AR488 GPIB Controller

The AR488 GPIB controller is an Arduino-based controller for interfacing with IEEE488 GPIB devices. The code has been tested on Arduino UNO, NANO and MEGA2560 boards and provides a low cost alternative to other commercial interfaces.

To build an interface, at least one Arduino board will be required to act as the interface hardware. Connecting to an instrument will require a 16 core cable and a suitable IEEE488 connector. This can be salvaged from an old GPIB cable or purchased from electronics parts suppliers.

Details of construction and the mapping of Arduino pins to GPIB control signals and data bus are explained in the *Building an AR488 GPIB Interface* section.

The interface supports most of the standard Prologix commands with the exception of the ++lon command which is currently unsupported. The commands closely adhere to the Prologix syntax but there are some minor differences. In particular, due to issues with the longevity of the Arduino EEPROM memory, the ++savecfg command has been implemented differently. Details of all commands can be found in the *Command Reference* section.

Installation

Windows 7 and Windows 10 will automatically recognize the FTDI and CH340G chipsets used by Arduino boards and automatically install the drivers from Windows Update.

The official source for FTDI drivers is here:
https://www.ftdichip.com/FTDrivers.htm

The VCP driver provides a virtual COM port for communication while the D2XX (direct) driver allows direct access via a DLL interface.

The official CH340G driver source is here:
http://www.wch.cn/download/CH341SER_EXE.html

Linux Mint appears to automatically recognize both chipsets as well. Since Linux Mint is based on Ubuntu, it is expected that Ubuntu should also automatically recognize both chipsets.

Firmware Upgrades

The firmware is upgradeable via the Arduino IDE in the usual manner. Updates are available from https://github.com/Twilight-Logic/AR488

Client Software

The interface can be accessed via a number of software client programs.

- Terminal software (e.g. PuTTY)
- EZGPIB
- HE5FX GPIB Toolkit – GPIB Configurator (prologix.exe)

Terminal clients connect via a virtual COM port and should be set to 115200 baud, no partity, 8 data bits and 1 stop bit when connecting to the interface. On Linux, the port will be a TTY device such as */dev/ttyUSB0* or */dev/ttyACM0*.

Specific considerations apply when using an Arduino based interface with EZGPIB and the HE5FX toolkit. These are described in the *Working with EZGPIB and KE5FX* section.

Operating Modes

The interface can operate in both controller and device modes.

Controller mode

In this mode the interface can control and read data from various instruments including Digital multimeters (DMMs). oscilloscopes, signal generators and spectrum analyzers. When powered on, the controller and sends out an IFC (Interface Clear) to the GPIB bus to indicate that it is now the Controller-in-Charge (CIC).

All commands are preceded with the ++ sequence and terminated with a carriage return (CR), newline [a.k.a. linefeed] (LF) or both (CRLF). Commands are sent to or affect the currently addressed instrument which can be specified with the *++addr* command (see command help for more information).

By default, the controller is at GPIB address 0.

As with the Prologix interface, the controller has and auto mode that allows data to be read from the instrument without having to repeatedly issue *++read* commands. After *++auto 1* is issued, the controller will continue to perform reading of measurements automatically after the next *++read* command is used and using the parameters that were specified when issuing that command.

Device mode

The interface supports device mode allowing it to be used to send data to GPIB devices such as plotters via a serial USB connection. Device mode commands except ++lon are supported.

Transmission of data

Interrupting transmission of data

While reading of data for the GPIB bus is in progress, the interface will still respond to the ++ sequence that indicates a command. For example, under certain conditions when the instrument is addressed to talk (e.g. when *eos* is set to 3 [no terminator character] and the expected termination character is not received from the instrument, or read with eoi and the instrument is not configured to assert eoi, or auto mode is enabled), data transmission may continue indefinitely. The interface will still respond to the ++ sequence followed by a command (e.g. ++auto 0 or ++rst). Data transmission can be stopped and the configuration can then be adjusted.

Sending Data and Special characters

Carriage return (CR, hex 0D, decimal 13), newline [a.k.a linefeed] (LF, hex 0A, decimal 10), escape (hex 1B, decimal 27) and '+' (hex 2B, decimal 43) are special "control" characters. Carriage return and newline terminate command strings and direct instrument commands, whereas a sequence of two '+'s precedes a command token. Special care needs to be taken when sending binary data to an instrument, because in this case we do not want control characters to prompt some kind of action. Rather, they need to be treated as ordinary and added to the data that is to be transmitted.

When sending binary data, the above mentioned characters must be 'escaped' by preceding them with a single escape (hex 1B, decimal 27) byte. For example, consider sending the following binary data sequence:

54 45 1B 53 2B 0D 54 46

It would be necessary to escape the 3 control characters and send the following:

54 45 **1B** 1B 53 **1B** 2B **1B** 0D 54 46

Without these additional escape character bytes, the special control characters present in the sequence will be interpreted as actions and an incomplete or incorrect data sequence will be sent.

It is also necessary to prevent the interface from terminating the binary data sequence with a carriage return and newline (0D 0A) as this will confuse most instruments. The command *++eos 3* can be used to turn off termination characters. The command *++eos 0* will restore default operation. See the command help that follows for more details.

Receiving data

Binary data received from an instrument is transmitted over GPIB and then via serial over USB to the host computer PC unmodified. Since binary data from instruments is not usually terminated by CR or LF characters (as is usual with ASCII data), the EOI signal can be used to indicate the end of the data transmission. Detection of the EOI signal while reading data can be accomplished with the *++read eoi* command, while an optional character can be added as a delimiter with the *++eot_enable* command (see the command help that follows). The instrument must be configured to send the EOI signal. For further information on enabling the sending of EOI see your instrument manual.

Configuration

The main configuration for the AR488 is Config.h. This is a C++ style header file containing various #define macros that can be used to configure the firmware. The file must be included in the main sketch as well as any other module header file. A number of these parameters are surrounded with `#ifdef..#endif` statements. These are neccessary and should not be changed or removed. Only the `#define` macros (parameters) within should be changed. With the exception of macros, nothing should need to be changed in any other file.

Firmware version

This is in the format:

```
#define FWVER "AR488 GPIB controller, ver. 0.47.32, 17/09/2019"
```

This entry should not exceed 47 characters and should not be changed.

Board Selection

There are currently four entries. ONE of the following boards MUST be selected. Do not uncomment more than one entry!

```
#define AR488_UNO
//#define AR488_NANO
//#define AR488_MEGA2560
//#define AR488_MEGA32U4
//#define AR488_CUSTOM
```

The default entry is *AR488_UNO*, which compiles the firmware for the Arduino UNO board. If a specific board is selected then a board template in *AR488_Hardware.h* is used to configure the board. If *AR488_CUSTOM* is selected, the pin layout can configured as required using the Custom Board Layout section. When a specific board is selected, the custom board layout is ignored. See the Custom Board Layout section below for more details.

Please make sure that the correct board is selected in the Arduino IDE Boards Manager (Tools : Board) otherwise the sketch will not compile correctly.

Serial port configuration

Currently, three types of serial port are supported:

1. HardwareSerial – a hardware UART port connected to physical Rx/Tx pins. The default port (*Serial*, Rx0, Tx0) is usually connected to the USB post. When the serial port is opened over USB, the board is reset, triggering the bootloader, which, in turn, allows the board to be programmed.
2. SoftwareSerial – this is a software port provided by the SoftwareSerial library and can be set up using a PWM pin to transmit, thereby emulating a real serial port.

3. USB CDC – a virtual serial port emulated over USB and provided by USB-core. This type of port is not usually broken out to physical pins. It is present on boards with the 32u4 MCU (Micro, Leonardo), which aslo have a HardwareSerial port that can be accessed via the TXO/RXI pins. The board is NOT reset when a serial port is opened via USB.

