino (in fact, for Atmel microcontrollers). You need to add some extra tools.

All needed tools are summarized in the following table. Each column represents one tool and a row represents the package (program) in which the tool can be found. Our goal is to have all the tools. You do not need to install all the packages. You are free to combine the packages as you wish to reach this goal.

| Package | GUI for debugging | Compiler and linker | Make tool | AVR Dude uploader | GDB debugger | Notes |
|--------------------------------|-------------------|---------------------|-----------|-------------------|--------------|--|
| Eclipse (for C/C++ developers) | Yes | - | - | - | - | The IDE we are using. |
| AVR Eclipse plugin | No | - | - | - | - | Needed to build AVR projects in Eclipse |
| Arduino IDE (1.8.1) | No | Yes | No | Yes | Yes | Needed for uploading the programs. |
| Atmel AVR toolchain | No | Yes | No | No | Yes | Is included in Atmel Studio but also available separately. |
| Atmel Studio | Not usable | Yes | Yes | No | Yes | We do not use the IDE, but contains many tools |
| Mingw tools | No | ? | Yes | ? | ? | Provides the make tool. |

In the following chapters these possible configurations are covered:

- Option 1: Easy Setup based on Arduino IDE and MinGW tools
- Option 2: Easy setup based on Atmel Studio and Eclipse
- Option 3: Setup without Atmel Studio but with Atmel AVR8 Toolchain.

Option 1 was added after Arduino IDE 1.6.5 IDE appeared, because it now again contains the GNU debugger (avr-gdb). Unfortunately, it still does not contain the make tool (make.exe) so this tool must be obtained by installing MinGW tools.

Option 2 with Atmel Studio is also easy, but requires more disk space – you need to install Atmel Studio.

Option 3 requires more steps but less disk space and in principle can be used as a guide for Linux users with some modifications.

The following tables show which packages are needed in each option to obtain the required tools.
We need to have “Yes” in all the columns.

Option 1 – Using Arduino IDE and MinGW

| Package | GUI for debugging | Compiler and linker | Make tool | AVR Dude uploader | GDB debugger |
|--------------------------------|-------------------|---------------------|-----------|-------------------|--------------|
| Eclipse (for C/C++ developers) | Yes | - | - | - | - |
| AVR Eclipse plugin | No | - | - | - | - |
| Arduino IDE | No | Yes | No | Yes | Yes |
| Atmel AVR toolchain | No | Yes | No | No | Yes |
| Atmel Studio | Not usable | Yes | Yes | No | Yes |
| Mingw tools | No | No | Yes | No | No |

Option 2 – Using Atmel Studio

| Package | GUI for debugging | Compiler and linker | Make tool | AVR Dude uploader | GDB debugger |
|--------------------------------|-------------------|---------------------|-----------|-------------------|--------------|
| Eclipse (for C/C++ developers) | Yes | - | - | - | - |
| AVR Eclipse plugin | No | - | - | - | - |
| Arduino IDE | No | Yes | No | Yes | No |
| Atmel AVR toolchain | No | Yes | No | No | Yes |
| Atmel Studio | Not usable | Yes | Yes | No | Yes |
| Mingw tools | No | No | Yes | No | No |

Option 3 – Without Atmel Studio but with Atmel AVR8 Toolchain

| Package | GUI for debugging | Compiler and linker | Make tool | AVRDude uploader | GDB debugger |
|--------------------------------|-------------------|---------------------|-----------|------------------|--------------|
| Eclipse (for C/C++ developers) | Yes | - | - | - | - |
| AVR Eclipse plugin | No | - | - | - | - |
| Arduino IDE | No | Yes | No | Yes | No |
| Atmel AVR toolchain | No | Yes | No | No | Yes |
| Atmel Studio | Not usable | Yes | Yes | No | Yes |
| Mingw tools | No | No | Yes | No | No |

Note: The fact that so many tools are needed is the result of some unfortunate decisions of the Arduino team which removed the make utility from the Arduino package. Ideally there would be some package with most of the tools together, as WinAVR was before it stopped being updated.

Steps needed to debug your program

These are the general steps on the way to debugging your program for Arduino.

Step 1: Prepare the Eclipse development environment

Step 2: Create program for the Arduino board and upload it to the board

Step 3: Add the debugger code (driver) to your program

Step 4: Connect to the program with the debugger (from Eclipse) and debug it

These steps will allow you to debug your program for the Arduino Uno board written in C/C++ language, but without the Arduino software library.

When this works, there are two more steps:

Step 5: Create program in Eclipse with Arduino functions

Step 6: Enable debugger support in a program with Arduino functions

The following sections will provide detailed instructions on these steps.

Which way to choose

There are three ways described, which may be confusing. Here is some help.

- If you have no preference, use the option 1.
- If you have plenty of disk space and do not mind installing big program you will not use, use the option with Atmel Studio. I think it will be more “future-proof” than Arduino IDE based solution.
- If you do not want to rely on tools provided by Arduino, but want to save disk space, use option with Atmel AVR8 toolchain without Atmel Studio. Use this option also if you encounter problems with running the debugger (avr-gdb), see the next section.

Problems with GDB (avr-gdb) included with Arduino

It seems that the avr-gdb included in newer Arduino IDE packages does not work because of some missing DLLs. In my experiments, I was able to use the avr-gdb from Arduino 1.6.8, but not from 1.6.10 and 1.8.1. In general I can recommend the following procedure:

- Try to set up everything with Arduino IDE
- If the debugging does not work (eclipse reports errors when starting debug session such as “could not get gdb version...”), try to run the avr.gdb.exe directly by double clicking it in your file explorer. If it does not start, you are experiencing the above mentioned problem.
- In this case install the Atmel AVR toolchain for AVR 8-bit. It is only about 15 MB and the avr-gdb from this toolchain works fine.

Note: It is always good idea to **use matching compiler and debugger**. So if you use the avr-gdb from the Atmel AVR toolchain, use also the build tools from this toolchain – set the paths in AVR Eclipse plugin configuration to the Atmel AVR toolchain instead of Arduino IDE paths.

Important limitations of the debugger

One pin must be reserved for the debugger

When debugger is used, one pin must be reserved for its use. It can be any pin with external interrupt function (INT0, INT1, etc..). For Arduino Uno this can be either digital pin 2 or 3 (PD2 or PD3 pin of the MCU). For Mega there are more options. By default, INT0 pin (Uno pin 2, Mega pin 21) is used. To change this, change the value of `AVR8_SWINT_SOURCE` define in avr8-stub.h file.

Tip: for Arduino mega you can use INT6 or INT7 (define AVR8_SWINT_SOURCE 6 or 7). These pins are not connected on the Arduino Mega board so you will not waste any usable pin.

The debugger needs to handle the INTx interrupt which is in conflict with the attachInterrupt function in Arduino software library. Small modification of the Arduino library code is required to build the program. This is described in Step 5 section of this document.

Reason: The debugger needs to generate software interrupts to work. Unfortunately, in the AVR processor there is no dedicated instruction for this and the interrupt must be generated using external interrupt which requires an I/O pin.

Serial communication cannot be used in your program

The Arduino Serial class (or any other library which uses the UART module) cannot be used in your program together with the debugger.

Arduino software library is in conflict with this use of UART by the debugger (to be exact it wants to handle the UART interrupt which the debugger library also needs). It is necessary to exclude the file which implements Serial class from the build in eclipse. Please see Step 5 section for details.

Reason: The debugger needs the UART (serial communication) module to communicate so it cannot be used by the user program. You can output text messages to debugger console using `debug_message` function which is part of the debugger library.

When using flash breakpoints the watchdog cannot be used

The watchdog module is used by the debug driver when it is configured to insert breakpoints into flash memory (as opposed to the default configuration with breakpoints in RAM). So it is not possible to use the watchdog in your application while using the debugger. Arduino library does not use watchdog so this causes no conflicts. If you need to use watchdog in your application, enable the code which works with the watchdog only after the application is debugged and the debugger is removed or disabled, or use the RAM breakpoints configuration.

Configuring project for Arduino Uno vs. Mega

The debugger now supports Arduino Mega board with ATmega1280 and ATmega2560 MCU. The procedures in this document describe configuration for Arduino Uno. For Arduino Mega the following changes apply:

- When creating new project in Eclipse select the proper MCU – ATmega1280 or ATmega2560. The clock speed is always 16000000 (16 MHz).
- When configuring the upload command in AVR eclipse plugin (AVRDude configuration, see section 1.5) use the following settings:
 - For ATmega2560 profile “Wiring” and baud rate 115200.
 - For ATmega1280 profile “Arduino” and baud rate 57600.

Other than this the settings are the same for Mega and Uno. The code in `avr-stub` files uses conditional compilation to adjust to the MCU selected in your project, so there is no change required.

The baudrate for communicating with the debugger is 115200 for ATmega2560 and 57600 for ATmega1280.

Note: For ATmega2560 the debugger does not properly display the call stack if the program size is over 128 kB (50% of flash memory).

Using breakpoints in flash memory

This chapter provides basic information about the optional feature of this debug driver which allows debugging program without affecting its execution speed. Information about setting up the options for using this feature can be found in chapter How to enable breakpoints in flash memory.

The new version of this debugger (as of July 2017) supports writing breakpoints into flash memory. In this document these are called *flash breakpoints* while the other option is called *RAM breakpoints*. Even though these names are not quite correct, I use them throughout this documentation and the source code for the lack of better name.

There are two options how to implement breakpoints in an AVR debug driver:

- Option 1 - store the address at which the program should stop in a variable. Then after executing every instruction of the program compare this variable with the current location of the program (the program counter register, PC). If you find a match, stop there and notify the debugger – let the user know that the program stopped on the breakpoint.
- Option 2 – replace the instruction at the address where the program should stop with a special instruction which causes “jump” into the debug driver so that it can notify the debugger.

In earlier versions of this debug driver only the option 1 was available. The disadvantage of this option is that the program must be stopped after executing every instruction to compare the PC with the addresses of desired breakpoint. This slows down the debugged program considerably. But in fact it is hardly noticeable unless you debug code with quite long busy loops based on a counter.

The advantage of option 2 is that there is no such slowing down. The program stops itself on the breakpoint. The drawback is that it requires replacing the bootloader in your Arduino.

The advantages and disadvantages are summarized below so that you can make your own decision.

It is recommended to start with the RAM breakpoints in all cases.

The reason is that using flash breakpoints requires replacing the bootloader in your Arduino, which is yet one more thing which may go wrong in the rather complicated process of setting up your environment for debugging. So it is better to start the easy way. It is not a detour, it is just taking the road step by step.

Once you are able to debug your program with RAM breakpoints AND if you decide that you can benefit from using the flash breakpoints, take the extra step to enable them in your program.

RAM vs Flash breakpoints – pros and cons

RAM breakpoints

cons

- The program runs slowly when one or more breakpoints are inserted.
It runs perhaps 100 times slower than without breakpoints. In many cases, this makes no

difference, you will not notice anything. But if your program contains busy loop delay which, for example, decrements some variable to 0 to obtain desired delay, such a delay will be stretched by a factor of 100 or more.

- You cannot place a breakpoint into an interrupt service routine (ISR).
The RAM breakpoints use external interrupt, e.g. INTO, whose ISR is executed after every instruction in the main code. No other ISR is executed in this situation. So if there is any breakpoint in your program, no ISRs are executed. With flash breakpoints it is possible to stop the program in an ISR but note that the ISR must be declared as `ISR_NOBLOCK`. This means that the interrupts are enabled while the ISR is executed. This makes it possible for the debugger to interrupt the execution of the ISR when it hits a breakpoint.

pros

- There is no wear of the memory when inserting and removing breakpoints.
See the cons of flash breakpoints for explanation.

Flash Breakpoints

cons

- The flash memory is overwritten often when debugging with flash breakpoints.
The flash memory in the Atmel AVR MCUs used in Arduino should survive about 10 thousand rewrites. When breakpoint is inserted or removed, part of the memory needs to be rewritten. To make things worse breakpoints are inserted and removed not only when you actually insert/remove a breakpoint in the IDE but also automatically when you continue from a breakpoint (the original instruction needs to be restored and executed) and also sometimes when you step through the code the debugger will insert temporary breakpoint, for example to stop the program after stepping over a function. In worst case you, you can expect one write to flash memory for each step/continue click you do in the IDE. This seems scary but it is still usable and similar to using the debugWIRE hardware on-chip debugger module, please see the notes below. You can check the number of writes to flash when debugging, this is described in the section on enabling flash breakpoints.

pros

- The program runs at full speed.
There is no need to stop the program after each instruction to see if it reached a breakpoint. The program will stop itself when breakpoint is encountered. There is small overhead in periodical testing whether the program stopped on a breakpoint but this has no noticeable effect on the speed of the program.
- It is possible to place breakpoints into interrupt service routines (ISR) if the ISR is declared as non-blocking (`ISR_NOBLOCK`) attribute. Note that if you do not declare the ISR as non-blocking, it blocks other interrupts by default. If you place a breakpoint into such an ISR the program will hang on this breakpoint without ever getting back to the debugger. See the

notes below for example code.

Notes

Breakpoints in ISRs

It is only possible to place breakpoints into an ISR if you use flash breakpoints and if you declare the ISR as non-blocking. This is because the debugger uses interrupts internally to detect the situation when the program stops on a breakpoint. If interrupts are disabled (which they are by default while any ISR is executed) the debugger cannot stop the program.

Example of ISR which can be debugged:

```
ISR(TIMER1_COMPA_vect, ISR_NOBLOCK )
{
    // toggle the LED
    PORTB ^= _BV(LED_PIN);
    result += 5;
    if ( result == 10 )
        result = 0;
}
```

Watchdog

You can't use the Watchdog module of the MCU when using flash breakpoints because it is used by the debug driver to periodically check for the situation when the program stops on a breakpoint.

Flash memory wear

To minimize the wear of the flash memory when using flash breakpoints I recommend using the following guidelines (the first two are taken from Atmel documentation for debugWIRE hardware debugging):

1. Try to minimize on the number of breakpoint additions and removals, as each one require a FLASH page to be replaced on the target
2. Try to add or remove a small number of breakpoints at a time, to minimize the number of FLASH page write operations
3. Use only as many breakpoints as really needed. Often you will only need one breakpoint at a time. Consider that the debugger must always update all the breakpoints when the program is run, not just the one which will be hit next – the debugger does not know which one will be hit next.
4. When you no longer need a breakpoint, remove it. This is not to say that you should remove and re-insert a breakpoint each time the program stops on it, but when you know that you will be dealing with other part of the program and the breakpoint will not be needed for some time, remove it. This may seem in conflict with guideline 1, but most of the time breakpoints are inserted and removed automatically when you step through the code. It only takes one write to remove a breakpoint upon your command while this same breakpoint would be unnecessarily removed and inserted automatically every time you let the program run (see guideline 3).

Loading the program through the debugger

Together with the option to write breakpoints to flash there is also new option to load the program into the MCU using the debug driver instead of AVRdude.

This option is not functionally connected with the flash breakpoints, you can use it with RAM breakpoints as well. The thing these options have in common is that they require replacing the bootloader in your Arduino.

If you replace the standard Arduino bootloader with the one provided with this debug driver, you can use the flash breakpoints and program load together or any of these features alone.

Why load the program through the debugger?

Because it is easier and faster to debug your program. Basically, the workflow can be just like this:

- Edit the code
- Click Debug button (or rather expand the Debug button menu and select debug configuration you want to run from the list). The code is built automatically before load.
- Debug the program

If you load the program via AVRdude the workflow is as follows:

- Edit the code
- Build the code
- Upload the code
- Click Debug button (or rather expand the Debug button menu and select debug configuration you want to run from the list).
- Debug the program

Why not to load the program through the debugger?

There are two obstacles.

- You need to replace the bootloader in your Arduino. This can be challenging for some people and you need additional hardware to do this – an ICSP programmer or another Arduino to work as such a programmer.
- When loading through the debugger the flash memory wears faster than when loading through AVRdude. If you do not know about flash memory wear please see the “cons” section for RAM vs Flash breakpoints – pros and cons section. I assume that when uploading via AVRdude the memory is written once. When uploading via the debugger the memory is written twice. So in theory the MCU should survive 10 thousand uploads via AVRdude and only 5 thousand via the debugger. For most people both these numbers are high enough, but you should be aware of this.

1. Step 1: Preparing Eclipse for Arduino development

This section describes how to set up Eclipse to be able to develop programs for Arduino boards with Atmel AVR MCUs. As mentioned above, there is more than one option how to do this. This section covers the easiest one which requires installing Arduino IDE 1.6.5 or later, Eclipse with AVR Eclipse plugin and small subset of MinGW tools.

There are two other options described in the next sections.

1.1 Install Arduino

From <http://www.arduino.cc/en/Main/Software> download the Arduino software. Current version (June 2015) is 1.6.5-r2. You can either download installer or a zip file. This text assumes you use the zip file.

Extract the downloaded zip file into any folder on your computer. The following text assumes you extracted it to c:\programs\arduino-1.6.5-r2.

To start the Arduino IDE, run arduino.exe from the folder. You do not need to run it now.

1.2 Install Eclipse

From <https://eclipse.org/downloads/> download the “Eclipse IDE for C/C++ Developers”. Current version (May 2015) is Luna.

There is no installation needed. You download a zip file which you can extract into any folder on your computer, for example, to c:\programs\eclipse.

Go to the eclipse folder and run eclipse.exe to start the IDE. You may want to create link on your desktop for quick access.

When Eclipse starts, you need to select location for your workspace. This is a folder on your computer where all your projects will be located. Later you can use several workspaces and change the default location but for now I recommend just accepting the default offered by Eclipse and moving on.

1.3 Install AVR Eclipse plugin

Start the Eclipse IDE and in the main menu select Help > Install New Software...

In the Work with box enter this update site address: <http://avr-eclipse.sourceforge.net/updatesite> and press Enter on the keyboard.

After a while the list below will display AVR Eclipse Plugin item. Select it by checking the box next to the AVR Eclipse Plugin name and click the Next button below.

Follow the wizard to install the plugin. It takes quite a while. You will need to agree with license agreement and confirm installing of unsigned plugin. After the installation, accept the offer to restart Eclipse.

TIP: You can find tutorial with pictures on the AVR Eclipse plugin website at:

http://avr-eclipse.sourceforge.net/wiki/index.php/Plugin_Download

1.4 Install Mingw tools

The MinGW tools are needed to obtain the GNU make utility. If you have Atmel Studio 6.x installed on your computer, you can skip this step; you will find make.exe in the [Atmel Studio location]\shellUtils. We will need this path in AVR Eclipse plugin configuration as described later.

To install MinGW:

From <http://www.mingw.org/> follow the Downloads link on the left. This will take you to <http://sourceforge.net/projects/mingw/files/>

Near the top of the page you will find "Looking for the latest version?" line and a link to download.