Selection of ports will depend on the type of board being used and to some extent this is automatically determined depending on the board type. However, since some boards provide mutiple ports, some manual configuration will be required if serial ports other than the default are to be used. This will depend on the facilities provided by the target board:

Uno/Nano:
These boards have only one UART and only one HardwareSerial port, called *Serial* which is connected to USB. They are configured in the *__AVR_Atmega328P__* section. An additional SoftwareSerial port could be created by using PWM pin 6 for transmit, and pin 13 for receive. Typically, configuration in this section will be as follows:

```
#define AR_HW_SERIAL
#define AR_SERIAL_PORT Serial
```

This will configure the AR488 to use the default serial port over USB for communications. To use a SoftwareSerial port instead, it is necessary to first comment out the above, and then set:

```
#define AR_SW_SERIAL
```

and then set the pins to use with:

```
 #define AR_SW_SERIAL_RX 13
 #define AR_SW_SERIAL_TX 6
```

Communication will then be via the SoftwareSerial port. This means that there will be no communication over USB. The USB connection can still be used to program the board.

Mega 2560
The Mega 2560 supports four HardwareSerial ports. The default port (*Serial*) is connected to USB, but the remaining 3 ports (*Serial1*, *Serial2* and *Serial3*) are implemented on pairs of Tx/Rx pins and can be used as an alternative to *Serial* for serial communications. Of course, SoftwareSerial could also be used to implement an additional port, but due to the availability of additional hardware ports on the Mega 2560, this is unlikely to be required. Due to the arrangment of the Arduino pin assigments to port registers, the default AR488 layout for the pinout makes use of the pins assigned to *Serial2* for GPIB signals, so *Serial2* is unavailable for use by the AR488, unless the layout is modified.

Configuration is set in the *__AVR_Atmega2560__* section, which typically will contain:

```
  #define AR_HW_SERIAL
  #define AR_SERIAL_PORT Serial
  //#define AR_SERIAL_PORT Serial1
  //#define AR_SERIAL_PORT Serial3
```

This will configure the AR488 to use the default serial port over USB for communications. An aternative port can be selected by uncommenting it and commented out ALL other ports in the this section. Only ONE port should be uncommented, and therefore selected, in this section.

Mega 32u4
The Mega 32u4 as used on Arduino Micro and Leonardo boards has two serial ports. The port named *Serial* is the USB CDC virtual port. USB can be configured to provide several virtual serial ports simmultaneously over one USB connection. The second port is *Serial1*, which is assigned to pins RXI and TXO (receive input and transmit output).

By default, the configuration, which is set in the *__AVR_Atmega32U4__* section, should be:

```
#define AR_CDC_SERIAL
#define AR_SERIAL_PORT Serial
```

This will configure the AR488 to communicate over the USB CDC virtual serial port. If *Serial1* is to be used instead, then the above should be commented out and the following used instead:

```
#define AR_HW_SERIAL
#define AR_SERIAL_PORT Serial1
```

Please note that, when using SoftwareSerial, the maximum baud rate that can be achieved reliably is 57600 baud.

Please note also, that when using USB CDC ports, the board will NOT be reset when a serial connection is made. The rest button bust be pressed in order to program the board via USB.

Detection of SRQ and ATN pin states

Arduino AVR boards support interrupts to detect a change in pin states. Interrupts usually respond faster then in-loop checking of states and were implemented for the UNO, NANO and MEGA boards. When a specific board template has been selected, (see Board Selection), then USE_INTERRUPTS will be activated by default.

Where boards do not support interrupts or a custom layout is being used, it is intead possible to detect pin states within the void loop() structure of the sketch. When AR488_CUSTOM is selected, or a non-AVR or unknown board is the target, the USE_PINHOOKS option will be selected.

For manual configuration, only ONE of the following options should be selected:

```
#define USE_PINHOOKS

#define USE_INTERRUPTS
```

The default for supported AVR boards is USE_INTERRUPTS.

Macro support

Macros are short sequences of commands that can be used to accomplish a particular task. Controlling an instrument usually requires sequences of commands to be sent to the device to configure it, or to perform a particular task. Sometimes such sequences are performed frequently or repetitively. In those circumstances, it may be more efficient to pre-program the required sequence and then execute it when required using a single command.

The AR488 supports a macro feature which allows user programmed command sequences to be run when the interface start-up, as well as up to 9 user defined command sequences to be executed at runtime.

Macros must be programmed before the sketch is compiled and uploaded it to the interface. Macros can be added to the designated AR488 MACROS SECTION in the AR488_Config.h file. Both interface ++ commands and direct instrument commands can be included in macros. Programming specific instruments is beyond the scope of this manual as commands will be specific to each instrument or implemented according to the manufacturers choice of programming language or protocol. However, in general, in order to create macros, a few simple rules will need to be followed.

Firstly, macros need to be enabled. In the AR488_Config.h file there are two definitions under the heading ‘Enable Macros’:

```
#define USE_MACROS    // Enable the macro feature
#define RUN_STARTUP   // Run MACRO_0 (the startup macro)
```

The `#define USE_MACROS` construct controls the availability of the macro feature. When this line is commented out by preceding it with `//` (double forward slash), macros are disabled. Neither the start-up macro (MACRO_0), nor any of the user macros can be run when macros are disabled. When not commented out as shown above, macros are enabled and the 9 user defined macros can now be executed by the user at runtime by using the *++macro* command. For further information please see the *++macro* command heading in the Command Reference.

The `#define RUN_STARTUP` construct controls the start-up macro. This is designated MACRO_0 and runs when the interface is powered on or reset.

In addition to interface settings that can be saved using the *++savecfg* command, the start-up macro can be used, not only to set up the interface, but also to initialise and configure the instrument for a specific function. In this way, instrument commands that select function, range and other control features can be sent automatically as the interface starts up.

Unless steps have been taken to disable the automatic reset that occurs when a USB serial connection is opened to the interface, the start-up macro will run every time that a serial connection is initiated to the interface. Disabling the reset prevents the Arduino from being programmed via USB, so is not advised unless the intention is to program the Arduino using a suitable AVR programmer.

In the AR488_Config.h file, sketch, below the help information there is a section that starts:

```
/*******************************/
/***** AR488 MACROS SECTION *****/
/***** vvvvvvvvvvvvvvvvvvvv *****/
#ifdef USE_MACROS
```

Macros are defined here. The first macro is the startup macro, an example of which might be defined as follows:

```
#define MACRO_0 "\
++addr 9\n\
++auto 2\n\
*RST\n\
:func 'volt:ac'
"
/* End of MACRO_0 (Startup macro)*/
```

Note that the macro code itself, is shown in **bold,** and has been inserted immediately after the #define MACRO_0 line and before the ending comment:

```
#define MACRO_0 "\
macro
"
/*<-End of startup macro*/.
```

All macro commands comprising the macro must be placed after the '\' on the first line and before the final quote on the line before the ending comment. Nothing outside of these lines, including the quote marks and the '\' and after the macro name should be modified. The final quote mark can be appended to the last command in the sequence if preferred. It is shown here on a separate line for clarity. Everything between the two quote marks is a string of characters and must be delimeted. The '\' character indicate to the pre-processor that the string continues on the next line. Each command ends with '\n' which is the newline terminator and serves to delimit each command. The actual sequence shown above is therefore comprised of 4 commands, each comand ending with '\n' and then a '\' to indicate that the next command is to follow on the next line. Try to avoid leaving or including any unneccessary spaces.

Each of these commands is either a standard AR488 interface command found in the command reference, or an instrument specific command. All AR488 interface Prologix style commands begin with `++` so the first two commands set the GPIB address to *7* and *auto* to *1*. The next two commands are direct instrument commands using the SCPI protocol, the first of which resets the instrument and the second selects the instrument AC voltage function.

As shown, each command must be terminated with a `\n` (newline) or `\r` (carriage return) delimiter character.

User defined macros that can be run using the *++macro* command follow next, and have a similar format, e.g:

```
#define MACRO_2 "\

"
/*<-End of macro 2*/
```

Once again, the required command sequence must be placed between the two quotes and after the first '/' and be terminated with a `\n` or `\r` delimiter. Each line must be wrapped with '\'.

There is a slightly shorter method of defining a macro by placing all commands on a single line. For example this:

```
#define MACRO_1 "++addr 7\n++auto 1\n*RST\n:func 'volt:ac'"
```

Is exactly the same as this:

```
#define MACRO_1 "\
++addr 7\n\
++auto 1\n\
*RST\n\
:func 'volt:ac'\
"
```

The first definition is more condensed and requires no line wrap characters, but it is perhaps easier to see what is going on in the latter example. Either will function just the same and take up the same amount of memory.

The macro definition area provided in the sketch ends with:

```
#endif
/***** ^^^^^^^^^^^^^^^^^^^^ *****/
/***** AR488 MACROS SECTION *****/
/********************************/
```

Anything outside of this section does not relate to macros.

Provided that the commands have been specified correctly and the syntax is correct, the sketch should compile and can be uploaded to the Arduino. The start-up macro will run as soon as the upload is completed so the instrument should respond immediately. Please be aware that, unless serial reset has been disabled, it will run again when a USB serial connection is made to the interface. The instrument will probably respond and reconfigure itself again.

Please note that, although AR488 interface `++` commands are verified by the interface, and will respond accordingly, there is no sanity checking by the interface of any direct instrument commands. These command sequences are sent directly to the instrument, which should respond as though the command sequence were typed directly into the terminal or sent from a suitable instrument control program. Please consult the instrument user manual for information about the behaviour expected in response to instrument commands.

Macro sequences can include any number delimiter separated of commands, but any individual command sequence should not exceed 126 characters. This may be particularly relevant to SCPI commands which can be composed of multiple instructions separated by colons.

Bluetooth Options

This section is used to configure Bluetooth options. Bluetooth is currently unsupported in this version of the AR488 interface.

Debug options

These need not be configured and are for testing only. For normal operation these macros should be commented out.

```
//#define DEBUG1  // getCmd
//#define DEBUG2  // setGpibControls
//#define DEBUG3  // gpibSendData
//#define DEBUG4  // spoll_h
//#define DEBUG5  // attnRequired
//#define DEBUG6  // EEPROM
//#define DEBUG7  // gpibReceiveData
//#define DEBUG8  // ppoll_h
```

Custom Board Layout Section

The custom board layout section in the Config.h file can be used to create a custom pin layout for the AR488. This can be helpful for non-Arduino boards and where an adjustment to the layout is required in order to accommodate additional hardware.

By default, the dection definition implements the Uno layout:

```
#define DIO1  A0  /* GPIB 1  */
#define DIO2  A1  /* GPIB 2  */
#define DIO3  A2  /* GPIB 3  */
#define DIO4  A3  /* GPIB 4  */
#define DIO5  A4  /* GPIB 13 */
#define DIO6  A5  /* GPIB 14 */
#define DIO7  4   /* GPIB 15 */
#define DIO8  5   /* GPIB 16 */

#define IFC   8   /* GPIB 9  */
#define NDAC  9   /* GPIB 8  */
#define NRFD  10  /* GPIB 7  */
#define DAV   11  /* GPIB 6  */
#define EOI   12  /* GPIB 5  */

#define SRQ   2   /* GPIB 10 */
#define REN   3   /* GPIB 17 */
#define ATN   7   /* GPIB 11 */
```

To make use of a custom layout, *AR488_CUSTOM* must be selected from the list of boards at the beginning of the Config.h file and the pin numbers/designations in the centre column (shown in bold) should be configured as required.

Please note that on some MCU boards, a number of GPIO pins may not be available as inputs and/or outputs despite a pad or connector being present. Please check the board documentation. Sometimes such information is revealed only in online forum discussions or blogs. For any board other than the Uno or Mega, it will probably be necessary to turn off USE_PCINTS and enable USE_PINHOOKS instead. It may also be neccessary to comment out *#define USE_SERIALEVENT* to remove dependence on the Serial event interrupt.

Command Reference

The controller implements the standard commands prefixed with two plus (++) character sequence to indicate that the following sequence is an interface command. Commands, with the exception of the *++savecfg* command, should be fully compatible with the Prologix GPIB-ETHERNET controller. However, the interface also implements a number of additional custom commands.

++addr

This is used to set or query the GPIB address. At present, only primary addresses are supported. In controller mode, the address refers to the GPIB address of the instrument that the operator desires to communicate with. The address of the controller is 0. In device mode, the address represents the address of the interface which is now acting as a device.

When issued without a parameter, the command will return the current GPIB address.

Modes: controller, device

Syntax: ++addr [1-29]
where 1-29 is a decimal number representing the primary GPIB address of the device.

++auto

Configure the instrument to automatically send data back to the controller. When auto is enabled, the user does not have to issue ++read commands repeatedly. This command has additional options when compared with the Prologix version.

When set to zero, auto is disabled.

When set to 1, auto is designed to emulate the Prologix setting. The controller will automatically attempt to read a response from the instrument after any instument command or, in fact, any character sequence that is not a controller command beginning with '++', has been sent.

When set to 2, auto is set to "on-query" mode. The controller will automatically attempt to read the response from the instrument after a character sequence that is not a controller command beginning with '++' is sent to the instrument, but only if that sequence ends in a '?' character, i.e. it is a query command such as '*IDN?'.

When set to 3, auto is set to "continuous" mode. The controller will execute continuous read operations after the first ++read command is issued, returning a continuous stream of data from the instrument. The command can be terminated by turning off auto with ++auto 0 or performing a reset with ++rst.

Modes: controller

Syntax: ++auto [0|1|2|3]
where 0 disables and 1 enables automatically sending data to the controller

Note:
Some instruments generate a "Query unterminated or "-420" error if they are addressed after sending an instrument command that does not generate a response. This simply means that the instrument has no information to send and this error may be ignored. Alternatively, auto can be turned off (++auto 0) and a ++read command issued following the instrument command to read the instrument response.

++clr

This command sends a Selected Device Clear (SDC) to the currently addressed instrument. Details of how the instrument should respond may be found in the instrument manual.

Modes: controller

Syntax: ++clr

++eoi

This command enables or disables the assertion of the EOI signal. When a data message is sent in binary format, the CR/LF terminators cannot be differentiated from the binary data bytes. In this circumstance, the EOI signal can be used as a message terminator. When ATN is not asserted and EOI is enabled, the EOI signal will be briefly asserted to indicate the last character sent in a multi-byte sequence. Some instruments require their command strings to be terminated with an EOI signal in order to properly detect the command.

The EOI line is also used in conjunction with ATN to initiate a parallel poll, however, this command has no bearing on that activity.

When issued without a parameter, the command will return the current configuration

Modes: controller, device

Syntax: ++eoi [0|1]
where 0 disables and 1 enables asserting EOI to signal the last character sent

++eos

Specifies the GPIB termination character. When data from the host (e.g. a command sequence) is received over USB, all non-escaped LF, CR or Esc characters are removed and replaced by the GPIB termination character, which is appended to the data sent to the instrument. This command does not affect data being received *from* the instrument.

When issued without a parameter, the command will return the current configuration

Modes: controller, device

Syntax: ++eos [0|2|3|4]
where 0=CR+LF, 1=CR, 2=LF, 3=none

++eot_enable

This command enables or disables the appending of a user specified character to the USB output from the interface to the host whenever EOI is detected while reading data from the GPIB port. The character to send is specified using the ++eot_char command.

When issued without a parameter, the command will return the current configuration.

Modes: controller, device

Syntax: ++eot_enable [0|1]
where 0 disables and 1 enables sending the EOT character to the USB output

++eot_char

This command specifies the character to be appended to the USB output from the interface to the host whenever an EOI signal is detected while reading data from the GPIB bus. The character is a decimal ASCII character value that is less than 256.

When issued without a parameter, the command will return a decimal number corresponding to the ASCII character code of the current character.

Modes: controller, device

Syntax: ++eot_char [<char>]
where <char> is a decimal number that is less than 256.

++help

Not currently supported

++ifc

Assert the GPIB IFC signal for 150 microseconds, making the AR488 the Controller-in-Charge on the GPIB bus.

Modes: controller

Syntax: ++ifc

++llo

Disable front panel operation on the currently addressed instrument. In the original HPIB specification, sending the LLO signal to the GPIB bus would lock the LOCAL control on ALL instruments on the bus. In the Prologix specification, this command disables front panel operation of the addressed instrument only, in effect taking control of that instrument. The AR488 follows the Prologix specification, but adds a parameter to allow the simultaneous assertion of remote control over all instruments on the GPIB bus as per the HPIB specification.

This command requires the Remote Enable (REN) line to be asserted otherwise it will be ignored. In controller mode, the REN line is asserted by default unless its status is changed by the ++ren command.