Download the mingw-get-setup.exe (direct link:

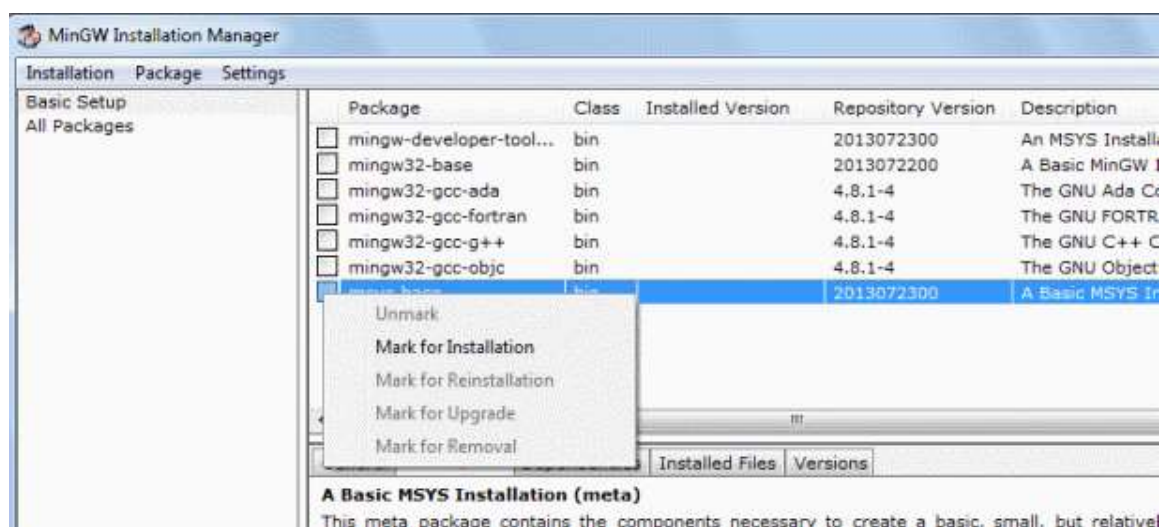
<http://sourceforge.net/projects/mingw/files/latest/download?source=files>).

Run the setup program. In the first screen leave all settings at defaults, change the Installation Directory if you prefer and click Continue.

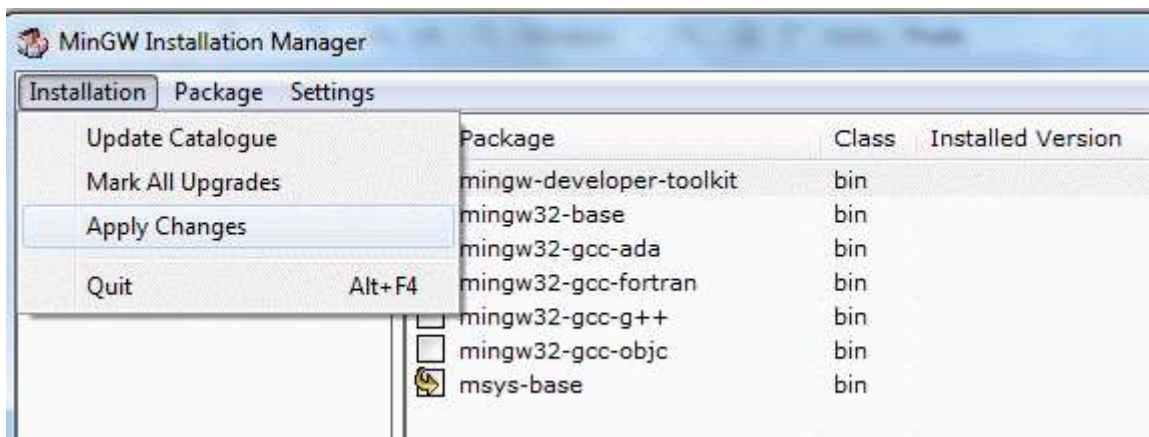
In the next step wait for the download of some files and click Continue.

You should see a MinGW Installation Manager window. In the list of available packages click on the box next to "msys base" (the last item in the list).

From the context menu select Mark for Installation.



From the menu at the top of the window select Installation > Apply Changes.



In the next step click Apply button.

After a while the MinGW tools should be installed. Close the window.

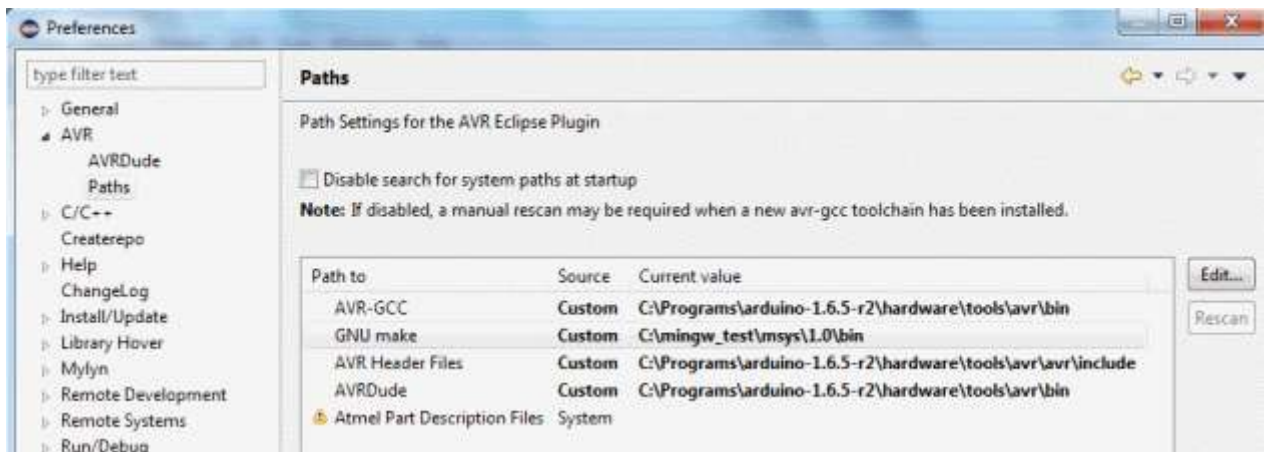
We are now ready to configure the AVR Eclipse plugin.

1.5 Configure the AVR Eclipse plugin

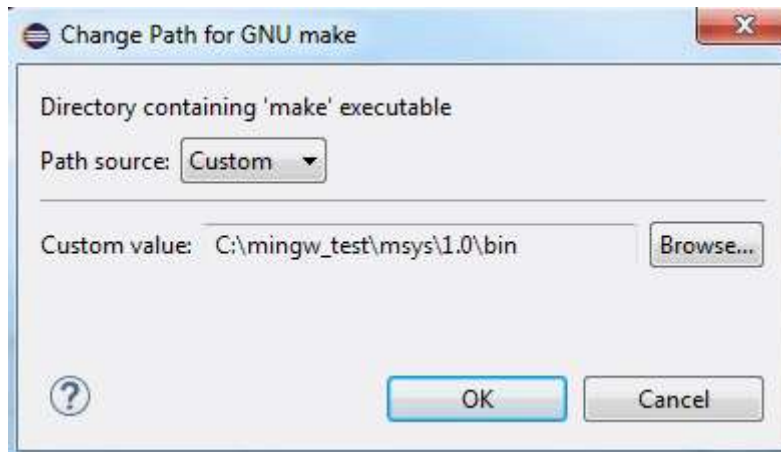
Once the AVR Eclipse plugin is installed, in the Eclipse main menu select Window > Preferences.

In the Preferences window expand AVR > Paths.

Use the Edit button on the right to set the paths as shown in the following picture.



The paths may be different on your system, depending on where you installed the tools. Use the Browse button in the window for path selection and "Custom" Path source; see the picture below.



Here are the paths on my computer:

AVR-GCC: C:\Programs\arduino-1.6.5-r2\hardware\tools\avr\bin

GNU make: C:\mingw_test\msys\1.0\bin

AVR Header Files: C:\Programs\arduino-1.6.5-r2\hardware\tools\avr\avr\include

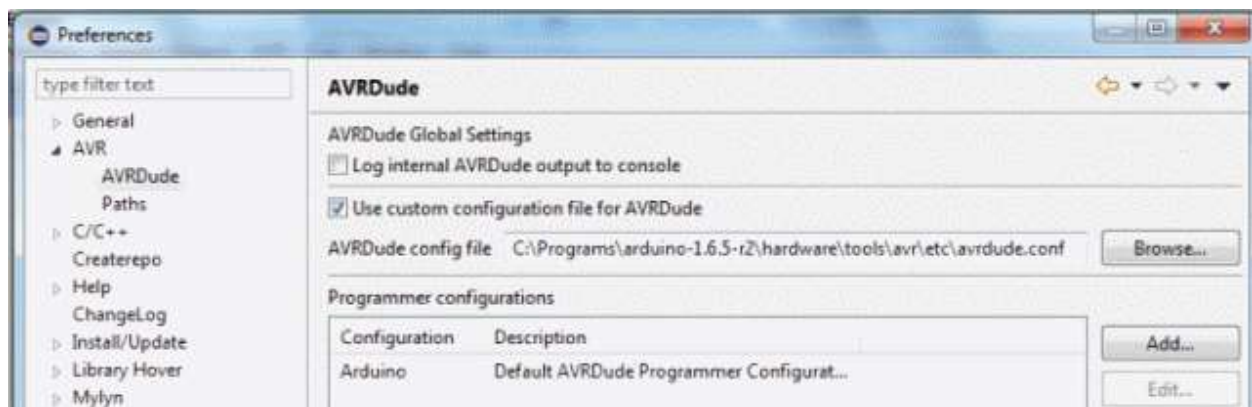
AVRDude: C:\Programs\arduino-1.6.5-r2\hardware\tools\avr\bin

Note that instead of the tools from Arduino installation shown here, you can also configure the plugin to use the tools from Atmel Toolchain, see the alternative setups below for more information.

Now select the AVRDude category on the left.

Check the box “Use custom configuration file for AVRDude”.

In “AVRDude config file” box browse to the path of this file in your Arduino installation. Here is how it looks:



The path is, for example, C:\Programs\arduino-1.6.5-r2\hardware\tools\avr\etc\avrdude.conf.

Close the preferences window by clicking the OK button.

Note: It seems closing the Preferences window is required to apply the changes. Without this, the next step, adding the programmer, fails with error that AVRDUDE cannot find its configuration file "".

Open again the Preferences from Window menu.

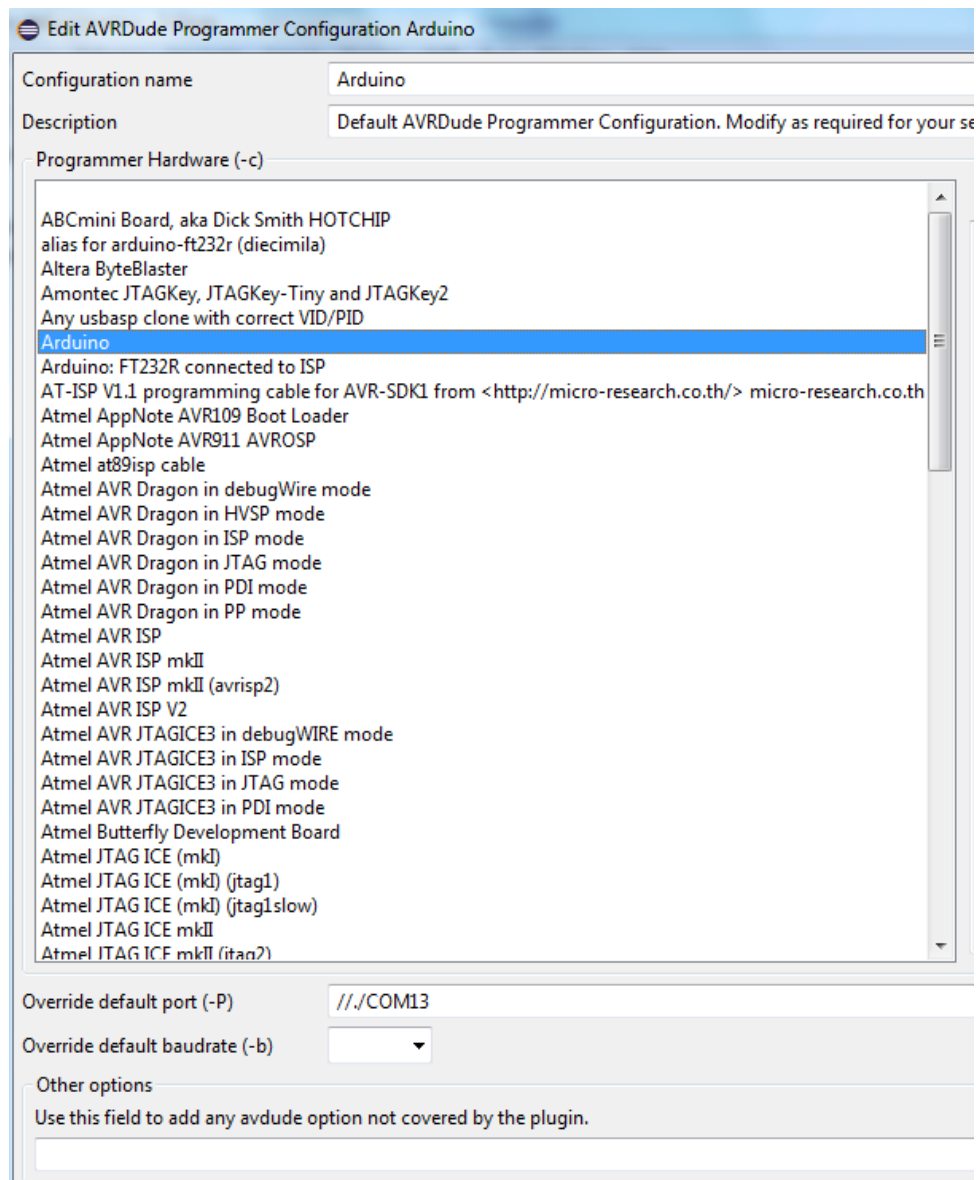
Select AVR > AVRDUDE.

Click the Add button on the right.

In the window which opens, select Arduino from the "Programmer Hardware" list.

Enter some name in the Configuration name field above the list, for example, Arduino.

Enter the serial port to which your Arduino is connected into the "Override default port" box below the list. Note that the port name must be written like this on Windows: "//./COM13". See the picture below.



Close the window with OK and then close the Preferences window also.

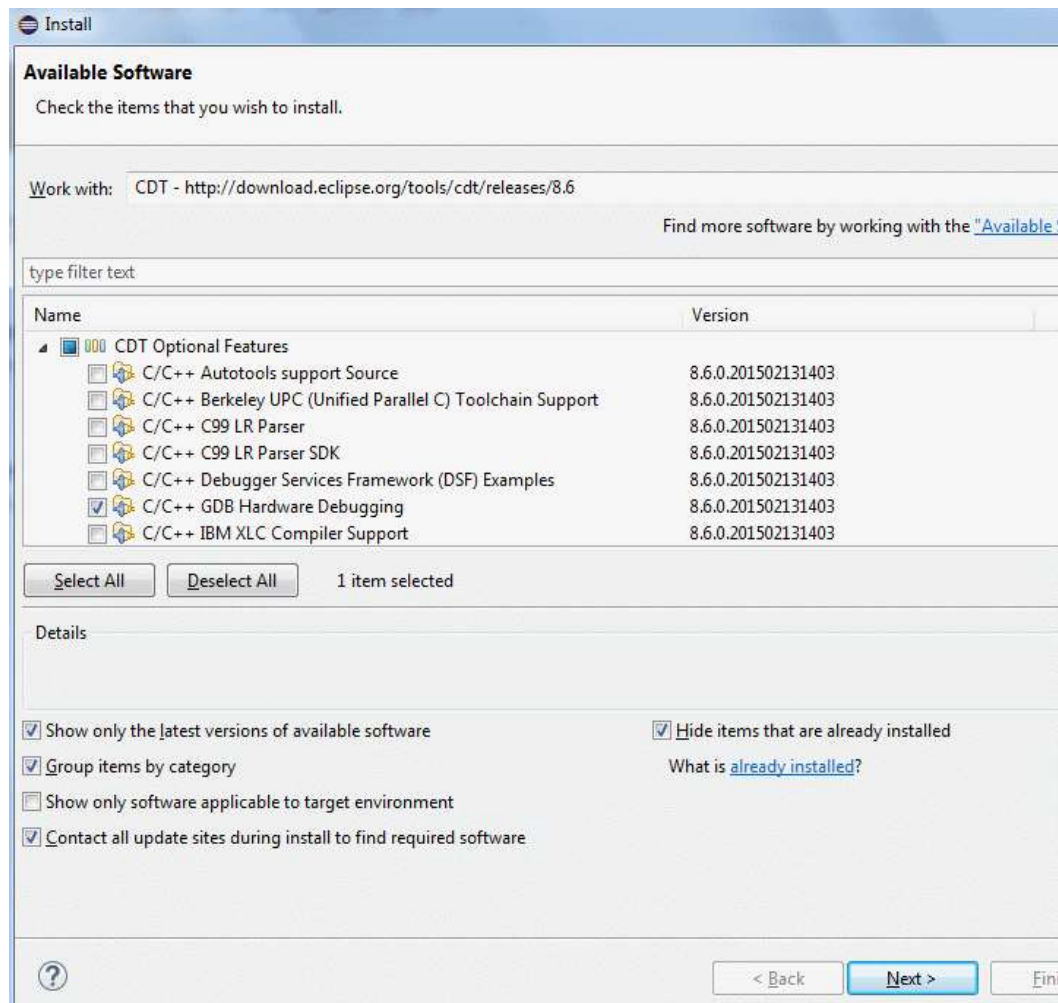
1.6 Install GDB Hardware Debugging launch configuration into Eclipse

In Eclipse go to menu Help > Install New Software...

In the “Work with” box enter this update site address and press the Enter key:

<http://download.eclipse.org/tools/cdt/releases/8.6>

After a while the list below will display some items. Expand the CDT Optional Features and select the C/C++ GDB Hardware Debugging.



Follow the wizard to install this feature and restart Eclipse when prompted to finish the installation.

Your development environment is now ready. You can continue with creating your first program as described in section “Step 2: Create your first project for the Arduino board” below.

1.7 Notes about the tools

If the above steps seem too complicated to you, you are not alone. Unfortunately, this is the simplest setup I could figure out. If you find simpler setup, let me know. There are several unfavorable factors, which caused this situation:

- The WinAVR toolchain seems no longer updated, so it cannot be used as the base for building AVR projects in Eclipse.
- Atmel AVR toolchain does not contain make utility, so make must be obtained separately. If you install Atmel Studio, the make is present there in the shellUtils directory. If you do not want to install Atmel Studio, you can use MinGW package or Cygwin.
- Arduino in recent versions does not include the make. From 1.6.5 it again contains avr-gdb, which can be used instead of the one from Atmel Toolchain.

Alternative setup with Atmel Studio (Option 2)

This section describes alternative way of setting up your development environment. The difference compared to the first way is that we do install Atmel Studio to obtain the build and debug tools rather than relying on the tools provided with Arduino IDE. This option requires more disk space (Atmel Studio is large) but it may be more stable and more up-to-date as the Atmel Studio and Atmel Toolchain are professional tools, unlike the Arduino IDE. Only the differences are described here. Please refer to the previous chapter for the other steps.

Difference(s) compared to option 1:

- Do not install MinGW tools (skip that step) and instead install Atmel Studio. All the other steps remain the same.
- For configuration of the AVR Eclipse plugin look at the section below rather than the one included with option 1.

1.2 Install Atmel Studio

From <http://www.atmel.com/tools/atmelstudio.aspx> download Atmel Studio. Current version (May 2015) is 6.2.

Run the installer and install the program.

When configuring the AVR Eclipse plugin (described in next sections), use the paths to build tools pointing to Atmel toolchain instead of into Arduino folder.

Alternative setup without Atmel Studio but with Atmel AVR8 Toolchain (Option 3)

This section describes alternative way of setting up your development environment without using the Arduino build tools. But note that you still need to have Arduino software! The difference is just in the setup of the build tools in AVR Eclipse plugin (described in next sections) – we do not point the plugin to tools in Arduino folder but rather into the Atmel Toolchain folder.