When the ++llo command is issued without a parameter, the LLO signal is sent to the addressed instrument and this locks out the LOCAL key on the instrument control pannel. Because the instrument has been addressed and REN is already asserted, the command automatically takes remote control of the instrument. Most instruments will display REM on their control screen and all front panel controls will be disabled.

If the ++llo command is issued with the 'all' parameter, it will lockout the LOCAL key on every instrument on the GPIB bus. However REM will not be displayed until the instrument is individually addressed. It is still possible to regain local control by pressing LOCAL on the instrument control panel. However, once the instrument is addressed and sent another command, the controller will automatically lock in remote control to that instrument and all front panel controls will be disabled.

Modes: controller

Syntax: ++llo [all]

++loc

Relinquish remote control and re-enable front panel operation of the currently addressed instrument. This command relinquishes remote control of the instrument by de-asserting REN and sending the GTL signal.

The Remote Enable (REN) line must be asserted and the instrument must already be under remote control otherwise the command has no effect.

In the original HPIB specification, this command would re-enable the LOCAL key on the instrument control panel on ALL instruments currently connected to the GPIB bus. In the Prologix specification, this command relinquishes remote control of the currently addressed instrument only. The AR488 follows the Prologix specification, but adds a parameter to allow the simultaneous release of remote control over all instruments currently addressed as listeners on the GPIB bus as per the HPIB specification.

If the command is issued without a parameter, it will re-enable the LOCAL key on the control panel on the currently addressed instrument and relinquish remote control of the instrument. If issued with the 'all' parameter, it put all devices on the GPIB bus in local control state.

Modes: controller

Syntax:++loc [all]

++lon

Currently unsupported.

++mode

This command configures the AR488 to serve as a controller or a device.

In controller mode the AR488 acts as the Controller-in-Charge (CIC) on the GPIB bus, receiving commands terminated with CRLF over USB and sending them to the currently addressed instrument via the GPIB bus. The controller then passes the received data back over USB to the host.

In device mode, the AR488 can act as another device on the GPIB bus. In this mode, the AR488 can only be set as a GPIB talker or listener and expects to receive commands from another controller (CIC). All data received by the AR488 is passed to the host via USB without buffering. All data from the host via USB is buffered until the AR488 is addressed by the controller to talk. At this point the AR488 sends the buffered data to the controller. Since the memory on the controller is limited, the AR488 can buffer only 120 characters at a time.

If the command is issued without a parameter, the current mode is returned.

Modes: controller, device

Syntax: ++mode [0|1]
where 0=device, 1=controller

++read

This command can be used to read data from the currently addressed instrument. Data is read until:

- the EOI signal is detected
- a specified character is read
- timeout expires

Timeout is set using the *read_tmo_ms* command and is the maximum permitted delay for a single character to be read. It is not related to the time taken to read all of the data. For details see the description of the *read_tmo_ms* command.

Modes: controller

Syntax: ++read [eoi|<char>]
where <char> is a decimal number corresponding to the ASCII character to be used as a terminator and must be less than 256.

++read_tmo_ms

This specifies the timeout value, in milliseconds, that is used by the ++read (and ++spoll) commands to wait for a character to be transmitted while reading data from the GPIB bus. The timeout value may be set between 0 and 32,000 milliseconds (32 seconds).

Modes: controller

Syntax: ++read_tmo_ms <time>
where <time> is a decimal number between 0 and 32000 representing milliseconds

++rst

Perform a reset of the controller.

Modes: controller, device

Syntax: ++rst

++savecfg

This command saves the current interface configuration. On the Prologix interface setting this to 1 would enable the saving of specific parameters whenever they are changed, including addr, auto, eoi, eos, eot_enable, eot_char, mode and read_tmo_ms.

Frequent updates wear out the EEPROM and the Arduino EEPROM has a nominal lifetime of 100,000 writes. In order to minimize writes and preserve the longevity of the EEPROM memory, the AR488 does not, at any time, write configuration parameters “on the fly” every time they are changed. Instead, issuing the *++savecfg* command will update the complete current configuration once. Only values that have changed since the last write will be written.

The configuration written to EEPROM will be automatically re-loaded on power-up. The configuration can be reset to default using the *++default* command and a new configuration can be saved using the *++savecfg* command.

Most, if not all Arduino AVR boards support EEPROM memory, however boards from other vendors may not provide this support. If the command is run on a board that does not support EEPROM, then the following will be returned:

EEPROM not supported.

The *++savecfg* command will save the following current parameter values: addr, auto, eoi, eos, eot_enable, eot_char, mode, read_tmo_ms and verstr.

Modes: controller, device

Syntax: ++savecfg

++spoll

Performs a serial poll. If no parameters are specified, the command will perform a serial poll of the currently addressed instrument. If a GPIB address is specified, then a serial poll of the instrument at the specified address is performed. The command returns a single 8-bit decimal number representing the status byte of the instrument.

The command can also be used to serial poll multiple instruments. Up to 15 addresses can be specified. If the *all* parameter is specified (or the command ++allspoll is used), then a serial poll of all 30 primary instrument addresses is performed.

When polling mulitple addresses, the *++spoll* command will return the address and status byte of the first instrument it encounters that has the RQS bit set in its status byte, indicating that it has requested service. The format of the response is SRQ:addr,status, for example: SRQ:3,88 where 3 is the GPIB address of the instrument and 88 is the status byte. The response provides a means to poll a number of instruments and to identify which instrument raised the service request, all in one command. If SRQ was not asserted then no response will be returned.

When *++srqauto* is set to 1 (for details see the ++srqauto custom command), the interface will automatically conduct a serial poll of all devices on the GPIB bus whenever it detects that SRQ has been asserted and the details of the instrument that raised the request are automatically returned in the format above.

Modes: controller

Syntax: ++spoll [<PAD>|all|<PAD1> <PAD2> <PAD3>…]

where <PAD> and <PADx> are primary GPIB address and *all* specifies that all instruments should be polled

++srq

This command returns the present status of the SRQ signal line. It returns 0 if SRQ is not asserted and 1 if SRQ is asserted.

Modes: controller

Syntax: ++srq

++srqauto

In controller mode, this command enables or disables automatic execution of a serial poll when SRQ is asserted. Without parameters, this command returns the present status of the SRQauto. It returns 0 if a serial poll is not aautomatically exectured (default) and 1 if a serial poll is automatically executed.

Modes: controller

Syntax: ++srqauto [0|1]

++status

Set or display the status byte that will be sent in response to the serial poll command. When bit 6 of the status byte is set, the SRQ signal will be asserted indicating Request For Service (RQS). The table below shows the values assigned to individual bits as well as some example meanings that can be associated with them. Although the meaning of each bit will vary depending on the instrument and the manufacturer, bit 6 is always reserved as the RQS bit. Other bits can be assigned as required.

Bit7	*Bit6*	*Bit5*	*Bit4*	*Bit3*	*Bit2*	*Bit1*	*Bit0*
128	64	32	16	8	4	2	1
Always zero	**RQS**	Calibration enabled or error	Output available. Front/rear switch.	Remote control	Auto-zero	Autorange enabled. Front/rear switch.	Operational error.

The values of the bits to be set can be added together to arrive at the desired status byte value. For example, to assert SRQ, a value of 64 would be sufficient. However if we wanted to use bit 1 to indicate an operational error, then a value of 65 might be used in the event of the error occurring.

Modes: device

Syntax: ++status [byte]
where byte is a decimal number between 0 and 255.

++trg

Sends a Group Execute Trigger to selected devices. Up to 15 addresses may be specified and must be separated by spaces. If no address is specified, then the command is sent to the currently addressed instrument. The instrument needs to be set to single trigger mode and remotely controlled by the GPIB controller. Using ++trg, the instrument can be manually triggered and the result read with ++read.

Modes: controller

Syntax: ++trg [pad1 … pad15]

++ver

Display the controller firmware version. If the version string has been changed with ++setvstr, then ++ver will display the new version string. Issuing the command with the parameter ‘real’ will always display the original AR488 version string.

Modes: controller, device

Syntax:++ver [real]

Custom commands

This section details ++ commands that are not part of the original Prologix implementation but represent custom commands that have been added and are specific to the AR488 firmware.

++allspoll

Alias equivalent to *++spoll all*. See *++spoll* for further details.

++dcl

Send Device Clear (DCL) to all devices on the GPIB bus.

Modes: controller

Syntax: ++dcl

++default

This command resets the AR488 to its default configuration.

When powered up, the interface will start with default settings in controller mode. However, if the configuration has been saved to EEPROM using the *savecfg* command, the controller will start with the previously saved settings. This command can be used to reset the controller back to its default configuration.

NOTE: unless the *++savecfg* command is used to overwrite the previously saved configuration, the previous configuration will be re-loaded from non-volatile memory the next time that the interface is powered up. Therefore, after using *++default*, configure the interface as required and use *++savecfg* to ensure that the new settings are applied on power up, or *++default* and then *++savecfg* without any further configuration to return the interface to its default state.

The interface is set to controller mode with the following parameters:

eot_enable	*false*
eot_char	*0*
eoi	*false*
controller mode	*true*
controller address	*0*
primary address	*1*
secondary address	*0*
status byte	*0*
read_tmo_ms	*1200*
version string	*default version string*

Modes: controller, device

Syntax: ++default

++macro

Instrument control usually requires a sequence of commands to be sent to the instrument to set it up or to perform a particular task. Where such a sequence of commands is performed regularly and repeatedly, it is beneficial to have a means to pre-program the sequence and to be able to run it with a single command.

The AR488 allows up to 9 sequences to be programmed into the Arduino sketch that can be run using the ++macro command. When no parameters have been specified, the macro command will return a list of numbers indicating which macros have been defined and are available to use. When called with a single number between 1 and 9 as a parameter, the command will run the specified macro.

Programming macros is beyond the scope of this manual and will be specific to each instrument or implemented programming language or protocol.

Modes: controller

Syntax: ++macro [1|9]

++ppoll

When many devices are involved, Parallel Poll is faster than Serial Poll but is not widely used. With a Parallel Poll, the controller can query up to eight devices quite efficiently using the DIO lines. Since there are 8 DIO lines, up to 8 devices can be queried at once. In order to get an unambiguous response, each device should ideally assign to a separate data line. Devices assigned to the same line are simply OR'ed. Devices respond to the parallel poll by asserting the DIO line they have been assigned.

Response to a Parallel Poll is a data byte corresponding to the status of the DIO lines when the Parallel Poll request is raised. The state of each individual bit of the 8-bit byte corresponds to the state of each individual DIO line. In this way it is possible to determine which instrument raised the request.

Because a single bit can only be 0 or 1, the response to a parallel poll is binary, simply indicating whether or not an instrument has raised the request. In order to get further status information, a Serial Poll needs to be conducted on the instrument in question.

Modes: controller

Syntax: ++ppoll

++setvstr

Set the version string that the controller responds with on boot-up and in response to the *++ver* command. This may be helpful where software on the computer is expecting a specific string from a known controller, for example 'GPIB-USB'.

The *++ver* command can be used to confirm that the string has been set correctly.

Modes: controller, device

Syntax: ++verstr [string]
where [string] is the new version string

++srqauto

When conducting a serial poll using a Prologix controller, the procedure requires that the status of the SRQ signal be checked with the *++srq* command. If the response is a 1, indicating that SRQ is asserted, then an *++spoll* command can be issued to determine the status byte of the currently addressed instrument or optionally an instrument at a specific GPIB address.

When polling multiple devices, the AR488 will provide a custom response that includes the address and status byte of the first instrument encountered that has the RQS bit set. Usually, the *++spoll* command has to be issued manually to obtain this information.

When *++srqauto* is set to 1, the interface will automatically detect when the SRQ signal has been asserted by an instrument. The interface will then automatically conduct a serial poll and return the address and status byte of the first instrument encountered that has the RQS bit set in its status byte. If multiple instruments have asserted SRQ, then another serial poll is conducted to determine the next instrument that has requested service. The process continues until all instruments that have requested service have had their status byte read and the SRQ signal has been cleared.

Modes: controller

Syntax: ++srqauto [0|1]
where 0=disabled, 1=enabled

++repeat

Provides a way of repeating the same command multiple times, for example, to request multiple measurements from the instrument.

Between 2 and 255 repetitions can be requested. It is also possible to request a delay between 0 to 10,000 milliseconds (or 10 seconds) between each repetition. The parameter buffer has a maximum capacity of 64 characters, so the command string plus any parameters cannot exceed 64 characters in total. Once started, there is no mechanism to stop the repeat loop once it has begun.

The command will run the number of interations requested and stop only when the request is complete.

Modes: controller

Syntax: ++repeat count delay cmdstring
where:
count is the number of repetitions from 2 to 255
delay is the time to wait between repetitions from 0 to 10,000 milliseconds
cmdstring is the command to execute

++tmbus

The GPIB bus protocol is designed to allow the bus to synchronise to the speed of the slowest device. However, under some circumstances it may be desirable to slow down the bus. The *tmbus* parameter introduces a periodic delay of between 0 to 30,000 microseconds between certain operations on the bus and so slows down the operation of the GPIB bus. The greater the delay, the slower the bus will operate. Under normal running conditions this parameter should be set to zero, which is the default setting.

Modes: controller, device

Syntax: ++tmbus [value]
where [value] is between 0 and 30,000 microseconds

++verbose

Toggle verbose mode ON and OFF

Modes: controller, device

Syntax:++verbose

Building an AR488 GPIB Interface

Construction of an Arduino GPIB interface is relatively straightforward and requires a single Arduino UNO, NANO or MEGA2560 board, a length of cable that is at minimum 16-way and preferably screened, and an IEEE488 connector. An old GPIB cable could be re-purposed by removing one end, or an old parallel printer cable could be used, in which case a separate 24-way IEEE488 connector will need to be purchased.

New GPIB/IEEE488 cables are expensive. Cheaper cables can be found from various sellers on eBay. Connectors can be found by searching for ‘Centronics 24’ rather than ‘IEEE488’ or ‘GPIB’. In the UK, RS Components sell these as part number 239-1207, for £2.86. They can also be found on eBay. Old parallel printer cables can still be found on charity/thrift shops or on market stalls.

For connection details and wiring diagrams for specific boards, please see:

Appendix A – Uno and Nano
Appendix B – Mega 2560
Appendix C – Micro 32u4

Ideally, in a GPIB cable, ground pins 18, 19, 20, 21, 22, 23 should be connected to a ground wire that forms a twisted pair with the DAV, NRFD, NDAC, IFC, SRQ and ATN control wires, and a shielded twisted pair cable with sufficient multiple pairs would be required. However, if such a cable is not available, then linking them together and connecting them to GND on the Arduino side should suffice, especially if sufficient numbers of conductors are not available.

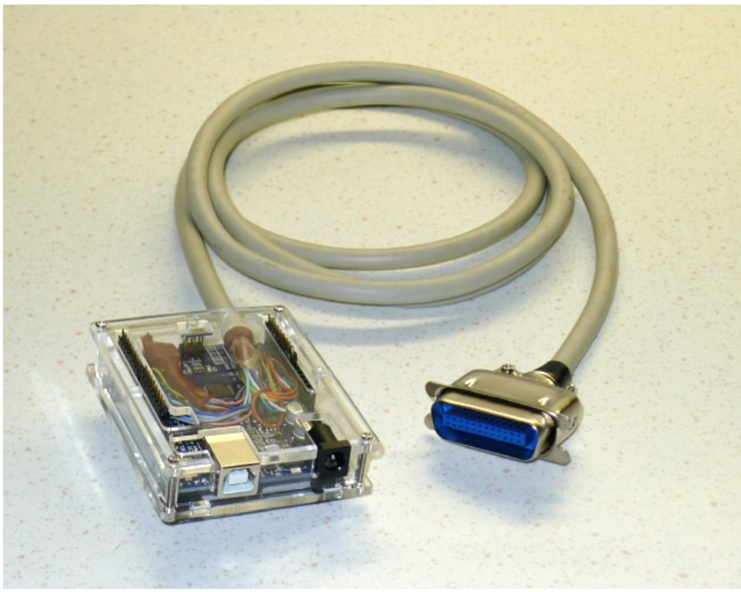
Further information can be found by following the links below:

Additional GPIB pinout information - Link 1
Additional GPIB pinout information - Link 2

Once the cable has been completed, the sketch should then be downloaded to the Arduino board and the interface should be ready to test. In order to provide multi-platform compatibility, the AR488 firmware sketch is modular and comes in several files:

Filename:	*Purpose:*
AR488.ino	This is the main AR488 firmware sketch
AR488_Config.h	This is the configuration file. All configuration options are set here.
AR488_Hardware.h	This is the hardware support C++ header file
AR488_Hardware.cpp	This is the harware support C++ program file

The firmware is supplied in a ZIP file. Download and unpack all files into a directory called AR488. Load the main sketch, AR488.ino into the Arduino IDE. This should open all files into separate tabs. Edit AR488_Config.h as required and save. The select the correct board from the list of boards within the Arduino IDE, Tools | Board menu option and compile and upload the sketch.