Difference(s) compared to option 1:

- Install all the tools as in option 1 plus install the Atmel AVR Toolchain.
- For configuration of the AVR Eclipse plugin look at the section below rather than the one included with option 1.

Install Atmel AVR Toolchain

This is needed to have the build tools and also the GDB debugger (avr-gdb.exe).

Note 1: If you have Atmel Studio installed on your computer, you will already have the AVR Toolchain installed. You can find the toolchain in: c:\Program Files\Atmel\Atmel Toolchain\AVR8 GCC. You also do not need to install MinGW tools, because you can use the Make utility found in [Atmel Studio location]\shellUtils instead of the one from MinGW tools.

Note 2: You can also use other AVR toolchain (AVR-GCC) instead of the one provided by Atmel, but make sure it contains current version of the GDB debugger (avr-gdb). Popular WinAVR will probably not work because it seems it is not updated for long time.

To download the Atmel AVR Toolchain:

Go to <http://www.atmel.com/tools/atmelavrtoolchainforwindows.aspx>.

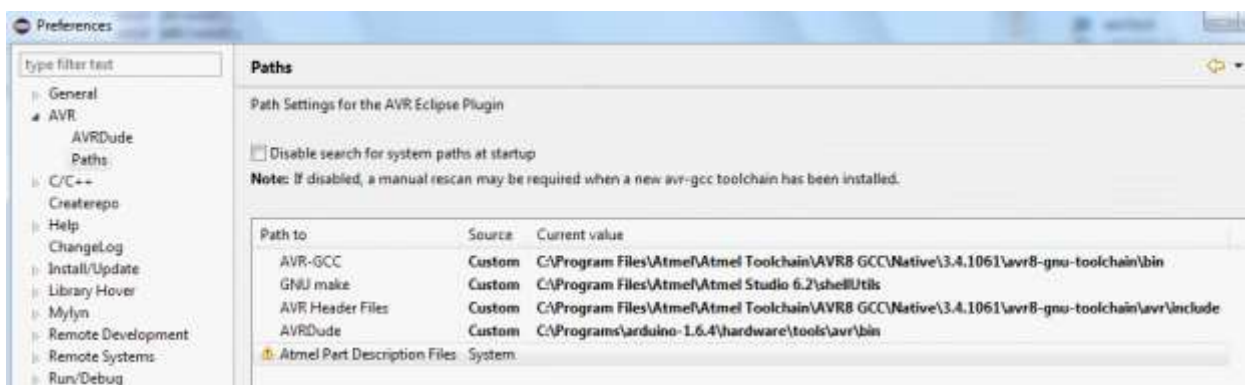
Download the package Atmel AVR 8-bit Toolchain 3.4.5 – Windows.

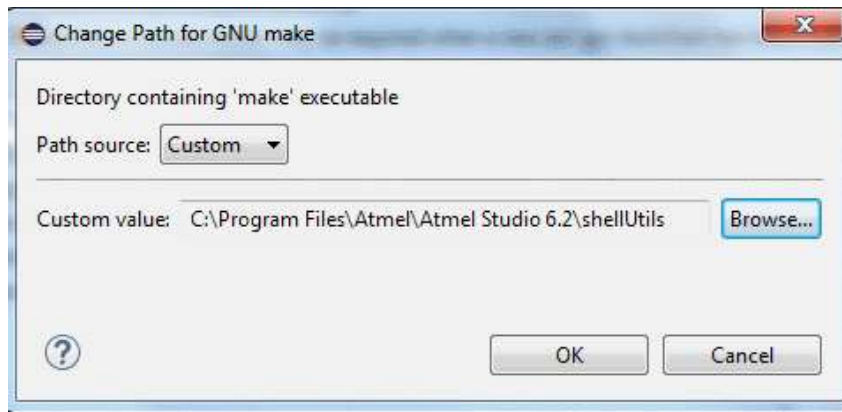
Run the installer and install the toolchain. The following text assumes you install it into the default folder: c:\Program Files\Atmel\Atmel Toolchain\AVR8 GCC.

Configuration of the AVR Eclipse plugin with Atmel Toolchain tools

In the pictures below you can see the AVR Eclipse plugin configured with the GNU make tool from Atmel Studio and the other paths pointing to Atmel AVR8 Toolchain instead of the Arduino folders.

Use this as a reference for setups based on Atmel Studio or Atmel Toolchain.





Here are examples of the paths:

AVR-GCC: C:\Program Files\Atmel\Atmel Toolchain\AVR8 GCC\Native\3.4.1061\avr8-gnu-toolchain\bin

GNU make: C:\Program Files\Atmel\Atmel Studio 6.2\shellUtils

AVR Header Files: C:\Program Files\Atmel\Atmel Toolchain\AVR8 GCC\Native\3.4.1061\avr8-gnu-toolchain\avr\include

AVRDude: C:\Programs\arduino-1.6.5-r2\hardware\tools\avr\bin

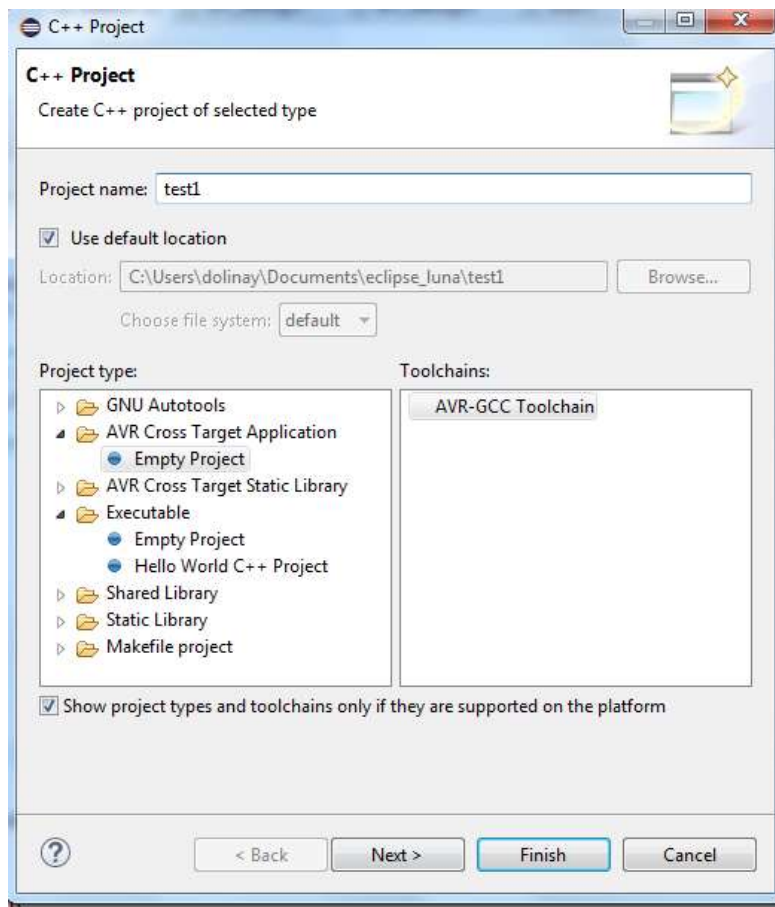
2. Step 2: Create your first project for the Arduino board

This section describes how to create project in Eclipse which will produce a program that you can upload to your Arduino Uno board. The program is written in “plain” C++ language; it does not use the Arduino MCU framework.

In Eclipse select New > C++ Project.

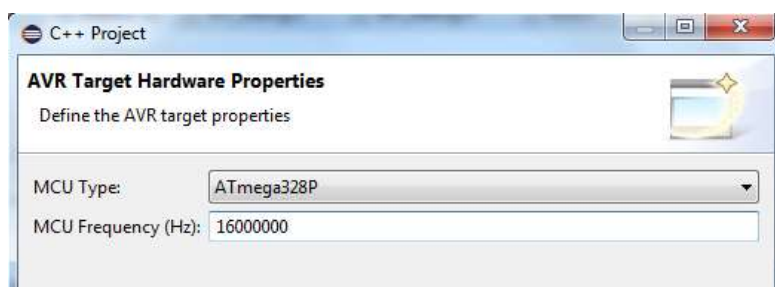
Enter a name for the project, for example, “test1”.

Select AVR Cross Target application > Empty project.



In the next step leave everything as offered (this will create Debug and Release configuration) for the project.

In the next step select the MCU Type: ATmega328P and MCU Frequency (Hz): 16000000.

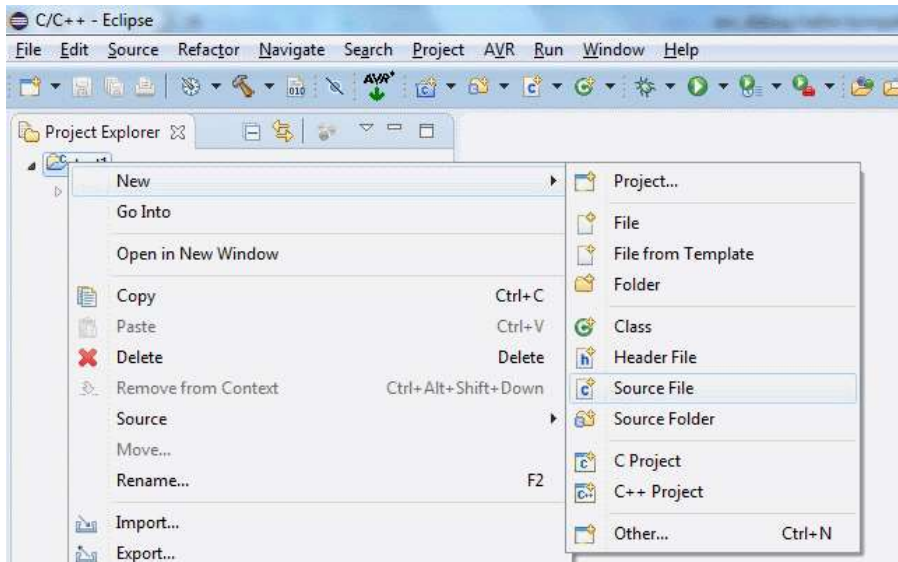


Click Finish to create the project.

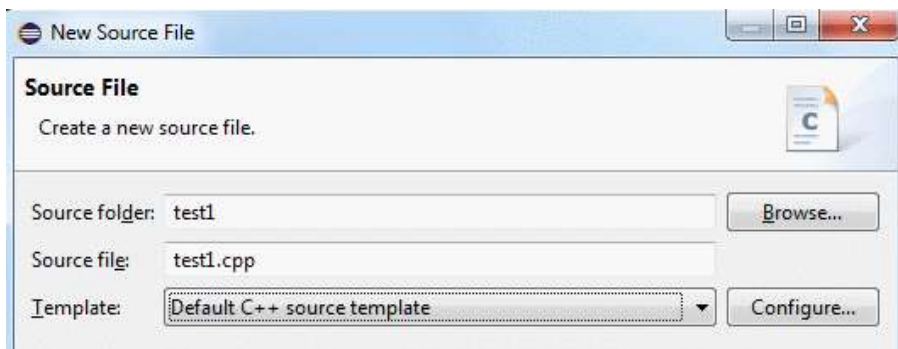
Now create main source file (.cpp) in the project:

Close the Welcome screen if you haven't closed it yet. Now you should see Project Explorer window on the left and the new project "test1" in it.

Right-click the project in Project Explorer and select New > Source File from the context menu.



In the New Source File window enter the name of the file, for example, use the same name as your project, "test1" with a .cpp extension.



Click Finish to create the file. It should appear under the project item in the Project Explorer on the left and also open in the editor in the right window.

Copy the following code into the file you've just created.


```

#include <avr/io.h>
#include <util/delay.h>
#include <avr/interrupt.h>

int main(void)
{
    DDRB |= _BV(5); // pin PB5 to output (LED)
    sei();           // enable interrupts
    while(1)
    {
        PORTB |= _BV(5); // LED on
        _delay_ms(100);
        PORTB &= ~_BV(5); // LED off
        _delay_ms(100);
    }
    return 0;
}

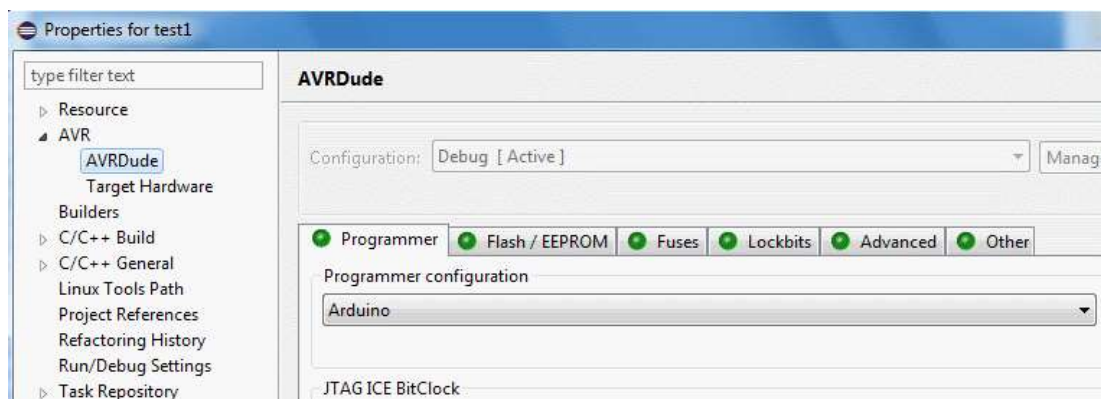
```

Save the file (Ctrl + S).

TIP: I recommend enabling automatic save before build in Window > Preferences > General > Workspace: "Save automatically before build". Without this you will often forget to save the changes after modifying the code and will be actually building the old version, without these changes.

Right-click the project in the Project Explorer and select Properties from the context menu. You can also press Alt + Enter to open the Properties window.

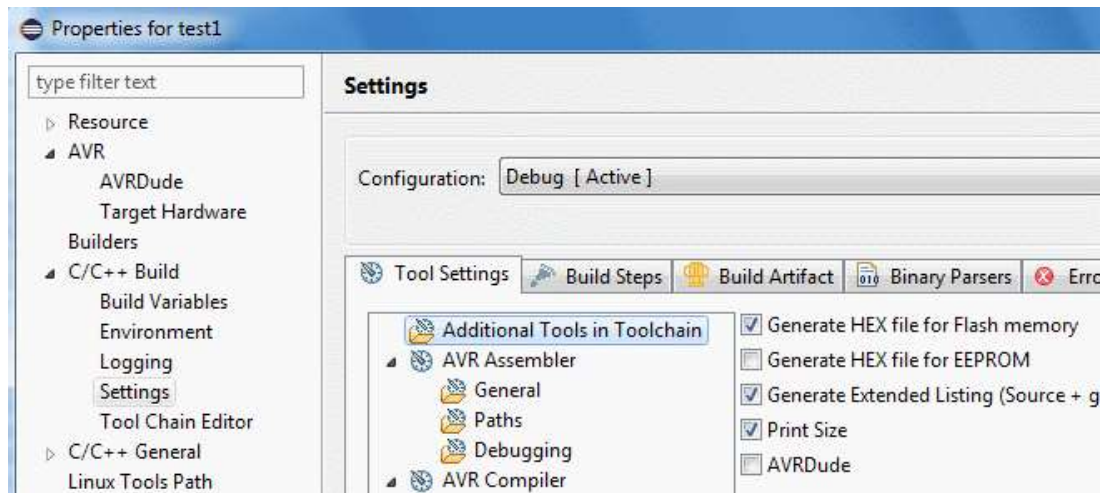
In the left part of the Properties window select AVR > AVRDude. On the Programmer tab in Programmer configuration select Arduino. This is the programmer configuration we created earlier, when configuring the AVR Eclipse plugin.



Still in the Properties window expand the C/C++ Build > Settings.

In the right-side window with sub-categories select "Additional Tools in Toolchain" category.

Check the "Generate HEX file for Flash memory" box.



Close the Preferences window with OK button.

To build the project:

Right-click the project and select Build Project from the context menu. You can also click the hammer icon in the toolbar.

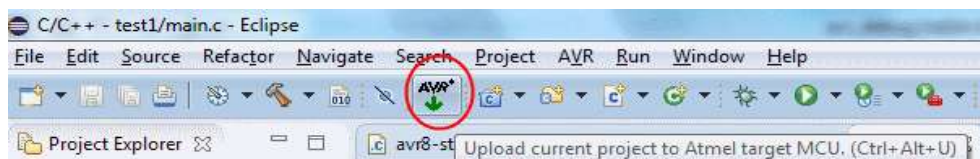
The project should build without errors. Check the Console tab in the bottom part of the Eclipse IDE for build messages. A warning about compiler optimizations from delay.h is OK for now.

To upload the program to Arduino board:

Connect your Arduino board to the computer if not already connected.

Click the AVR icon in the toolbar.

This will upload your program to the board. Check the result in the Console window. There will be some messages from AVRDUDE. It should finish with “avrdude done. Thank you.”



You should now see that the LED on your Arduino is blinking fast (100 ms on, 100 ms off). This means our program is running.

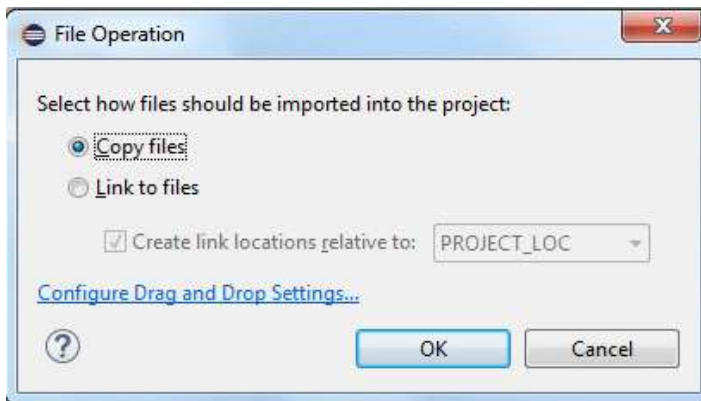
If you get error messages such as “port is blocked” you probably have wrong COM port number in the AVR Eclipse plugin configuration. Go to Window > Preferences > AVR > AVRDUDE. In the “Programmer configurations” list select your Arduino item and click Edit. Make sure the number of COM port (for example //./COM15) is correct. You can find this number either in Arduino IDE or in Hardware manager of your computer.

3. Step 3: Add debugger support to your program

This section describes how to add support for the debugger to the project and how to work with the debugger. It assumes that you have set up your Eclipse with the AVR Eclipse plugin to be able to build programs for Arduino and that you have created a project in Eclipse which you can build and upload to your Arduino board.

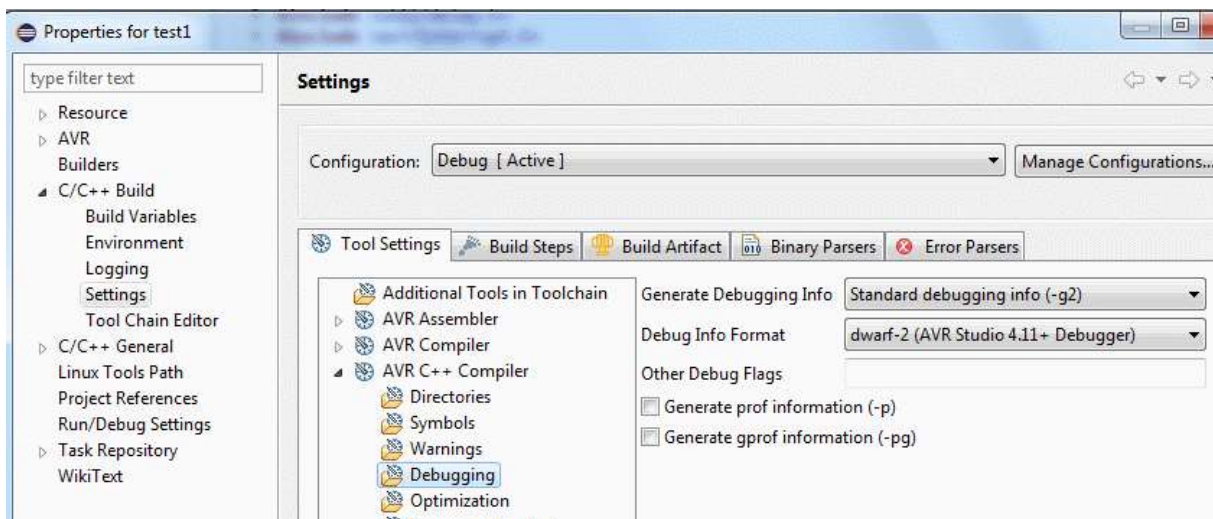
Add **avr8-stub.c** and **avr8-stub.h** files into your project. These files are located in the [Arduino debugger]\avr8-stub folder. You can drag the files from your file manager and drop them on the project “test1” in the Project Explorer view in Eclipse. Select Copy files option in the File Operation window which appears after dropping the files.

If you want to use flash breakpoints, add also the files **app_api.h** and **app_api.c** from the same location.



Open Properties of your project (Alt + Enter) and go to C/C++ Build > Settings.

Select AVR C++ Compiler > Debugging. In the “**Debug Info format**” select dwarf-2.



Do the same for the AVR C Compiler. It is not necessary now but can come in handy later when we also have some .c files in the project.

Close the Preferences window with OK.

Replace the program with the following one:

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include "avr8-stub.h"

int cnt = 0;
int main(void)
{
    debug_init();
    DDRB |= _BV(5); // pin PB5 to output (LED)
    sei();           // enable interrupts
    while(1)
    {
        PORTB |= _BV(5); // LED on
        cnt++;
        PORTB &= ~_BV(5); // LED off
        cnt++;
    }
    return 0;
}
```

Note these changes:

- Included the header file for the debug driver (#include "avr8-stub.h")
- Added call to function debug_init(); to initialize the debug driver.
- Added global variable cnt, so that we have something to inspect in the debugger
- Removed delays (_delay_ms()).

Build your project.

Connect your Arduino board.

Click the AVR icon in the toolbar. In the Eclipse console window you should see how your program is uploaded, ending with "avrdude done. Thank you."

Now the program is uploaded in the microcontroller and running. The LED cannot be seen blinking because the speed is too fast. We will see it turning on and off when debugging.

We now need to create Debug configuration in Eclipse to be able to connect to the program and debug it. This is covered in the next section.

Summary of the important steps to add the debugger support to your program

- Add avr8-stub.c and avr8-stub.h files into your project.
- Add #include "avr8-stub.h" into your source file.
- Call debug_init() somewhere at the beginning of your main function.

- Enable interrupts by calling sei().
- Optionally, call function breakpoint() at the point(s) where the program should stop. You can also break the program when you connect to it from the debugger.

Alternative, more portable way for adding the debugger support

The method for adding the debugger files into your project described above is simple, but not the best one for advanced users. For example, if the debug driver is updated and you download new version, you would have to replace all the avr8-stub.c and avr8-stub.h files in all projects which use it to update the driver in these projects.

Recommended method for more advanced users is as follows:

In the Eclipse main menu select Window > Preferences.

In the Preferences window go to General > Workspace > Linked Resources.

In the right-side part of the window create new Path variable using the New button. Name it, for example, AVR8_STUB_PATH. Use the Folder... button in the New Variable window to point the variable to the location of the debug driver files on your system. For example, c:\avr_debug\avr8-stub.

Close the Preferences window.

Right-click your project in Project Explorer and select New > Folder from the context menu. New Folder window will open.

In the Folder name box enter avr8-stub.

Expand the Advanced options.

Select "Link to alternate location (Linked Folder)" option.

Click the Variables button and select the AVR8_STUB_PATH variable which we've created earlier.

Click Finish. A folder avr8-stub should now appear under your project.

Go to preferences for your project (Alt + Enter or right-click the project and select Properties).

Expand C/C++ Build > Settings category.

At the top of the window, in "Configuration" select [All configurations].

In the AVR C++ Compiler > Directories add the following path:

"\${workspace_loc}/\${ProjName}/avr8-stub".

You can either copy-paste it from here or use the Workspace button in the Add directory path window and select your project > avr8-stub folder. The result should be the same. This will add the avr8-stub folder into the search path of the compiler so that the compiler can find the header file(s) located in this folder.

Do the same procedure also for the directories of the C compiler in AVR C Compiler > Directories.

Your project should now build without error. Do not forget to enable the HEX file output and select the programmer for the project as described in the chapter about creating your first project for the Arduino board above (if you haven't done it yet).

This method has several advantages:

- If you update the debug driver, you just need to update it in the original location and all the projects will automatically use the new version.
- If you move the location of the debug driver, you just need to update the value of the `AVR8_STUB_PATH` variable and all projects will still build correctly.
- If you move the project itself, for example, to another computer, you will just need to create or update the `AVR8_STUB_PATH` variable so that it points to the correct location of the debug driver.

4. Step 4: Connect to your program with the debugger

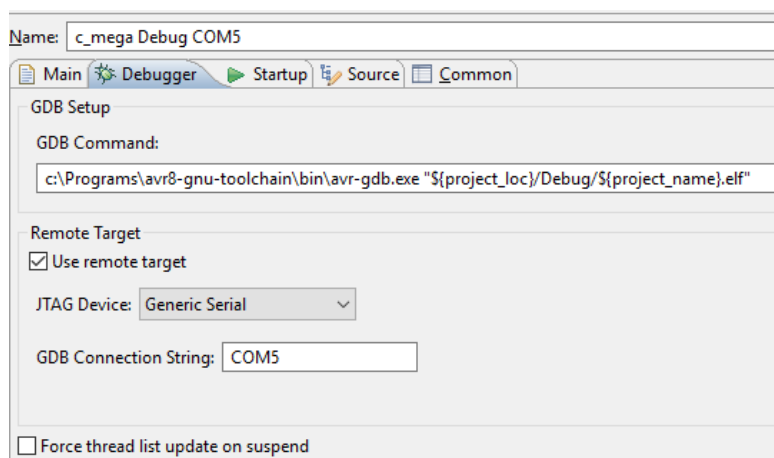
This section describes how to create the debug configuration in Eclipse to be able to debug the program in Arduino. It assumes that the program running in Arduino was built with the debug driver as described in the previous section.

Important note on the TCP-Serial proxy

The procedure below assumes use of a program which converts TCP/IP communication from the IDE to serial communication used by the debugger. This was the only option for Windows at the time of first release of this debugger. It seems with some boards (USB drivers) and especially on Window 10 this convertor is not necessary and the debugging will work directly over serial line. I recommend the following procedure:

- If you are using Linux, just use direct connection to serial line (e.g. to /dev/ttyACM0)
- On Windows, first set up the debug configuration with direct serial connection
- If you are able to debug your program, you are done.
- If it does not work, use the TCP to Serial proxy as described below.

To use direct serial connection, select “Generic Serial” in the JTAG Device field in debug configuration, see the picture below.

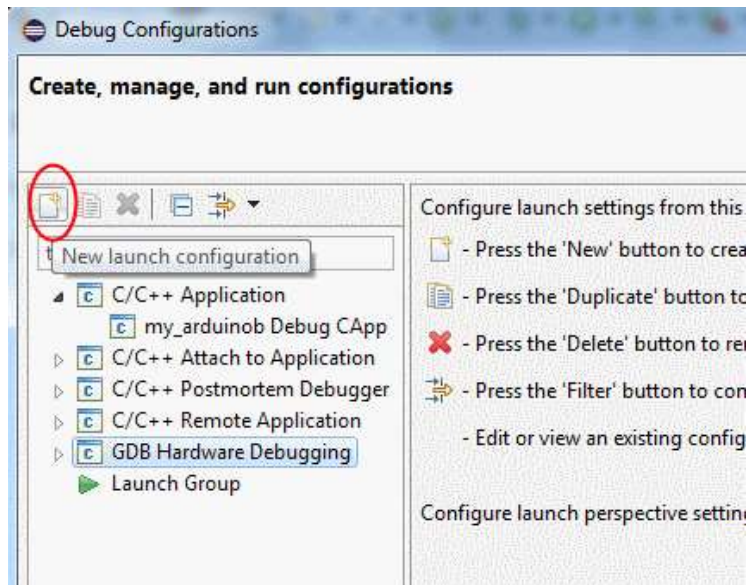


Note: if you get errors “COM x. No such file or directory” try to enter the COM port name in this format: **\\.\COM10** (example for COM 10). It seems that for higher port numbers the simple name without the backslashes does not work.

Step-by-step instructions

Right-click your project in the Project Explorer in Eclipse. From the context menu select Debug As > Debug configurations...

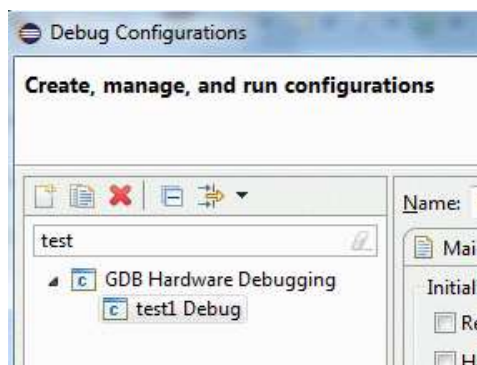
In the Debug Configurations window select GDB Hardware debugging item and click the New launch configuration button in upper left corner of the window.



This will create new launch configuration under the GDB Hardware debugging item.

Note: If you do not see the GDB Hardware Debugging item in the list, you probably haven't installed this type of configuration. Please refer to the chapter about setting up your development environment.

Select the new configuration under GDB Hardware debugging to configure its properties:



In the Debugger tab in the "GDB command" field enter (or browse to) the path to the GDB executable `avr-gdb.exe`, followed by the path to your "executable" file (.elf).

The path to your file can use eclipse variable to refer to the project executable. Here is my example for this field:

```
c:\Programs\arduino-1.6.5-r2\hardware\tools\avr\bin\avr-gdb.exe
"${project_loc}/Debug/${project_name}.elf"
```

Or if you use the Atmel Toolchain build tools instead of those from Arduino package.

```
C:\Program Files\Atmel\Atmel Toolchain\AVR8 GCC\Native\3.4.1061\avr8-gnu-toolchain\bin\avr-
gdb.exe "${project_loc}/Debug/${project_name}.elf".
```


TIP: Use the Browse button to select the avr-gdb.exe. Then enter space after the path into the edit box and then paste the following line: "\${project_loc}/Debug/\${project_name}.elf".

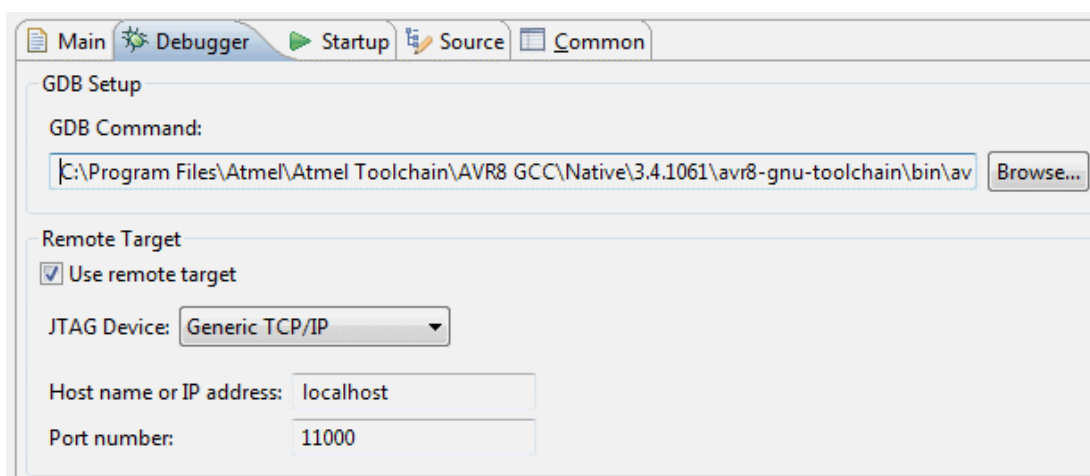
Check the "Use remote target" box.

Note: The following steps describe the connection via TCP-to-Serial converter. It may be possible and easier to use direct serial connection, please see "Important note on the TCP-Serial proxy" section above.

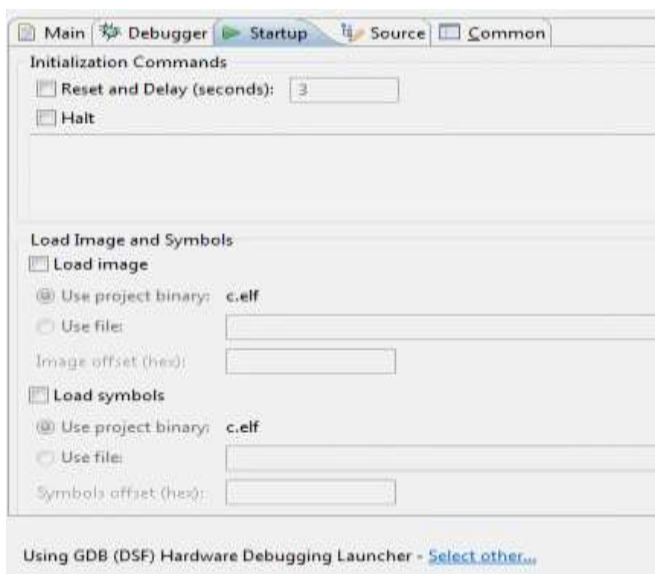
In "JTAG device" select "Generic TCP/IP" and enter:

Host name or IP address: localhost

Port number: 11000.



Switch to Startup tab. Uncheck (clear) all the boxes (Reset and Delay, Halt, Load image and Load symbols).



Click Apply button to save the changes, but do not close the Debug configurations window yet.

Now use your file manager to open the folder where the Arduino debugger package is located. For example, c:\avr_debug. You should see a start_proxy.bat file in this folder.

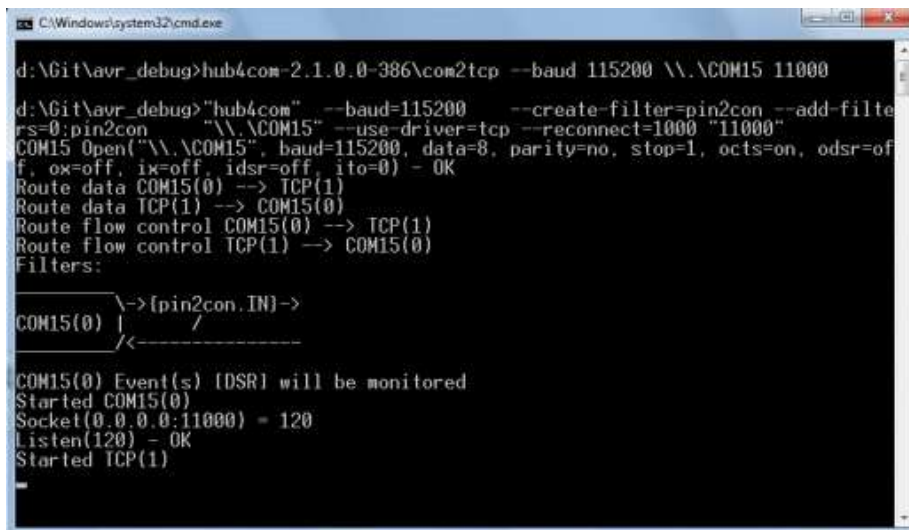
Open the start_proxy.bat file in Notepad or other text editor. Change the number of the COM port in this file. There is this line:

```
hub4com-2.1.0.0-386\com2tcp --baud 115200 \\.\COM15 11000
```

Just change the number after COM from 15 to the number of your COM port to which the Arduino board is connected. If you prefer, you can also use the com2tcp program directly; use the command in this .bat file as an example.

Save and close the start_proxy.bat file.

Run the bat file. This will start convertor between TCP/IP port used by the GDB (as configured above) and the serial port to which your Arduino is connected. You should see a console window with some information. This window will be opened all the time during the debugging.