An example of a completed Arduino GPIB adapter

The following section details further hardware tweaks that may be required to make the board work correctly with specific GPIB software.

Working with EZGPIB and KE5FX

FTDI serial vs CH340G serial

EZGPIB is an IDE programming environment that can be used to work with GPIB devices. KE5FX provides testing tools that can be used with various instruments that support GPIB. Both programs support the Prologix interface and when communicating with it, both programs assert RTS and expect a CTS response to confirm that the interface is ready to accept data.

The CH340G chipset present in many Arduino compatible boards does not respond with the CTS signal. There appear to be two possible workarounds, one of which requires very good soldering skills. The RTS and CTS signals are exposed via pins 14 and 9 respectively on the CH340G chip. While pin 9 connects to an easily accessible pad for soldering, pin 14 is not connected to anywhere and because it is very small, attaching a wire to it is rather tricky. For this reason, workaround 2 is easier to implement. Disclaimer: please proceed only if you are confident in your soldering skills. I take no responsibility for damaged Arduino boards so if in doubt, ask a qualified or skilled person for assistance.

Workaround 1

The workaround requires that pin 14 be connected to pin 9 on the CH340G chip. When RTS is asserted by the host over USB, the signal is passed to the RTS output on pin 14 of the CH340G. This signal would ordinarily be passed to a serial hardware device which would respond by sending a response to the CTS input on pin 9 of the the CH340G to indicate that it is ready to send. The workaround passes this signal back to the CTS input via the link so that a CTS response will always be echoed back to the host over USB. While this does not provide proper RTS/CTS handshaking, it does allow the interface to respond with a CTS signal and, in turn, the host to be able to accept responses to the commands sent to the interface, even when RTS/CTS handshaking is used.

Workaround 2

Pin 9 of the CH340G needs to be connected to GND. This will keep CTS signal asserted on the Arduino at all times, so again, proper handshaking is not provided. Simply solder a short wire to the pad and connect to a convenient ground point.

A big thanks goes to Hartmut Päsler, who is currently looking after the EZGPIB program, for informing me that the CH340G exposes the RTS/CTS signals via pins and that it might be possible to make use of these pins to device a solution.

Where Arduino boards are recognized as FTDI serial devices, the functionality is embedded within the ATMEGA MEGA 16U2 chip. This chip does not expose the RTS/CTS signals so this modification is not possible nor is it required to work with the KE5FX toolkit. An Arduino board running with the 16U2 chip running AR488 will work fine with the KE5FX GPIB toolkit, but for some reason, it is not recognized by the EZGPIB program.

EZGPIB and the Arduino bootloader

On older Arduino boards it was necessary to press the reset button to program the board. This causes the board to reset and the bootloader to run. The bootloader will expect a particular sequence of bytes within a timeout period and it will then expect a new compiled sketch to be uploaded into memory. On completion of the upload, program control is passed to the newly uploaded code. The timing of the upload is rather tricky and if the timeout period expires or the upload is started too soon, then it will fail and the board will start with the current program code.

Current versions of the board allow code to be uploaded via USB without having to use the reset button. This is accomplished by triggering a reset of the board each time a serial connection is opened. The bootloader is then re-loaded and if the required sequence of bytes is received, and an upload of code proceeds automatically. When this is finished, program execution passes to the new code as before.

The problem with this is that the bootloader is loaded every time that the serial port is opened. This causes a delay of about 1 second before the compiled user program is actually run and the interface is initialised. EZGPIB (and possibly other programs) that do not re-try the connection attempt after waiting a second or so, fails to establish a connection to the interface. Closing the program and immediately trying again usually results in a successful connection.

The solution is to eliminate the delay caused by the board re-starting and the bootloader being re-loaded into memory. This can be done quite easily by placing a 10µF capacitor between the RST and GND pins on the Arduino. This causes the reset pulse, which is generated by activating the serial DTR signal, to be drained to ground without affecting the RESET input on the AtMega328P processor. Since it’s a capacitor, there is no direct DC coupling between RESET and GND. When the serial port is now opened, the interface will just respond without the delay caused by re-booting. Assuming the sequence “GPIB-USB” exists in the response to the ++ver command, EZGPIB will now recognize it first time.

The drawback of this approach is that placing a capacitor permanently in this position will prevent the Arduino IDE from being able to program the board. The reset button now has to be used or a switch added to provide an on to run, off to program facility.

Hacking the Ezgpib binary

If you are familiar with using a hex editor, there is another approach that involves editing the EZGPIB.EXE binary to prevent it looking for an RTS signal being asserted. If the standard Windows USBSER.SYS driver is used, this never happens, so EZGPIB will never find the GPIB adapter. This workaround involves changing a specific byte in the RTS Check routine.

Open up a copy of EXGPIB.EXE version 20121217 in a hex editor. Look for the HEX sequence:

```
F6 04 24 10 74 06
```

Note, that these instructions can also be found on http://www.dalton.ax/gpib/, but show the sequence as `F6` **`02`** `24 10 74 06`. I found the sequence to be as above. I’m not sure whether this is an error or because my binary is different from the one that the author was working with. If you can’t find the sequence with `04`, check for the one with `02`.

```
0013DDB053 8B D8 84 D2 74 07 B8 05 00 00 00 EB 05 B8 06S....t..........
0013DDC000 00 00 8B 93 82 00 00 00 83 FA FF 74 17 50 52............t.PR
0013DDD0E8 73 90 EC FF 66 8B 0D E8 E9 53 00 8B D3 8B C3.s...f....S.....
0013DDE0E8 97 01 00 00 5B C3 00 10 00 00 00 53 8B D8 84.....[......S...
0013DDF0D2 74 07 B8 03 00 00 00 EB 05 B8 04 00 00 00 8B.t..............
0013DE0093 82 00 00 00 83 FA FF 74 17 50 52 E8 37 90 EC........t.PR.7..
0013DE10FF 66 8B 0D 24 EA 53 00 8B D3 8B C3 E8 5B 01 00.f..$.S......[..
0013DE2000 5B C3 00 08 00 00 00 53 56 57 51 8B F0 8A 1D.[......SVWQ....
0013DE308C EA 53 00 8B BE 82 00 00 00 83 FF FF 74 44 54..S..........tDT
0013DE4057 E8 5A 90 EC FF 85 C0 74 39 F6 04 24 10 74 06W.Z.....t9..$.t.
```

That sequence is the check for RTS. Change the penultimate byte to 75, so that the sequence now reads:

F6 04 24 10 **75** 06

```
0013DDE0E8 97 01 00 00 5B C3 00 10 00 00 00 53 8B D8 84.....[......S...
0013DDF0D2 74 07 B8 03 00 00 00 EB 05 B8 04 00 00 00 8B.t..............
0013DE0093 82 00 00 00 83 FA FF 74 17 50 52 E8 37 90 EC........t.PR.7..
0013DE10FF 66 8B 0D 24 EA 53 00 8B D3 8B C3 E8 5B 01 00.f..$.S......[..
0013DE2000 5B C3 00 08 00 00 00 53 56 57 51 8B F0 8A 1D.[......SVWQ....
0013DE308C EA 53 00 8B BE 82 00 00 00 83 FF FF 74 44 54..S..........tDT
0013DE4057 E8 5A 90 EC FF 85 C0 74 39 F6 04 24 10 75 06W.Z.....t9..$.u.
0013DE508A 1D 90 EA 53 00 F6 04 24 20 74 09 A0 94 EA 53....S...$ t....S
0013DE6000 0A C3 8B D8 F6 04 24 40 74 09 A0 98 EA 53 00.......$@t....S.
0013DE700A C3 8B D8 F6 04 24 80 74 09 A0 9C EA 53 00 0A......$.t....S..
```