```
C:\Windows\system32\cmd.exe
d:\Git\avr_debug>hub4com-2.1.0.0-386\com2tcp --baud 115200 \\.\COM15 11000
d:\Git\avr_debug>"hub4com" --baud=115200 --create-filter=pin2con --add-filter=rs=0:pin2con "\\.\COM15" --use-driver=tcp --reconnect=1000 "11000"
COM15 Open("\\.\COM15", baud=115200, data=8, parity=no, stop=1, octs=on, odsr=off, ox=off, ix=off, idsr=off, ito=0) - OK
Route data COM15(0) --> TCP(1)
Route data TCP(1) --> COM15(0)
Route flow control COM15(0) --> TCP(1)
Route flow control TCP(1) --> COM15(0)
Filters:
COM15(0) \-> [pin2con.IN]->
          /
          /<-----
COM15(0) Event(s) [DSR] will be monitored
Started COM15(0)
Socket(0.0.0.0:11000) = 120
Listen(120) - OK
Started TCP(1)
```

Note: You may want to configure your firewall to block access to the port 11000 from other computers. You can also change the port number both in the .bat file and in the Eclipse debug configuration.

Now return to Eclipse. We still have the debug configurations window opened.

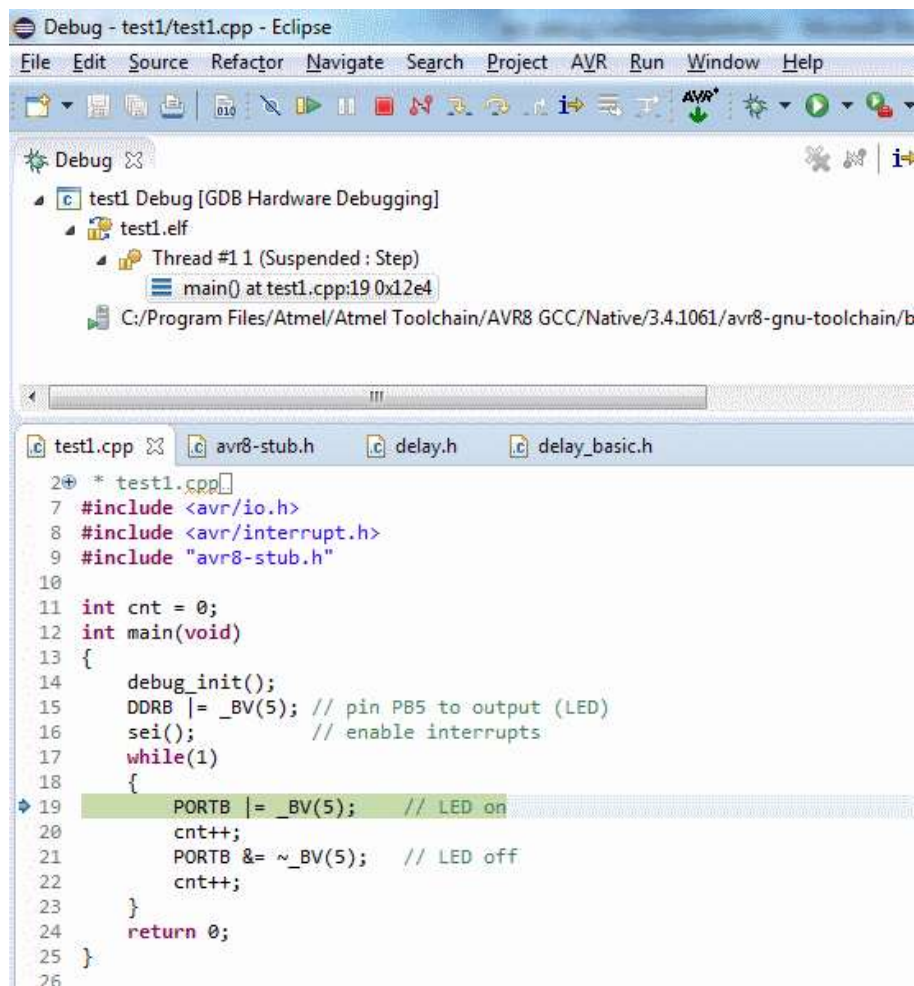
Click the Debug button at the bottom of this window.

After some time, Eclipse should ask you if you want to switch to debug view (Perspective). Answer Yes.

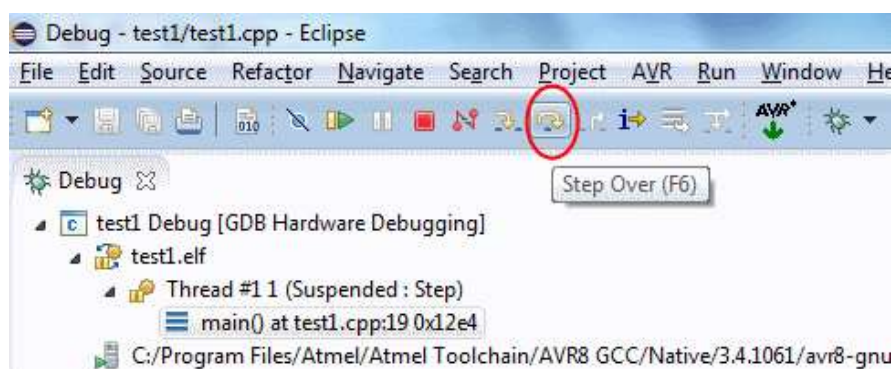
TIP: Switch between the Debug and C/C++ perspective using the buttons in upper right corner of the window. When you finish debugging, click the C/C++ button to reorganize the windows for coding. When you start debugging, Eclipse will automatically switch to window arrangement suitable for debugging.

You should see the program stopped in debugger, as in the following picture.

The point at which the program stops is random; the program was just stopped at any point in its run when the debugger connected.



You can now single step the program using the **Step over** button in the toolbar. This will advance the program by one line. Note that when you step over the `PORTB |= _BV(5);` line, the LED on Arduino board will turn on.



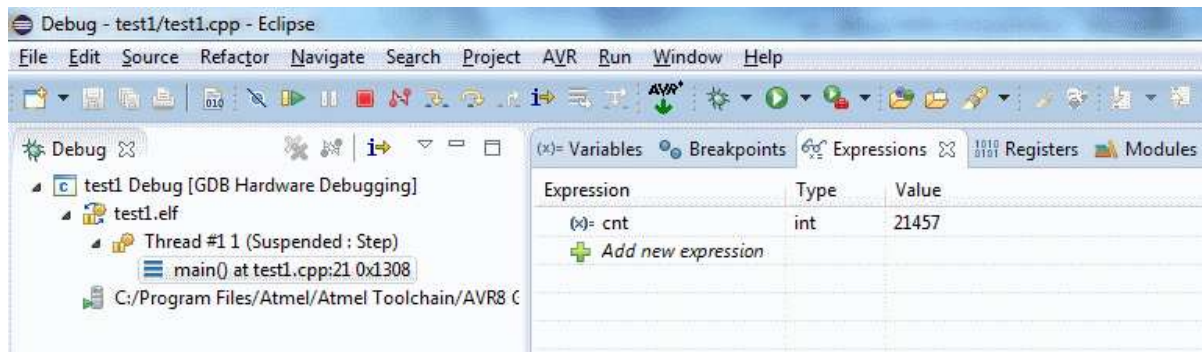
We can also look at the value of the “cnt” variable. Just hover the cursor at the `cnt++;` code and the value will be displayed. Don’t be surprised the value is high, remember, we interrupted the program at random moment.

We can also change the value of the cnt variable:

In the upper right corner switch to the Expressions tab. If it is not open, go to the main Eclipse menu Window > Show View and select Expressions. This will open the Expressions tab.

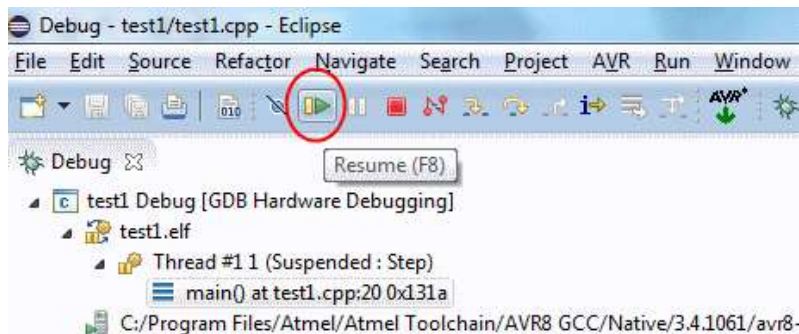
Click at the Add new expression in the Expression tab. Enter “cnt” and press Enter.

You should now see the value of the cnt variable there, as in the following picture.



Click at the value and enter 0. Then press Enter. The cnt variable should now have value 0. If you step through the code, you can see how the value increases with every cnt++; command.

You can also let the program run at full speed. Click Resume button in the toolbar to do so.



Interrupt the program at any time using the Suspend button (pause) which is just next to the Resume button.

Breakpoints

You can also stop the program at any line. To do so, right click at the line where you want the program to stop. Make sure you click into the gray left margin, not into the code.

From the context menu select Toggle breakpoints. A blue point will appear. To remove a breakpoint, use the same procedure.

Now resume the program (click **Resume** button). It will stop at the breakpoint. You can then inspect the variable(s), step or resume again.

To end the debug session, click the **Terminate** button (red square) in the toolbar.

If you plan to modify your program, make sure you rebuild and upload it to the board before debugging again. For this, the COM to TCP proxy server must be stopped so that the serial port is free for the upload. Here is the procedure for modifying the program:

- Edit and build your program
- Close the console window with COM to TCP proxy server, if still opened.
- Upload the program using the AVR button in Eclipse
- Start the COM to TCP server (use the start_proxy.bat file)
- Start the debug in Eclipse (Expand the Debug button in the toolbar and select your debug configuration, for example “test1 Debug”).

Note about the delay function

Earlier, we removed the `_delay_ms` function from the program, because it would make the debugging time-consuming. This kind of delay with busy loops is affected very much by the breakpoints in RAM used by the debugger; the program runs much slower when there is any breakpoint set or when stepping over a line of code. The reason is explained in the description of the principles of the debug driver. In the next section, when we enable the Arduino functions, we will see that the Arduino delay which is based on timer will perform much better and it is quite comfortable to step through the code even with delay.

Troubleshooting

If you encounter an error right after clicking the debug button with “gdb –version”, select your project in the Project Explorer and try again. Alternatively, instead of using the Debug button in toolbar, right-click the project and select Debug As > Debug configurations. Select the debug configuration and click Debug.

If you encounter an error later during the startup of the debug session, make sure the COM to TCP proxy server is running and that your program calls the `debug_init()` function.

Please see also the Troubleshooting problems with debugging later in this document for more tips.

Exercise – more complex program

Here is another program which contains also a function and local variables. Try to build, upload and debug this program as an exercise.

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include "avr8-stub.h"

int cnt = 0;
int function(int a);
```

```

int main(void)
{
    debug_init();
    DDRB |= _BV(5); // pin PB5 to output (LED)
    sei();           // enable interrupts
    breakpoint();
    while(1)
    {
        PORTB |= _BV(5); // LED on
        cnt++;
        cnt = function(cnt);
        PORTB &= ~_BV(5); // LED off
        cnt++;
    }
    return 0;
}

int function(int a)
{
    int n;
    n = 2*a;
    return n;
}

```

Things to note

We have added call to `breakpoint()` function before the `while(1)` cycle. This will stop the program; it will wait for us to connect with the debugger instead of running freely until we connect. Then we can step or resume.

If you step through the code in the `while(1)` cycle with Step Over, you will never get into the `function()`. If you use the step into function you should eventually get there after several steps. Easier way to get into the function is to set a breakpoint inside it (on the `n = 2*a;` line). Then Resume the program and it will stop inside the function.

The behavior of the program when stepping through is sometimes different than expected. This is caused by compiler optimizations which reorganize the code or completely skip some commands. By default the project is built with “No optimizations(O0)” option, but that does not mean that the compiler will exactly follow the order of the code as you write it. Try to experiment with “-Og” option. This option is not available in the selection list, but you can enter it into the Other Optimization Flags box. Optimizations are set in project Properties > C/C++ Build > AVR C++ Compiler > Optimization. It can also be useful if you are running out of program memory (your program is too big to fit into the microcontroller). The `-Og` option should save some memory without affecting the debug experience much.

Local variables (n in the function) can be seen on the Variables tab (in the upper right corner view). These are displayed automatically; you do not need to add them.

5. Step 5: Set up a project in Eclipse with Arduino functions

This section describes how to create project with Arduino MCU Framework (the software library), so that you can use the Arduino functions in your program.

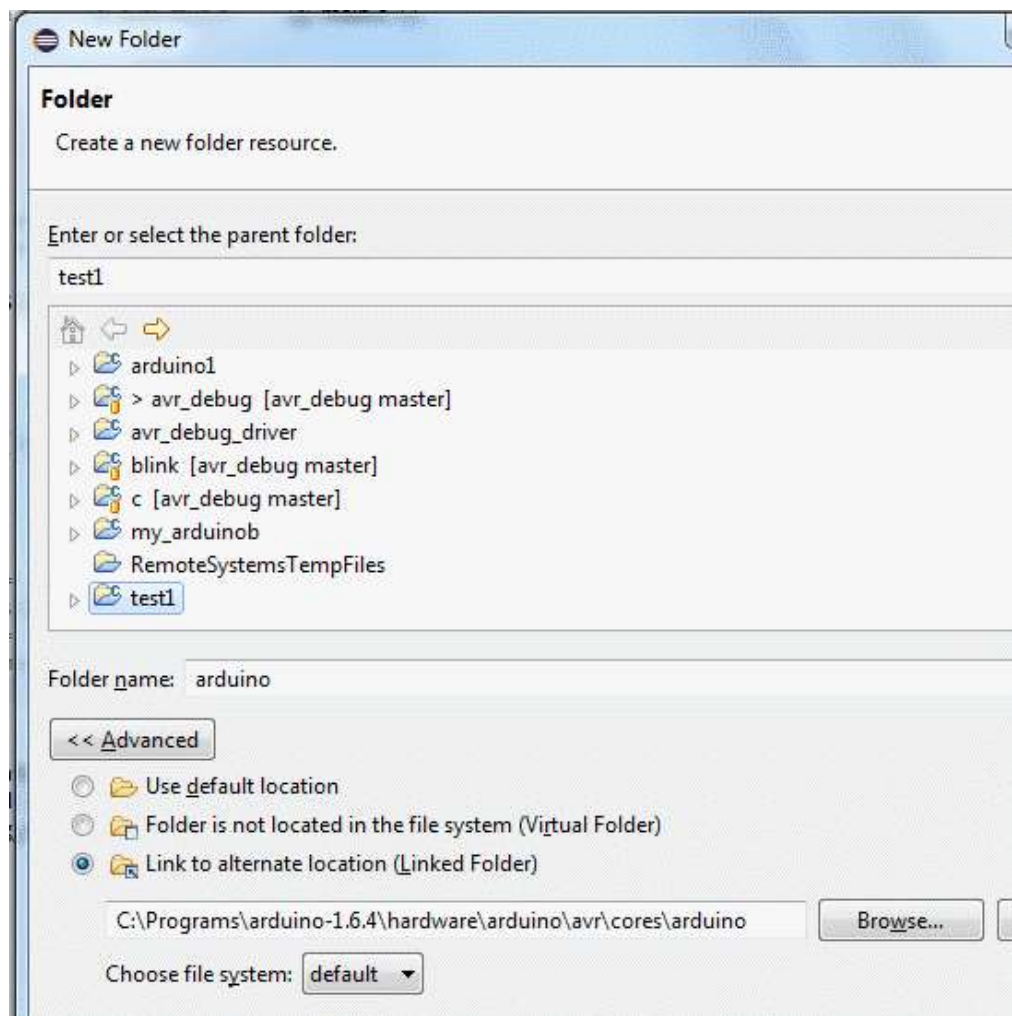
Create new project in Eclipse as described earlier in Step 2. Here is summary of the main points to select: C++ Project type, C++ Cross Target Application > Empty project, MCU Type Atmegas328P and MCU Frequency 16000000.

Right-click the project in Project Explorer in Eclipse and select New > Folder. New Folder window will appear.

In the Folder name box enter arduino.

Click the Advanced button at the bottom of the window. Folder options will appear. Select the type "Link to Alternate location (Linked folder)".

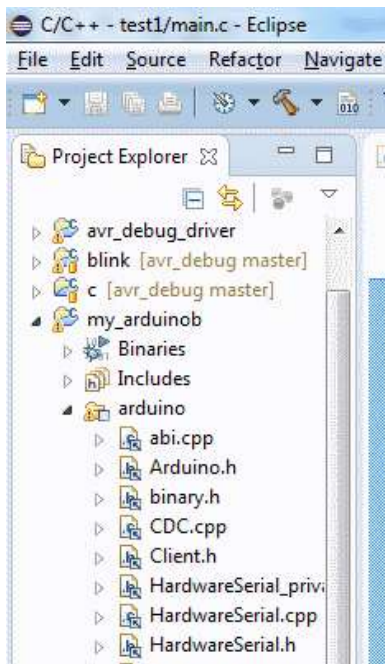
Click the Browse button and select the location of hardware\arduino\avr\cores\arduino in your Arduino installation. See the picture below.



Click Finish to create (link) the folder.

Follow the same steps to create another folder. Name it “standard” and point it to hardware\arduino\avr\variants\standard in your Arduino installation.

You should now see under your project in Eclipse the subfolders “Arduino” and “standard” and if you expand them, you will see the files from these folders. In the “Arduino” folder, there are many files. In the “standard” folder there is only one file – pins_arduino.h.



Note that these folders are linked to the location in your Arduino installation; they are not copied into the project. If you modify or delete the files under these folders; you could damage your Arduino installation.

Right-click the project and select New > Source File.

Enter some name for the file with .cpp extension and click Finish. The name could be the same as the project's name or sketch.cpp.

Paste the following code into the new file and save it:

```
#include "arduino.h"

void setup(void)
{
    pinMode(13, OUTPUT);
}

void loop(void)
{
    digitalWrite(13, HIGH);
    delay(200);
    digitalWrite(13, LOW);
    delay(500);
}
```


Go to preferences for your project (Alt + Enter or right-click the project and select Properties).

Expand C/C++ Build > Settings category.

At the top of the window, in "Configuration" select [All configurations].

In the AVR C++ Compiler > Directories add the two Arduino folders we now have in the project (Arduino and standard). The easiest way is to copy-paste the following two paths, including the quotation marks (click the small Add button and then paste one path; repeat for the other):

```
"${workspace_loc}/${ProjName}/arduino"
```

```
"${workspace_loc}/${ProjName}/standard"
```

Alternatively, click the Add button, then Workspace button in the Add directory path window. In the Folder selection window select your project > Arduino and click OK. Click OK again to close the Add directory path window. Repeat the same for the "Standard" folder.

This will add the two folders with Arduino files into the search path of the compiler so that the compiler can find the header file(s) located in these folders.

Do the same also for the directories of the C compiler in AVR C Compiler > Directories.

Your project should now build without errors. There are just some warnings from delay.h which can be ignored for now.

It is a good idea to upload the program into the board now to see if it works. The LED should blink.

NOTE: Before uploading, enable the HEX file output in Properties > C/C++ Build > Additional Tools in Toolchain and select the programmer for the project in Properties > AVR > AVRDUDE. This is described in the chapter about creating your first project for the Arduino board above (if you haven't done it yet).

In the next section we will add the debug driver so that we can finally debug the program.

TIP: When adding the Arduino folders to your project, you can also use a variable instead of the absolute path. Create a variable, for example, ARDUINO_LOCATION in Eclipse menu Window > Preferences > General > Workspace > Linked Resources. Then in the New Folder window use the Variables button and Extend... to point to the Arduino folders using this variable instead of full absolute path. This was described in more details earlier, in the chapter about adding the debug driver into your project in a more portable way.

6. Step 6: Enable debugger support in a program with Arduino functions

This section explains how to add debugger support to the program with Arduino software library created in previous step. It does not provide detailed instructions for the steps covered in previous chapters, so please refer to these chapters as needed.

Important note

With the debugger support included your program cannot use the Serial functions (the hardware serial) and it cannot use one of the pins with external interrupt function (INT0 by default, but this can be changed in `avr8-stub.h`). These are both used by the debug driver.

We will start with the project created in Step 5. That is we now have a project which can use Arduino functions, we are able to build this project and upload it to the board.

Add the debug driver into you project as described in Step 3, that is:

Drag and drop the required files and set the debug format in Preferences to dwarf2.

In the program, add the `#include "avr8-stub.h"` and call to `debug_init()` and `breakpoint()`. The code could look like this:

```
#include "arduino.h"
#include "avr8-stub.h"

void setup(void)
{
    debug_init();
    pinMode(13, OUTPUT);
}

void loop(void)
{
    breakpoint();
    digitalWrite(13, HIGH);
    delay(200);
    digitalWrite(13, LOW);
    delay(500);
}
```

Note: This example code assumes that interrupts are enabled by the Arduino core – which happens in the `main()` function contained in the Arduino core code. However, if you use your own main code and call the `setup()` and `loop()` yourself, please enable interrupts by calling `sei()` after the call to `debug_init()`, see the example code in Step 3 above.

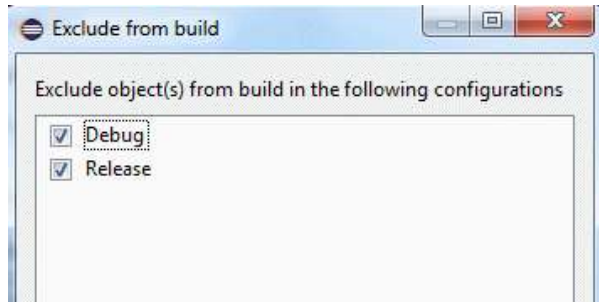
The program will not build now because of some errors. The linker is complaining about “multiple definition of `__vector_1” and vector 18. These are interrupt vectors for the INT0 external interrupt (on pin 2) and interrupt from UART module which signals that a character was received through the

serial line. Both these interrupts are needed for the debug driver to work but are currently handled also by the Arduino software library. To fix this:

Expand the Arduino folder in Project Explorer and locate file HardwareSerial0.cpp.

Right-click this file and from the context menu select Resource Configurations > Exclude from Build...

In the window which opens select both Debug and Release configurations and click OK.



Now this file will not be built with your program. This will solve the multiple definition for vector 18 (UART) but it also means the Arduino Serial functions will not work. Note that this applies only to this program (project), not to other programs you create either in eclipse or in the Arduino IDE. You are not modifying anything in your Arduino installation.

Repeat the same procedure for the file WInterrupts.c, that is exclude this file for built as well.

This solves the multiple definition for vector 1, but by excluding WInterrupts.c from build, your program cannot use the attachInterrupt Arduino function. If you need to use attachInterrupt in your program, please see the subsection about Alternative ways of solving multiple definitions below.

Build the project. It should now build without error.

Create Debug configuration for your project as described in Step 4 section. Do not start the proxy or start debugging yet, just set up the options.

TIP: You will see the configuration for our previous project (test1) in the Debug Configurations window. You can copy the settings from this configuration by duplication it (the button next to New launch configuration). Then you just need to change the Project and C/C++ Application fields on the Main tab. Use the Browse and Search Project... buttons to select the proper project and the corresponding .elf file.

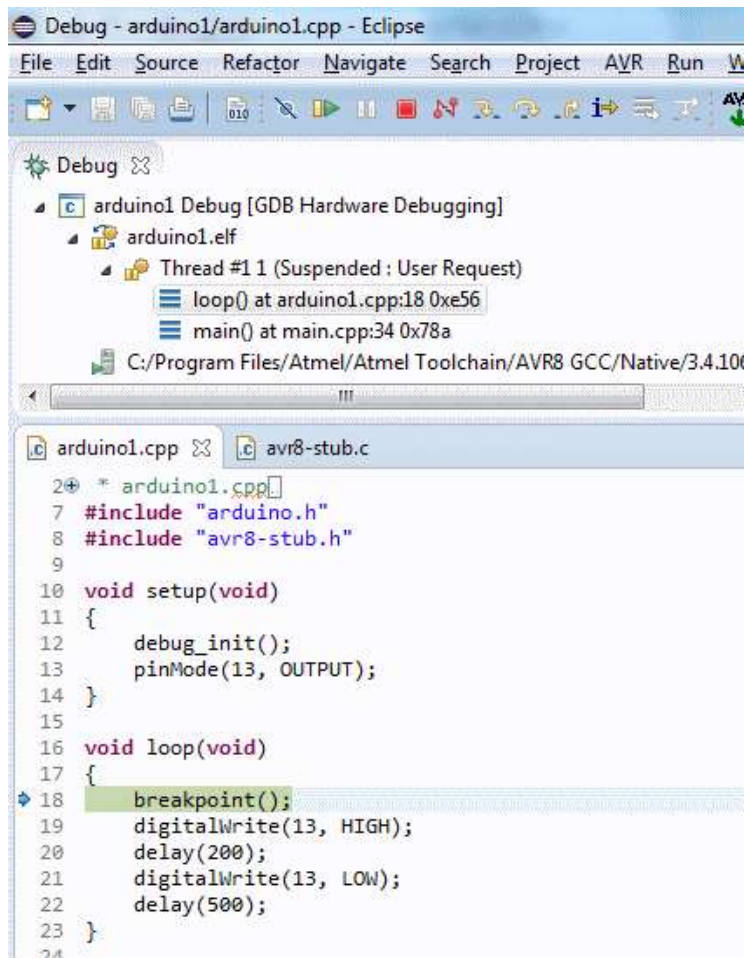
Close the Debug Configurations window.

Upload the program into your board if you haven't done it yet.

Start the COM to TCP proxy server (see Step 4 for details).

In Eclipse expand the Debug button, select Debug Configurations, and then your configuration and click Debug.

After a while, the Eclipse will switch to debug perspective and you should see something like this:



The program is stopped at the breakpoint line.

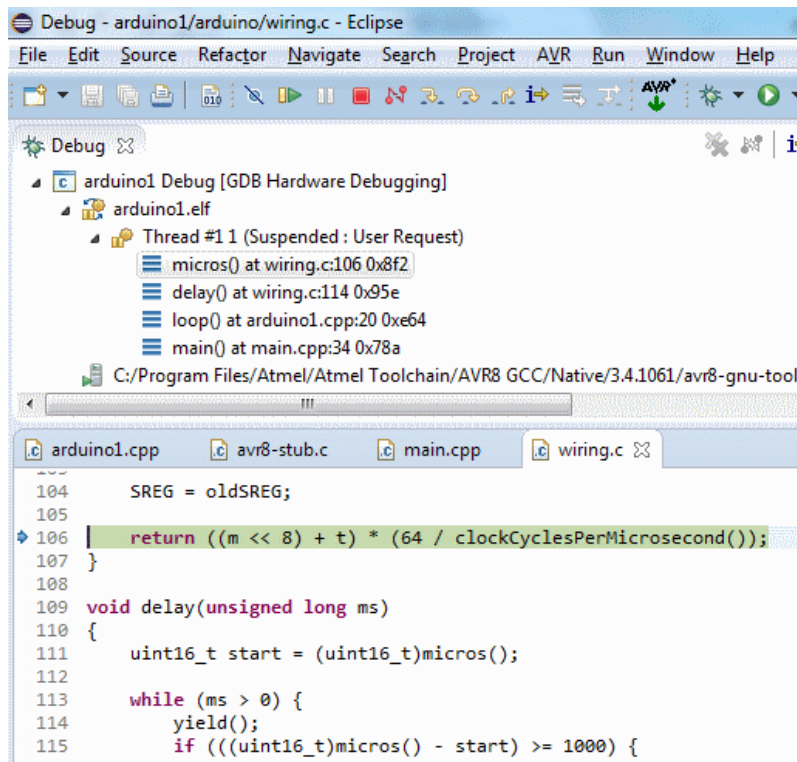
You can now step through the code (Step over button in toolbar) to see the LED go on, etc. Note that after stepping from the end of the loop, you will find yourself in the Arduino library's main.cpp file. If you continue stepping, you will get into your loop again. Also it seems like the setup is called again, but this is just discrepancy between the code you see in the C language and the real code generated by the compiler; the setup is not really executed again. You can use the Resume button to let the program run until it hits the breakpoint we have "hard-coded" at the beginning of loop.

Of course, you can also place breakpoints by right-clicking the left margin and selecting Toggle Breakpoint from context menu.

You can also remove the call to breakpoint() from the loop if you want to see the program running at full speed. Note that you need to rebuild and re-upload the program into the board. See Step 4 for details.

Note about debugging the program without the breakpoint() function in the code

If you do not place the call to breakpoint() function into your program, it will run (LED blinking) right after upload. When we connect with the debugger, it will stop at any random place; most likely somewhere in the delay() code. You may see this:



In the upper window (Debug) there is so called **call stack**, the “chain” of calls which led us into current place. The program is stopped inside the `micros()` function, which was called from the `delay()` function, which was itself called from `loop()` function and so on.

To quickly get to your own code, click `loop()` in the Debug window (select the `loop` function). This will display code of the `loop` function in the lower window. Now you can place a breakpoint, for example, on the `digitalWrite(13, HIGH);` line and resume the program. It will stop at the breakpoint.

Alternative ways of solving the multiple definitions of vector1 error

As mentioned above, by excluding `WInterrupts.c` from build, your program cannot use the `attachInterrupt` Arduino function.

If you need to use `attachInterrupt` in your program, do not exclude the `WInterrupts` file from build, but just disable (comment out) the code related to the `INT0` interrupt in this file.

There are three ways how to do it:

- Comment the code out
- Put the code into conditional block `#ifndef`
- Use modified `WInterrupts.c` file provided with this debugger with the conditional blocks already added and define the `AVR_DEBUG` symbol in compiler symbols for your project. The modified file is located in `avr_debug/arduino` folder. You can copy it to your Arduino package replacing the original file. Please do make a backup and use the appropriate file for your version of Arduino. The file can be changed in new versions of Arduino and if you replace the original file with one from older Arduino version, it may not work.

Comment out the code

Open the WInterrupts.c file from eclipse (it is located in the Arduino virtual folder in your project).

Locate this code:

#else

```
ISR(INT0_vect) {  
    if(intFunc[EXTERNAL_INT_0])  
        intFunc[EXTERNAL_INT_0]();  
}
```

Note the exact look, including the #else at the beginning!

The same code is located at 3 points in the file, this is the last one; at line about 305. You can use the red dot in the left margin indicating the place of the error to quickly locate the code.

Comment the block out by placing /* above the ISR() and */ below the “}”; it should look as follows:

```
#else  
/*  
ISR(INT0_vect) {  
    if(intFunc[EXTERNAL_INT_0])  
        intFunc[EXTERNAL_INT_0]();  
}*/
```

By this you just disable the code which handles INT0 (the interrupt used by the debug driver), but still be able to use the other interrupts.

You should now be able to build the project.

Important note

The advantage of this method compared to exclude from build is that you can still use the attachInterrupt function.

The **disadvantage** is that attachInterrupt will not work for the interrupt INT0 in any program. The change in the WInterrupts.c file affects all your Arduino projects.

Use conditional compilation block

You may want to do this instead of commenting the block out

```
#ifndef AVR_DEBUG  
ISR(INT0_vect) {  
    if(intFunc[EXTERNAL_INT_0])  
        intFunc[EXTERNAL_INT_0]();  
}  
#endif
```

Then define the AVR_DEBUG symbol in project properties > C/C++ Build > Settings > AVR Compiler > Symbols. This way only projects with AVR_DEBUG symbol defined will exclude this code. Other project will not be affected.

Opening example projects

The debugger for Arduino comes with example programs. You can import these programs into your workspace in Eclipse to quickly try the debugger. This is easier than creating your own program from scratch as described in the other parts of this document.

Set up your development environment

First, please set up your development environment as described in Step 1 chapter in this document.

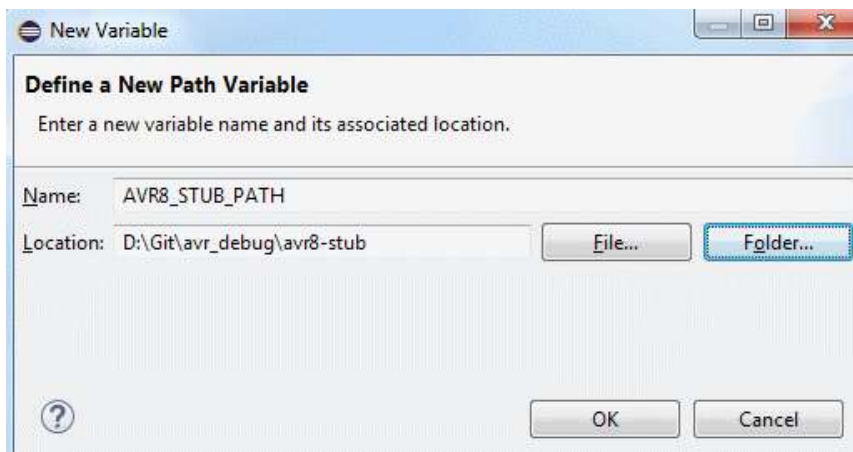
Create path variables

Next, we need to create path variables which are used in the example projects to refer to the location of the Arduino software library and the debug driver. This is only done once in a new workspace. If you've already created these variables in your workspace, skip this step.

Go to Eclipse menu **Window > Preferences and expand General > Workspace > Linked resources**.

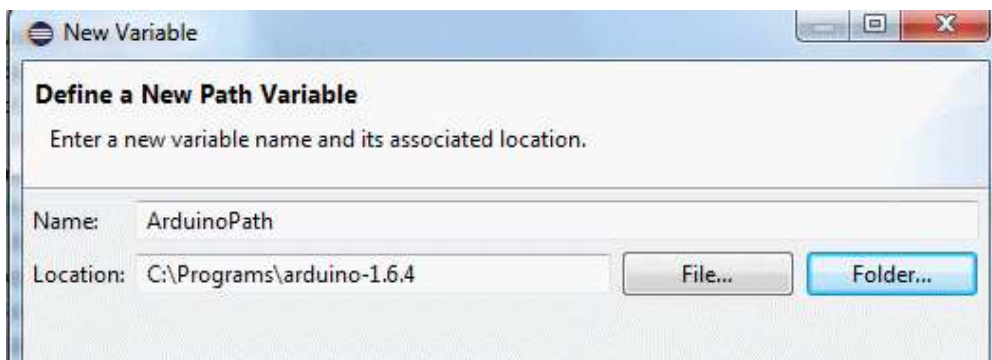
In the right-side part of the window create new Path variable using the New button:

The name must be: AVR8_STUB_PATH. Use the Folder... button in the New Variable window to point the variable to the location of the debug driver files on your system. For example, c:\avr_debug\avr8-stub.

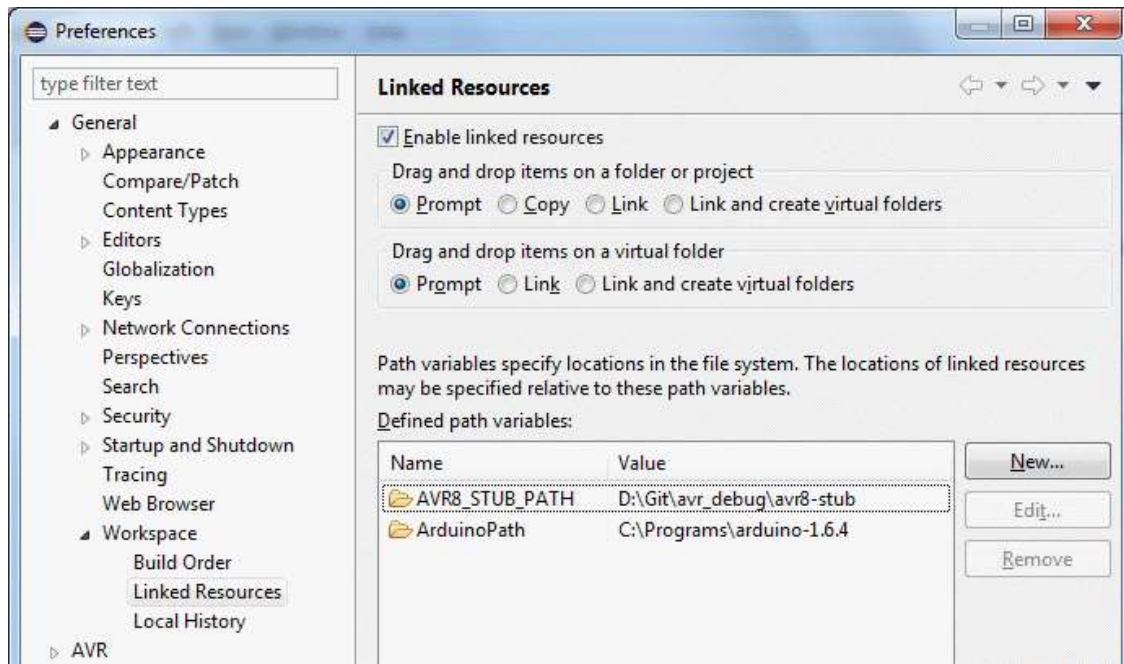


In the same way create another variable named ArduinoPath.

Set the location to the root of your Arduino installation, for example c:\Programs\arduino-1.6.4\.



There should now be these two variables in the list:

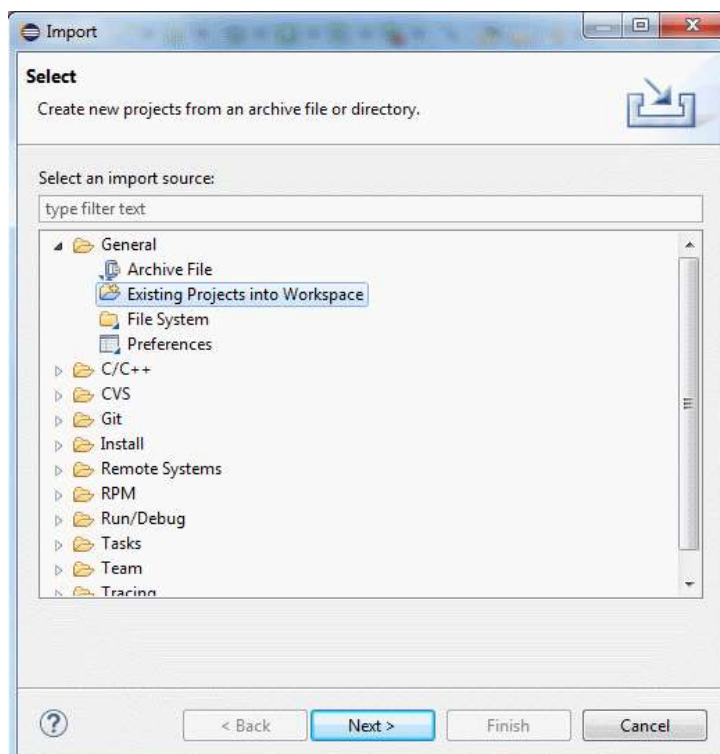


Import example projects

To import an example program into your workspace:

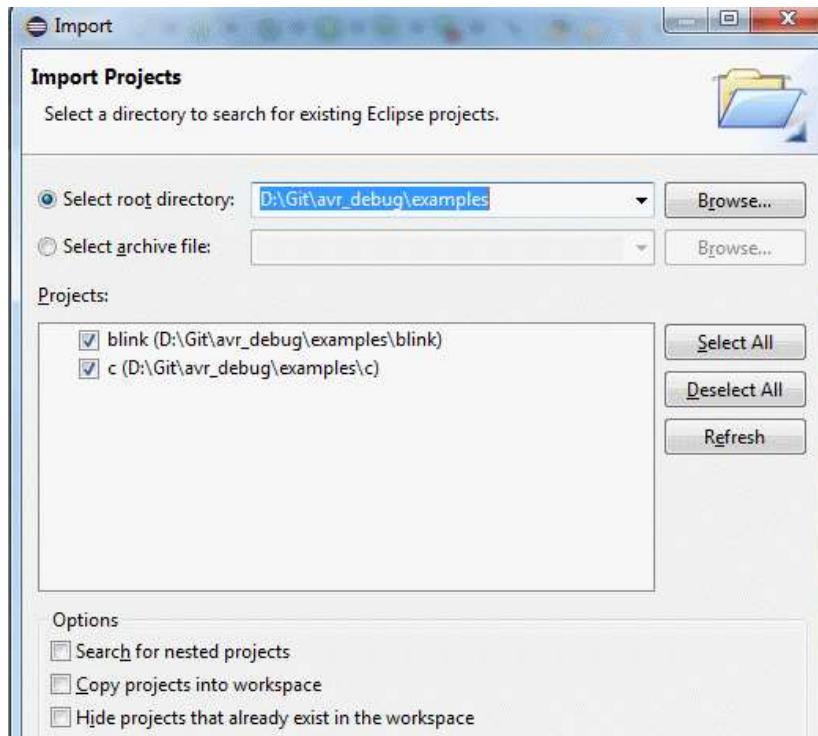
Start Eclipse and select **File > Import** from the main menu.

In the Import window select **General > Existing projects into workspace**. Click **Next**.



In the “Select root directory” use the Browse button to locate the examples folder in the AVR debug directory, for example c:\avr_debug\examples. You should see the example projects in this folder.

Select one or more projects to import. Make sure the “Copy projects to workspace” option is NOT enabled.