Now look for sequence:

24 04 10 0F 95

```
00125930E8 7B 01 00 00 84 C0 74 1E 80 7B 43 00 74 0D 6A.{.....t..{C.t.j
0012594003 8B 43 34 50 E8 FE 14 EE FF EB 0B 6A 04 8B 43..C4P.......j..C
0012595034 50 E8 F1 14 EE FF 5B C3 8D 40 00 53 8B D8 884P.....[..@.S...
0012596053 45 8B C3 E8 47 01 00 00 84 C0 74 1E 80 7B 45SE...G.....t..{E
0012597000 74 0D 6A 08 8B 43 34 50 E8 CA 14 EE FF EB 0B.t.j..C4P.......
001259806A 09 8B 43 34 50 E8 BD 14 EE FF 5B C3 8D 40 00j..C4P.....[..@.
0012599053 56 83 C4 F8 8B F0 C6 04 24 00 33 DB 8B C6 E8SV.......$.3....
001259A00C 01 00 00 84 C0 74 21 8D 44 24 04 50 8B 46 34......t!.D$.P.F4
001259B050 E8 EA 14 EE FF 83 F8 01 1B DB 43 84 DB 74 09P..........C..t.
001259C0F6 44 24 04 10 0F 95 04 24 88 5E 30 8A 04 24 59.D$.....$.^0..$Y
```

Change the last byte to 94 so that the sequence now reads:

24 04 10 0F **94**

```
0012595034 50 E8 F1 14 EE FF 5B C3 8D 40 00 53 8B D8 884P.....[..@.S...
0012596053 45 8B C3 E8 47 01 00 00 84 C0 74 1E 80 7B 45SE...G.....t..{E
0012597000 74 0D 6A 08 8B 43 34 50 E8 CA 14 EE FF EB 0B.t.j..C4P.......
001259806A 09 8B 43 34 50 E8 BD 14 EE FF 5B C3 8D 40 00j..C4P.....[..@.
0012599053 56 83 C4 F8 8B F0 C6 04 24 00 33 DB 8B C6 E8SV.......$.3....
001259A00C 01 00 00 84 C0 74 21 8D 44 24 04 50 8B 46 34......t!.D$.P.F4
001259B050 E8 EA 14 EE FF 83 F8 01 1B DB 43 84 DB 74 09P..........C..t.
001259C0F6 44 24 04 10 0F 94 04 24 88 5E 30 8A 04 24 59.D$.....$.^0..$Y
001259D05A 5E 5B C3 53 56 83 C4 F8 8B F0 C6 04 24 00 33Z^[.SV.......$.3
001259E0DB 8B C6 E8 C8 00 00 00 84 C0 74 21 8D 44 24 04..........t!.D$.
```

Save the file and close the hex editor. EZGPIB should now find your adapter.

Multiple Arduinos on the bus and problems with instruments

The AR488 can be used in both controller mode and device mode. Only ONE controller can be active at any one time. When there is just one Arduino controller on the bus controlling one or more instruments, this does not present a problem, provided that the Arduino is operating within its current handling limits.

However, it is possible to have one AR488 as operating as a controller and another as a device simultaneously on the bus along with other instruments. In this situation, problems can arise when and Arduino is on the BUS but is powered down. This is manifest by instruments failing to respond to the ++read or other commands, to direct instrument commands or both.

The reason for this is because when powered down, Arduino control pins do not present with a high impedance. In a powered down state, voltages present on the various signal and data lines are passed via protection diodes internal to the ATMega processor, to the +VCC rail on the powered down interface. This then causes all pins on the unpowered Arduino to effectively go HIGH. Furthermore, enough power may be present on the +VCC rail to at least partially power the processor, which, even if it does manage to operate, is likely to do so in an unpredictable manner the result of which may be interference with the proper functioning of other equipment on the GPIB bus. This is a parasitic power phenomenon that is not specific to Arduino microcontrollers and affects various other devices too. Further information can be found here:

https://www.eevblog.com/forum/blog/eevblog-831-power-a-micro-with-no-power-pin!/

Consequently, unpowered Arduino devices will adversely affect other devices on the GPIB bus. It is therefore essential to either keep Arduino devices powered on, or physically disconnected from the bus. This is NOT an issue when there is just ONE Arduino-based GPIB controller remotely controlling instruments on a bus. Therefore, other than when an Arduino is operating as a controller, it is not recommended to leave unpowered Arduino's connected to the bus.

Arduino brownout detection setting

The first three bits of the Arduino extended fuse determine the brownout detection (BOD) setting. BOD will hold the processor in the reset state when the power rail volktage falls below a specific threshold. There are three lthreshold levels that can be set depending on the bits that is set.

On the boards that were used for development, the default setting of the Extended Fuse seems to be FD, which means that the last three bist will be 101 and therefore that the BOD level is set to BODLEVEL1.

It has been reported that when BOD is disabled (e.g. fuse set to FF) and the Arduino signal pins are connected to power, that under some circumstances the Arduino flash memory can get corrupted and the sketch will have to be downloaded again. It is therefore inadvisable to disable BOD on an Arduino being used as a GPIB interface.

Arduino BOD settings are as follows:

BOD Level:	*Bit setting*	*Threshold*
DISABLED	111	BOD disabled
BODLEVEL0	110	1.7 – 2.0v (avg 1.8v)
BODLEVEL1	101	2.5 – 2.9v (avg 2.7v)
BODLEVEL2	100	4.1 – 4.5v (avg 4.3v)

To check the extended fuse setting, the following AVRDUDE command line can be used:

UNO/NANO:
avrdude -P /dev/ttyACM0 -b 19200 -c usbasp -p m328p -v

MEGA 2560:
avrdude -P /dev/ttyACM0 -b 115200 -c usbasp -p m2560 -v
MEGA 32u4:
avrdude -P /dev/ttyACM0 -b 115200 -c usbasp -p m32u4 -v

The ATMega328p part can be specified as *-p m328p* or *-p atmega328p*. The Mega 2560 and Mega 32u4 can also be specified using either convention. If your Arduino has a 328pb processor IC, then this will have a different signature to the 328p and the -p parameter needs to be specified as *-p m328pb* or *-p atmega328pb*.

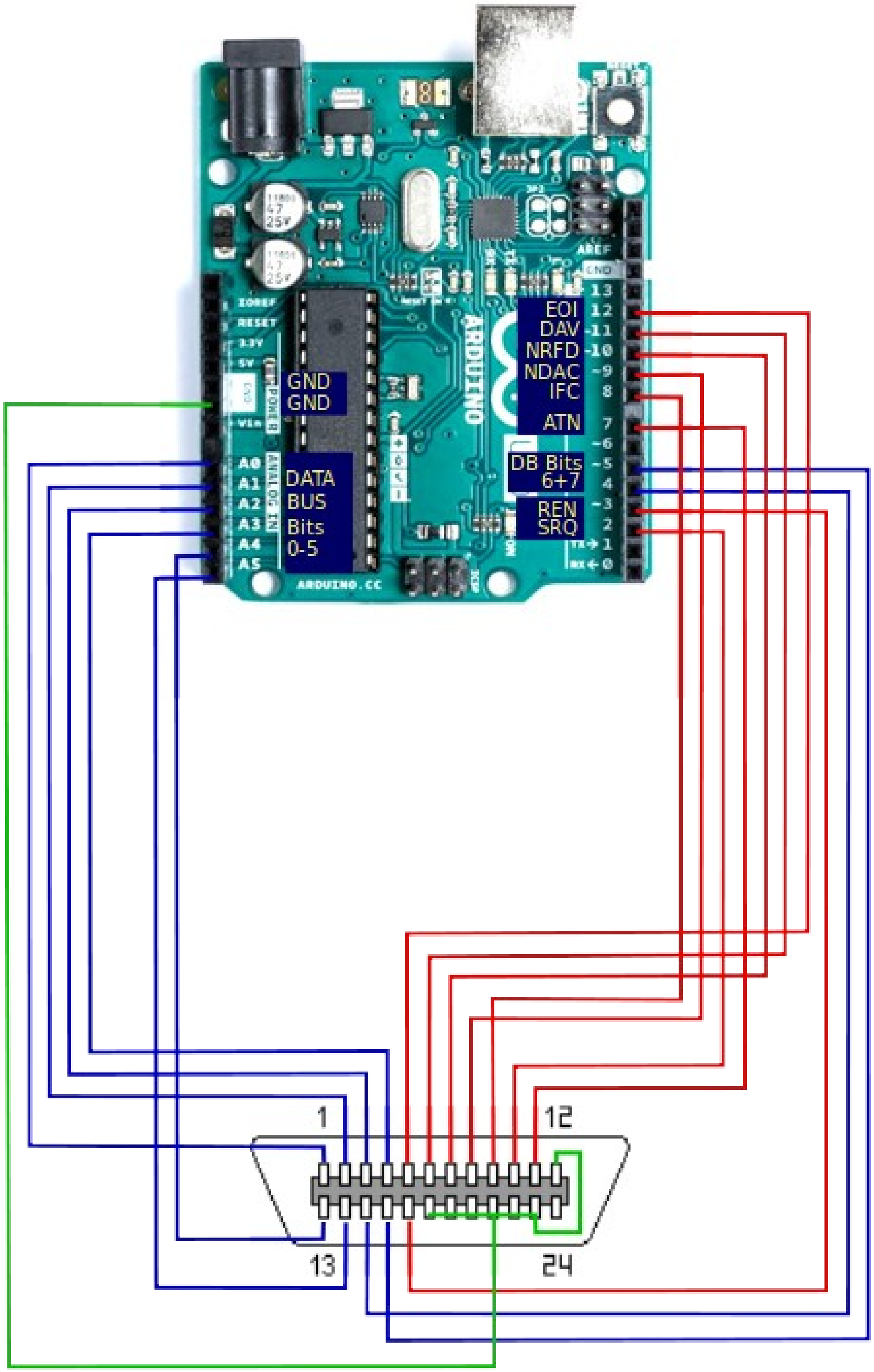
Appendix A – Connection and technical information for Uno and nano boards