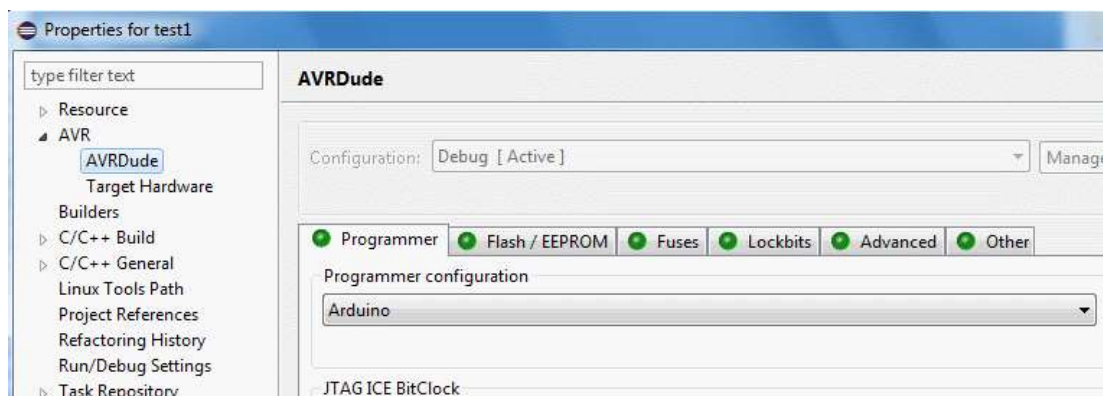
Build the project(s). There should be no errors.

Before uploading to the board we need to select the programmer. To do so:

Go to preferences for your project (Alt + Enter or right-click the project and select Properties).

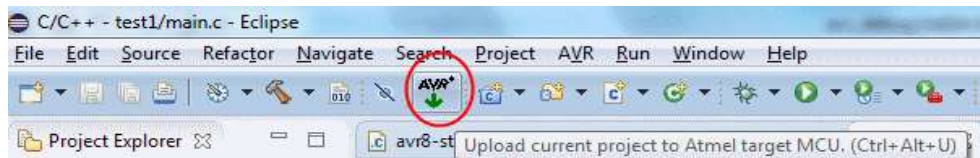
Expand AVR > AVRDude category.

On the Programmer tab select your Programmer configuration from the list. There should be the “Arduino” configuration we have created when setting up the development environment (see the Step 1 chapter, Configure the AVR Eclipse plugin subsection).



Close the Properties window with the OK button.

Click the AVR icon in the toolbar (Upload current project).



In the Eclipse console window you should see how your program is uploaded, ending with "avrdude done. Thank you."

Debug example projects

Now we will connect to the program with debugger. There are two options:

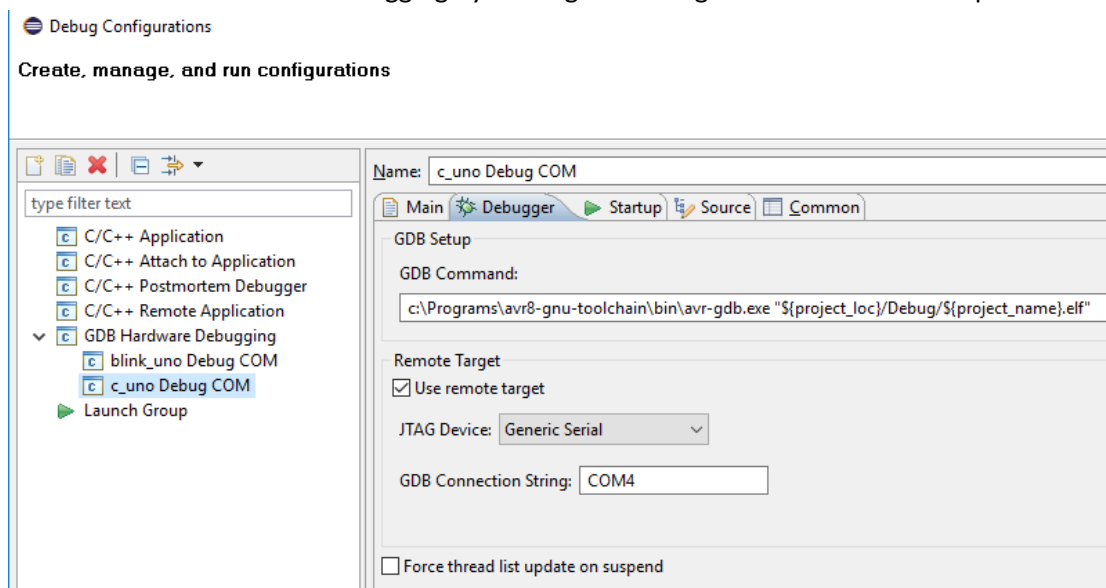
- Direct serial connection
- Connection via TCP to serial port converter (proxy server)

The direct connection is easier to use, so I recommend trying it first. If it does not work, use the connection via TCP-to-Serial proxy.

Direct serial connection

There is debug configuration included in the project. You just need to change the serial port number – COMx. To do so:

- Right-click the project in eclipse and select **Debug As... > Debug Configurations** from the context menu.
- In the Debug configurations window expand **GDB Hardware debugging** category and select the configuration for the project you wish to debug, e.g. c_uno Debug COM.
- On the right side select Debugger tab.
- Change the number of the COM port to the port where you Arduino is connected. See the picture below.
- You can now start debugging by clicking the Debug button in the bottom part of this window.



Connection via TCP-to-Serial proxy

If the direct serial connection does not work, use this option.

Before starting debug session in eclipse, we need to start a special program which converts the commands sent by the debugger to a TCP port to serial port where the Arduino board is connected (COM to TCP proxy server).

Use your file manager to open the folder where the Arduino debugger package is located. For example, c:\avr_debug. You should see a start_proxy.bat file in this folder.

Open the start_proxy.bat file in Notepad or other text editor (right-click the file and select Edit or drag and drop it into Notepad window).

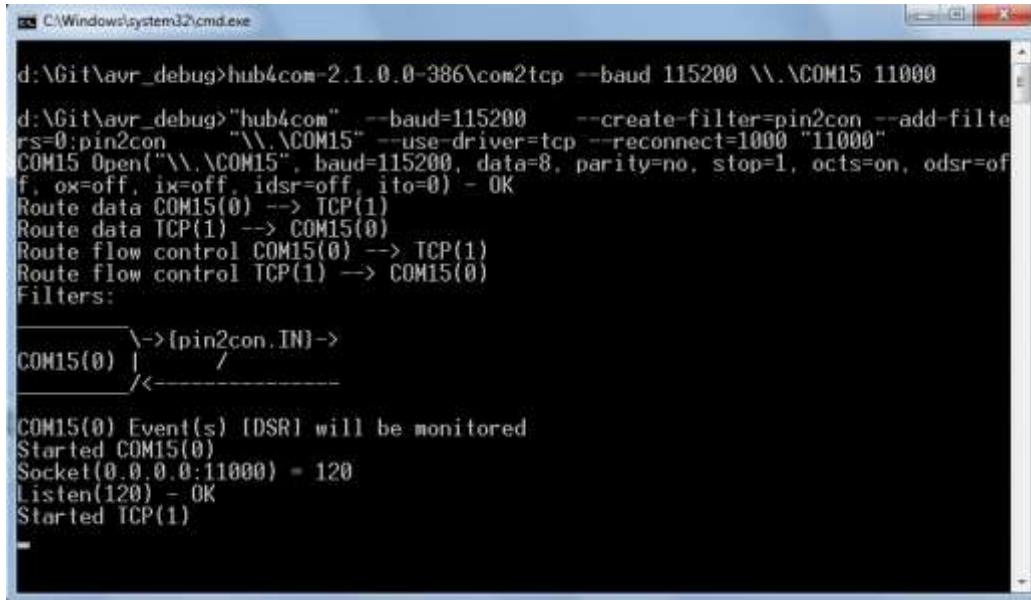
Change the number of the COM port in this file. There is this line:

```
hub4com-2.1.0.0-386\com2tcp --baud 115200 \\.\COM15 11000
```

Just change the number after COM from 15 to the number of your COM port to which the Arduino board is connected. If you prefer, you can also use the com2tcp program directly; use the command in this .bat file as an example.

Save and close the start_proxy.bat file.

Run the start_proxy.bat file. This will start the proxy server. You should see a console window with some information. This window will be opened all the time during the debugging.



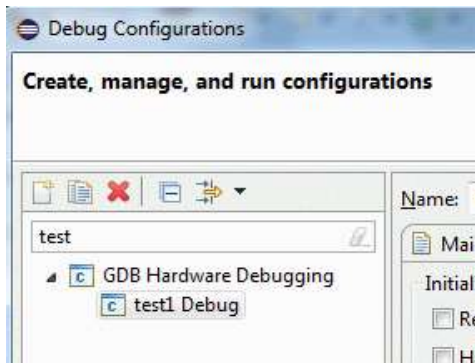
```
C:\Windows\system32\cmd.exe
d:\Git\avr_debug>hub4com-2.1.0.0-386\com2tcp --baud 115200 \\.\COM15 11000
d:\Git\avr_debug>"hub4com" --baud=115200 --create-filter=pin2con --add-filter=0:pin2con "\\.\COM15" --use-driver=tcp --reconnect=1000 "11000"
COM15 Open("\\.\COM15", baud=115200, data=8, parity=no, stop=1, octs=on, odsr=off, ox=off, ix=off, idsr=off, ito=0) - OK
Route data COM15(0) --> TCP(1)
Route data TCP(1) --> COM15(0)
Route flow control COM15(0) --> TCP(1)
Route flow control TCP(1) --> COM15(0)
Filters:
COM15(0) | \->[pin2con.IN]->
          | /
          /<-----
COM15(0) Event(s) [DSR] will be monitored
Started COM15(0)
Socket(0.0.0.0:11000) = 120
Listen(120) - OK
Started TCP(1)
```

Note: You may want to configure your firewall to block access to the port 11000 from other computers. You can also change the port number both in the .bat file and in the Eclipse debug configuration.

Now return to Eclipse.

Right-click the project and select Debug as > Debug Configurations from the context menu.

In the Debug Configurations window you should see a configuration with name in this format “[project_name] Debug” under the GDB Hardware Debugging category. For example, if you are using the “blink” example project, there will be “blink Debug” configuration.



Select the configuration and in the right-side window select the Debugger tab.

In the GDB Command box make sure the path to the GDB debugger (avr-gdb.exe) is valid. The example projects use the default path but if you installed the Atmel AVR8 toolchain into another location or if you have another version, the path will not be valid.

If you need to change the path, use the Browse button to select the avr-gdb.exe. Then enter a space after the path into the edit box and then paste the following line:

"\${project_loc}/Debug/\${project_name}.elf".

Here is example of the value for this field using tools from Arduino package:

c:\Programs\arduino-1.6.5-r2\hardware\tools\avr\bin\ avr-gdb.exe

"\${project_loc}/Debug/\${project_name}.elf".

And from Atmel Toolchain:

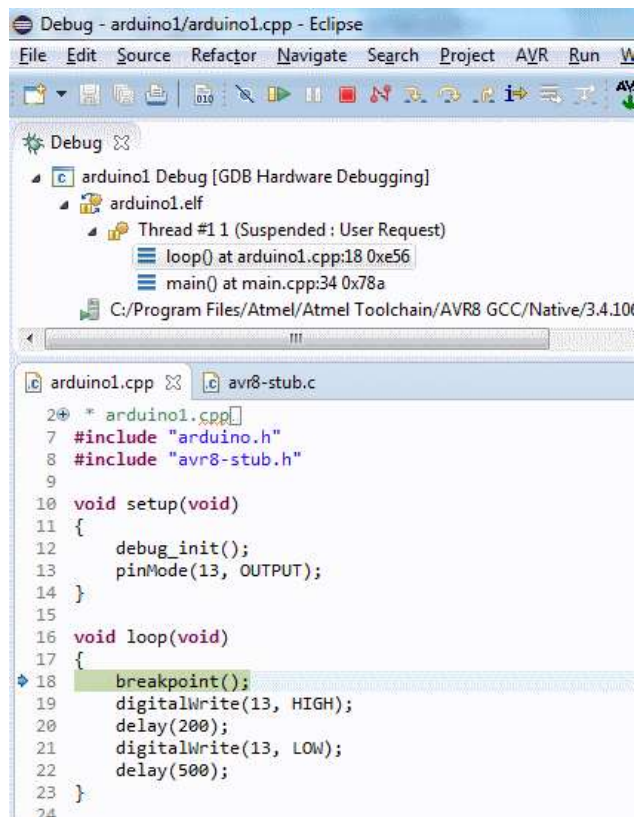
C:\Program Files\Atmel\Atmel Toolchain\AVR8 GCC\Native\3.4.1061\avr8-gnu-toolchain\bin\avr-gdb.exe "\${project_loc}/Debug/\${project_name}.elf".

Click Apply button to save the changes, if needed.

Click the Debug button in lower right corner of the window.

Debug session

After a while, the Eclipse will switch to debug perspective and you should see something like this:



The program is stopped at a line where `breakpoint()` function is placed in the code.

You can now step through the code (Step over button in toolbar) to see the LED go on, etc. Note that after stepping from the end of the loop, you will find yourself in the Arduino library's `main.cpp` file. If you continue stepping, you will get into your loop again. Also it seems like the `setup` is called again, but this is just discrepancy between the code you see in the C language and the real code generated by the compiler; the `setup` is not really executed again. You can use the Resume button to let the program run until it hits the breakpoint we have "hard-coded" at the beginning of loop.

Of course, you can also place breakpoints by right-clicking the left margin and selecting Toggle Breakpoint from context menu.

Please see Step 4 chapter for more information on debugging.

How to enable breakpoints in flash memory

For explanation of flash breakpoints and their comparison to the RAM breakpoints please see the chapter RAM vs Flash breakpoints – pros and cons. This section provides instructions on using the flash breakpoints for debugging.

Here are the steps needed:

1. Update the bootloader in your Arduino board and change the fuses
2. Change the option in `avr8-stub.h` to use flash breakpoints
3. Add files `app_api.h` and `app_api.c` to your project (if not already there)

Step 1 - Update the bootloader in your Arduino board and change the fuses

You need to do this step only once per Arduino board. Once you have the bootloader in your Arduino, you can use the flash breakpoints and also upload the programs via the debugger. You can also upload the programs as usual from Arduino IDE or Eclipse via AVRDUDE.

The bootloader binary can be found in `avr_debug/bootloader`.

For Arduino Uno use the file **optiboot.hex** in `c:\Git\avr_debug\bootloader\optiboot\Debug`.

Arduino Mega is not supported for now.

To “burn” the bootloader into your Arduino you need an ICSP programmer or another Arduino board to serve as such programmer.

The software used for burning the bootloader can be the Arduino IDE, Atmel Studio or some custom program made by the manufacturer of the programmer. Please refer to the documentation for the programmer you will use or search the internet.

The settings presented here are general information which you should be able to apply in any tool. Below is also screenshot with the appropriate settings in Atmel Studio Device programming window.

Please note that you also need to **change the fuse settings**.

Raw fuses values

EXTENDED: 0xFD

HIGH: 0xD2

LOW: 0xFF

Fuse settings for humans

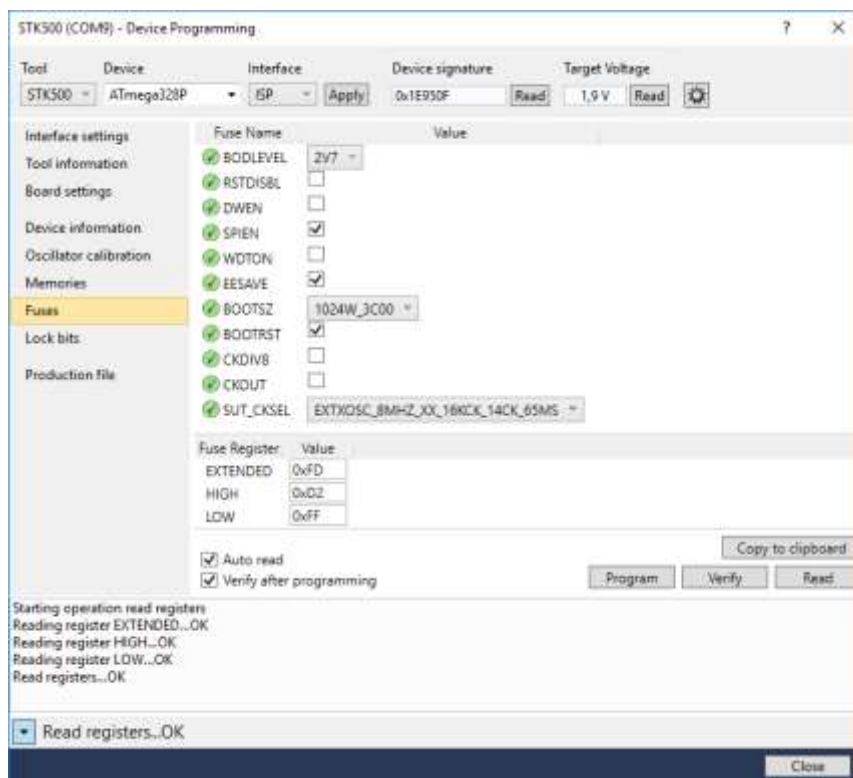
Enable SPIEN

Enable BOTRST

Enable EESAVE

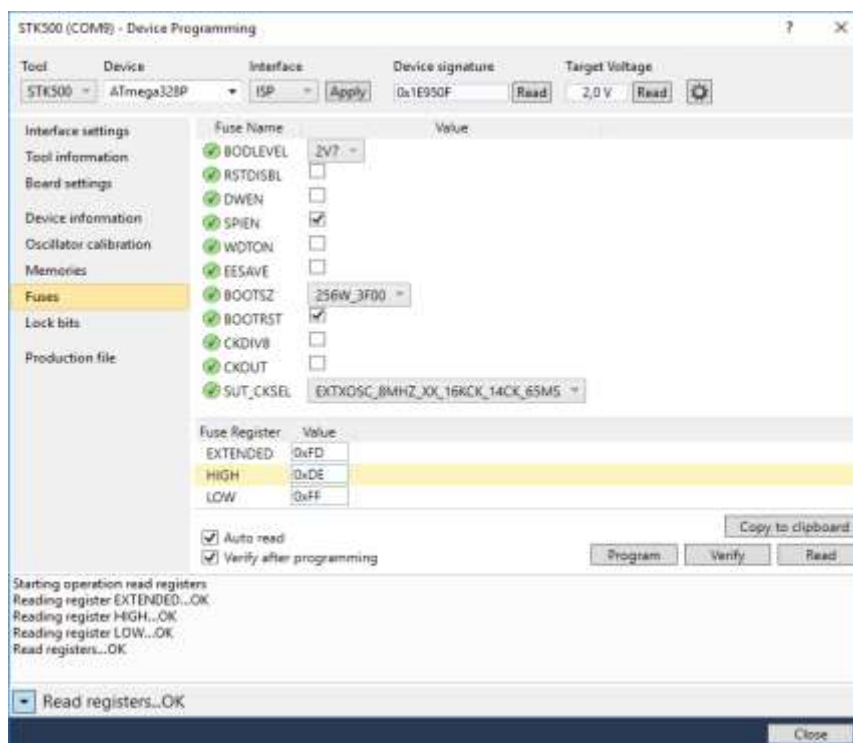
Set BOOTSZ to 1024 words (bootloader start address 0x3c00)

Set clock to EXT OSC 8 or 16 MHz



Fuse settings for the modified bootloader.

For your reference (and if you need to change the fuses back), here are the fuse settings for Arduino Uno as shipped from factory.



Fuse settings for Arduino Uno for the standard bootloader (factory shipped).

Notes about bootloader

The modified bootloader works also for normal uploading from Arduino IDE or Eclipse using AVRDUDE. It is not limited to uploading via the debugger. So you can have this bootloader in your Arduino board and use the board as usual, for example, with Arduino IDE.

The bootloader is bigger than the standard bootloader shipped with Arduino Uno. It uses 2 KB of program memory. So with this bootloader your programs are limited to 30 KB of program memory (flash).