Connection details:

These connections are required between the Arduino UNO/Nano and the IEEE488 connector:

Arduino:	*GPIB connector:*	*Function:*
D2	10	SRQ
D3	17	REN
D7	11	ATN
D8	9	IFC
D9	8	NDAC
D10	7	NRFD
D11	6	DAV
D12	5	EOI
A0	1	DIO1
A1	2	DIO2
A2	3	DIO3
A3	4	DIO4
A4	13	DIO5
A5	14	DIO6
D4	15	DIO7
D5	16	DIO8
GND	12	Shield
GND	18,19,20,21,22,23	GND

Wiring diagram:



Appendix B – Connection and technical information for Mega 2560 boards

Connection details:

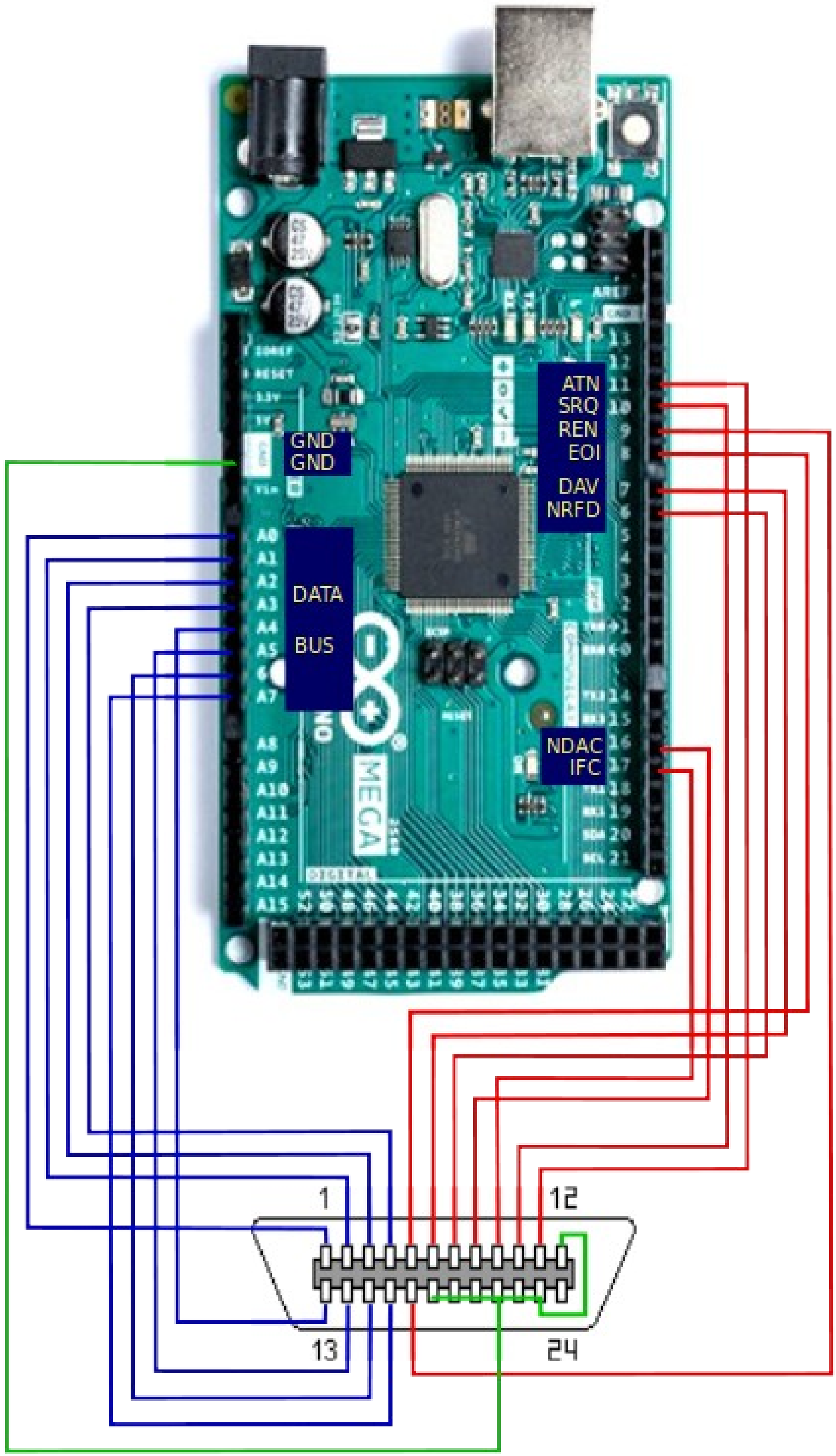
The pinout on the Mega 2560 is as follows:

Arduino:	*GPIB connector:*	*Function:*
D6	7	NRFD
D7	6	DAV
D8	5	EOI
D9	17	REN
D10	10	SRQ
D11	11	ATN
D16	8	NDAC
D17	9	IFC
A0	1	DIO1
A1	2	DIO2
A2	3	DIO3
A3	4	DIO4
A4	13	DIO5
A5	14	DIO6
A6	15	DIO7
A7	16	DIO8
GND	12	Shield
GND	18,19,20,21,22,23	GND

The layout on the Mega was chosen so as to leave pins A8-A15 and the two rows of pins at the top of the board free for expansion including for displays and other peripherals.

Pins 16 and 17 correspond to Serial2. As these have been used for controlling signals on the GPIB bus, they cannot be used for serial communication. If *Serial2.begin* is added to the sketch, these pins will be enabled for serial communication and will no longer function as GPIB control signals. In addition to the default serial port (RX0 and TX0), Serial1 and Serial3 are still available for expansion if required. These two pins were chosen for GPIB signals as they belong to port H along with pins 6 – 9.

Wiring Diagram:



Appendix C – Connection and technical information for Mega 32u4 boards

Connection details:

The pinout on the Mega 32u4 is as follows:

Arduino:	*GPIB connector:*	*Function:*
A2	7	NRFD
A1	6	DAV
A0	5	EOI
D5	17	REN
D7	10	SRQ
D2	11	ATN
A3	8	NDAC
D4	9	IFC
D3	1	DIO1
D15	2	DIO2
D16	3	DIO3
D14	4	DIO4
D8	13	DIO5
D9	14	DIO6
D10	15	DIO7
D6	16	DIO8
GND	12	Shield
GND	18,19,20,21,22,23	GND