If you want to build the bootloader yourself, there is an eclipse project in `avr_debug/bootloader/optiboot`. You can import this project into Eclipse and build it in the same way as the example projects provided with this debug driver.

Step 2 - Change the option in `avr8-stub.h` to use flash breakpoints

Open the file `avr8-stub.h`. You will have this file in your eclipse project when you add this debugger to your program.

Locate the following line in the file:

```
#define AVR8_BREAKPOINT_MODE (0)
```

Set the value of `AVR8_BREAKPOINT_MODE` to 0.

Value 0 means that the breakpoints are written to flash memory. Detailed explanation of the possible values can be found in the comment above the definition.

Step 3 - Add files `app_api.h` and `app_api.c` to your project

The files `app_api.h` and `app_api.c` are located in the Arduino debugger]\avr8-stub folder – in the same place as the main debug driver files `avr8-stub.h` and `avr8-stub.c`.

Drag and drop these files into your project in Eclipse.

These files contain the interface between the debug driver and the bootloader which is needed to write to flash memory.

Debugging your program with flash breakpoints

There is virtually no difference in usage when you switch to flash breakpoints. One example of a program where you can see the difference is a program with delay implemented as busy loop.

If you have code like this in the main loop:

```
digitalWrite(13, HIGH);  
my_delay();  
digitalWrite(13, LOW);  
my_delay();
```

And the delay function looks like this:


```

void my_delay(void)
{
    unsigned long i = 50000;
    while ( i > 0 )
        i--;
}

```

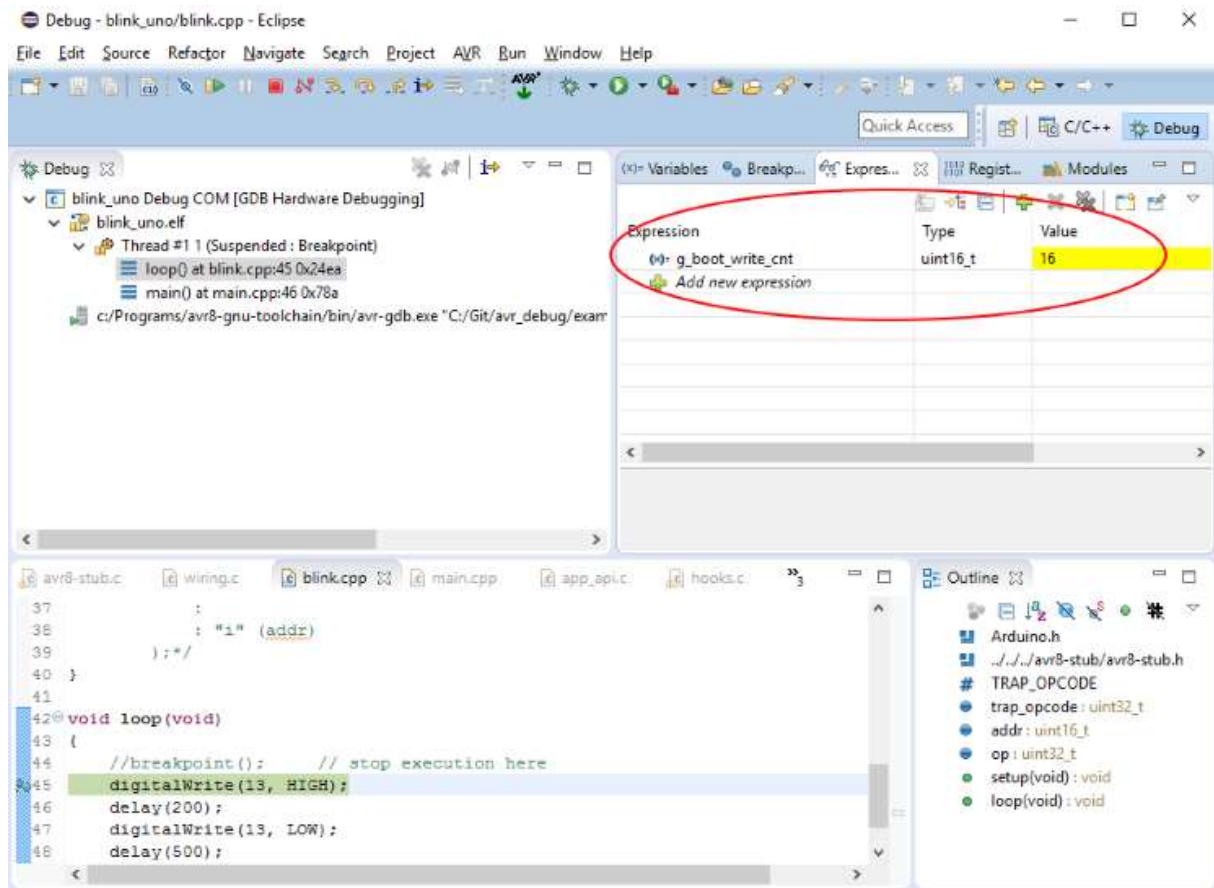
Then using RAM breakpoints it will take several seconds to step over the my_delay functions. When the program runs without breakpoints, the delay is some fraction of a second, but if there is a breakpoint, it takes several seconds. With flash breakpoints there is no such difference; the delay should still take only fraction of a second to execute.

Please note that the flash memory is rewritten several times when you debug with flash breakpoints and that the flash memory can survive only limited number of writes. This is discussed in detail in chapter Using breakpoints in flash memory.

You can view how many times the flash memory has been written to during debug session if you enable certain option in the debug driver. To do so:

- In your project open the app_api.c file.
- Uncomment the line **#define AVR8_API_DEBUG**
- In Eclipse when debugging go to menu Window > Show View > Expressions.
- In the Expressions window click new line with “Add new expression” and copy-paste or type this name of a variable: **g_boot_write_cnt**.
- This variable shows how many times flash memory was written. Note that this counts the total writes in any location of the memory, not the writes into particular page of the memory.

The picture shows the flash write counter in the Expressions window in eclipse.



There is one breakpoint at the digitalWrite(13, HIGH) command at line 45. When you step through the program, you will notice that the write counter variable g_boot_write_cnt increases by 2 for each step. This is because to step over a function the debugger inserts a temporary breakpoints after the function call and continues the program. So there are actually 2 breakpoints written/erased each time – the one set by the user at line 45 and the temporary breakpoint.

Uploading your program via the debugger

This option is available if you update the bootloader in your Arduino (which is also required to use flash breakpoints). It allows you to upload and debug your program by just starting the debug session – no need to first upload via AVRdude and then connect with the debugger. For information on updating the bootloader please see chapter Step 1 - Update the bootloader in your Arduino board and change the fuses.

To use this option you need to:

- Configure the debug driver
- Set the options in the Debug configuration to load the program

Step 1 - Configure the debug driver

In your project in Eclipse open the file **avr8-stub.h**.

Locate the line with this definition: `#define AVR8_LOAD_SUPPORT (1)`

Set the value of the `AVR8_LOAD_SUPPORT` to 1.

Value 1 means that the debugger will support loading the program into target MCU.

Step 2 - Configure the Debug configuration to load the program

In your project in eclipse open the Debug configurations (right-click the project and select Debug As – Debug configuration).

In the list on the left hand side select your project under the GDB Hardware Debugging category.

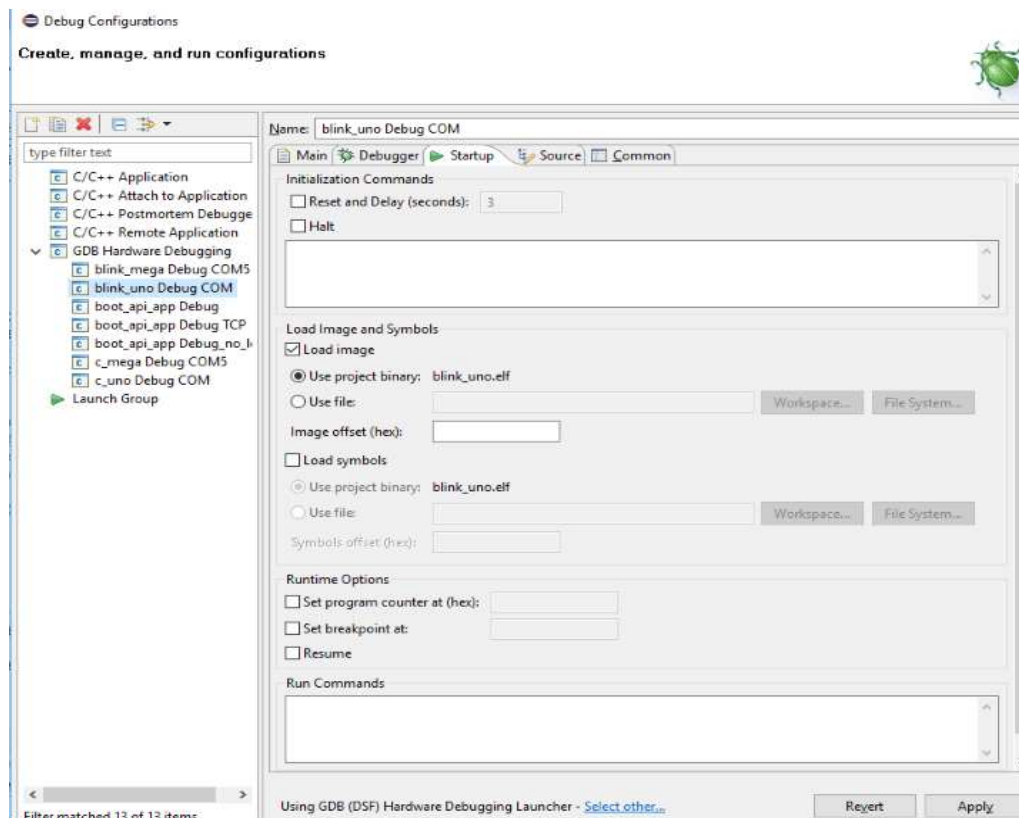
In the Debug configurations window go to the **Startup** tab.

Check the box **Load image**.

If you want the program to run after load you can also check the box **Resume** in the **Runtime options** area in the lower part of the window. Otherwise the program will be stopped at random location after load.

Do not enable any other options as they are not supported by the debug driver anyway.

The following picture shows the configuration for blink_uno project.



Tip

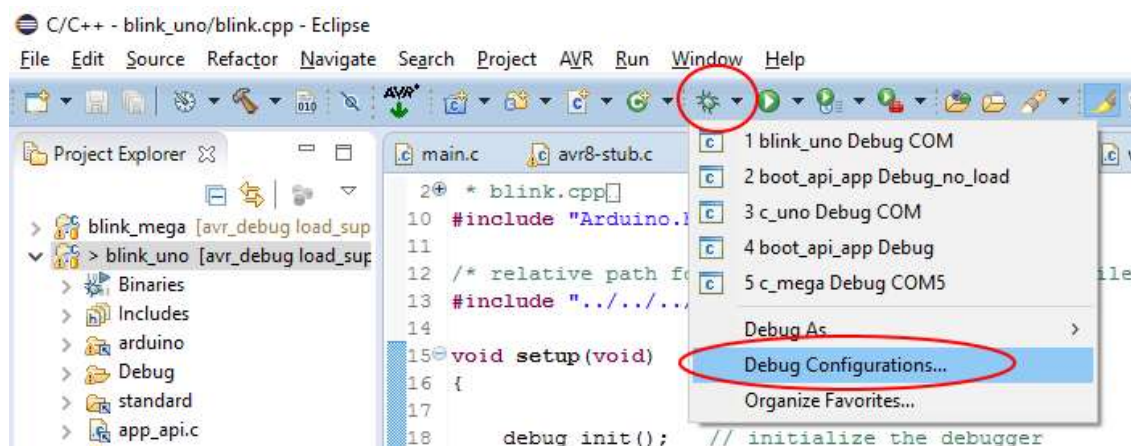
You can create two debug configurations for your project. One with load disabled and one with load enabled. If you need to connect to a program which is already running in the MCU or a program uploaded via AVRdude, you can use the no-load configuration. If you need to upload the program, use the load configuration. This saves the flash memory from unnecessary rewrites because every load means overwriting the flash memory.

Uploading and running the program

To upload and run the program after a change in code, just click the arrow of the Debug button and select Debug Configurations from the menu. Then select the configuration you want to run.

Eclipse will build the program, upload it and start debugging.

Note: To debug the program next time you can just select the configuration from the menu – there will be list of recently run configurations. So you don't need to go to the Debug Configurations window to run the program every time.



The program will be loaded and you will find it stopped in the debugger at random location (unless you've enabled the Resume option in the debug configuration).

Note that at this point the debugger does not really know where it stopped and it will show no call stack. Click the **Step over** button to advance the program one step and now the call stack will be shown correctly.

If you enable the Resume option the program will be running and you can stop it using the **Suspend** button. In this case it will show correct call stack.

You can use the Step Over (F6) command to continue stepping from the current location. Or you can insert a breakpoint in the program and use the Resume (F8) command to let the program run until it hits the breakpoint.

You can also insert call to **breakpoint()** function into your code to stop the program at desired point. For example, insert it into the setup function right after the initialization of the debugger as in the following picture.

```
15 void setup(void)
16 {
17
18     debug_init(); // initialize the debugger
19     breakpoint(); // stop execution here
20     pinMode(13, OUTPUT);
21     digitalWrite(13, HIGH);
22 }
23
```

Note that after the program is loaded it does not show the correct location of the breakpoint call. But after you execute Step Over command, it will point to the correct location and you can continue stepping from the breakpoint line onwards.

Understanding the load function

This section provides some background information about loading the program into the target MCU via the debugger.

When you instruct the debugger to load the program and start debugging, it tries to communicate with the target MCU to upload the new program. There must be a program in the target MCU already which is able to handle this communication.

For uploading your programs via AVRdude (from Arduino IDE), such a program is always present in the MCU – it is the bootloader. But for uploading via the debugger the debug driver is used (the code in the avr8-stub.c file). In order to load the program there must already be a program with the debug driver in the MCU. So before you can upload via the debugger, you need to load your program into the MCU by AVRdude. After this initial load, you can do the subsequent loads via the debugger.

In principle it would be possible to put the code for loading via debugger into the bootloader so it would be always present in the MCU, but there are several problems. First, it would increase the size of the bootloader. Second, normally the user program runs all the time; not the bootloader. When you load your program via AVRdude, it resets the MCU to interrupt the user program and activate the bootloader. But the debugger does not know how to reset the program before loading. The user would have to reset the MCU manually before uploading the program. So in general it would be possible to further improve loading via the debugger but I believe that the current version is usable – once you have some program with the debug driver in your MCU, you can upload via the debugger over and over again...until the program gets somehow corrupted, which should not happen often. And if it happens, you can just upload via AVRdude once and then again upload via the debugger.

Troubleshooting problems with debugging

Problem: Debug session fails to start.

Reason 1: Project is not selected in Eclipse Project Explorer.

Solution: If you encounter an error right after clicking the debug button; message tells you about “gdb –version”, select your project in the Project Explorer and try again. Alternatively, instead of using the Debug button in toolbar, right-click the project and select Debug As > Debug configurations. Select the debug configuration and click Debug.

Reason 2: COM port is not set correctly (error message talks about No such file or directory).

Solution: Make sure the Arduino board is connected and the COM port number is correct – verify this in Windows Device Manager. If it is correct, try to enter the COM port name in this format:

\\.\COM10 (example for COM 10). It seems that for higher port numbers the simple name such as COM10 without the backslashes does not work.

Reason 3: Communication with the board cannot be established.

Solution: If you encounter an error later during the startup of the debug session, make sure the COM to TCP proxy server is running and also that your program calls the debug_init() function somewhere at the beginning (in setup() function if you use Arduino functions, or at the beginning of main for plain C/C++ programs).

Reason 4: The debugger itself (avr-gdb.exe) cannot be started.

Solution: If you encounter error later during startup of debug session saying “cannot get GDB version with command...” or so, try to start avr-gdb.exe directly from your file manager or command line. If it cannot be started because of some missing .dlls, install the Atmel AVR toolchain and use the avr-gdb from this toolchain instead of the one included in Arduino IDE package. For more information please see section *Problems with GDB* in the Introduction of this document.

Problem: The program is not jumping at some line or is jumping somewhere I don’t want it to...

Reason 1: There is another program in the microcontroller than in the debugger.

Solution: If you made any changes in the program make sure you rebuild and re-upload the program to the board. If you just opened some older project, make sure you upload it to the board before you start debugging.

Reason 2: Compiler optimizations and code reordering by the compiler.

Often, when you debug your program, it does not behave as you expect. In most cases, this is not caused by an error in the debugger but by the difference between the program as you have written it

(and see it in the debugger) and the actual code generated by the compiler. For example, when you write:

```
while ( i-- > 0 ) ;
```

The compiler can translate it into:

1: jump to line 3.

2: subtract 1 from i.

3: if (i > 0) jump to line 2.

This can happen even with no optimizations (-O0 option). Things can be even more confusing if you enable optimizations.

Solution: By default, use -O0 option (no optimizations) – this is enabled by default when you create new project in Eclipse. You can also try -Og which results in more optimized program but still with reasonable debugging experience – useful if your program grows too big to fit into the MCU with O0.

Reason 3: Interrupts are not enabled in your program.

Solution: Call sei() in your code. See example below.

Note: In Arduino programs interrupts are enabled automatically by the Arduino core code, but if you create a “plain” C/C++ program, you need to enable it yourself by calling sei().

```
int main(void)
{
    debug_init();
    DDRB |= _BV(5);    // pin PB5 to output (LED)
    sei();             // enable interrupts
    breakpoint();
    while(1)
    {
        ...
    }
}
```

Problem: The program does not stop on a breakpoint

Reason: There are more breakpoints set in the program than the debug driver supports.

Solution: Check how many breakpoints are there in the Breakpoints window in Debug perspective. If you cannot see this window, open it from the main menu Window > Show View > Breakpoints.

Delete the breakpoints you do not need.

To see the supported number of breakpoints search for AVR8_MAX_BREAKS symbol in avr8-stub.h file. Default is 8 breakpoints for RAM breakpoints and 4 breakpoints for Flash breakpoints. Note that you should not set more than this number – 1, e.g. more than 7 breakpoints in case of the breakpoints-in-RAM configuration. There should be one extra breakpoint available for use by the debugger – it sets temporary breakpoints when stepping over a function and so on.

Problem: The Console view in Eclipse shows error “No source file named ...”.

Reason: This is because Eclipse remembers all the breakpoints you set, even from other projects you debugged earlier. If you debug project “Test1” and place a breakpoint in test1.cpp file and then start debugging “test2” project, this error can appear for test1.cpp file.

Solution: Remove the unneeded breakpoints in the Breakpoints view – switch to the view in upper right corner of Eclipse and select Remove / Remove all breakpoints command.

Problem: The disassembly cannot be displayed

Reason: This is long time known bug in avr-gdb. See here for more information:
https://sourceware.org/bugzilla/show_bug.cgi?id=13519.

Solution: It should be possible to apply the patch mentioned on the webpage above to avr-gdb sources and build it on your own. I have not tried it yet because I can live without the disassembly.

Problem: Loading the program via the debugger ends with error “Load failed”.

Reason: The load via the debugger is not enabled in the debug driver.

Solution: Please see the AVR8_LOAD_SUPPORT define in avr8-stub.h and make sure the load is enabled. Then rebuild your program and upload it to the MCU using AVR Dude. Once the program with this option enabled is in the MCU, you can upload via the debugger. Note that there is no need to update the bootloader after this change but you do need to have the modified bootloader in your MCU for this option to work.