

AFRecorder 4800R Serial Port Programming Interface Description

For Software Version 9.5

(Last Revision 8-27-08)

Changes from Version 9.2

1. The communication baud rate is raised to 9600.
2. Testing with a PC as the host computer has shown that no delay is required between bytes sent to the AFRecorder. If overrun errors occur with your system, insert a 2ms delay between bytes sent to the AFRecorder.
3. All checksums are changed from 16bit to 8bit.
4. Checksums include all bytes of the packet including the header where applicable.
5. Checksums are calculated so that the unsigned 8bit sum of all bytes in the packet is zero.
6. The command strings for all three types of commands have been changed. All commands to the AFRecorder now contain a checksum.
7. Almost all commands are acknowledged by the AFRecorder.
8. Acknowledgement responses sent to the host computer have been changed.
9. The host computer must wait for one command to be acknowledged or completed before sending another command.
10. The header sent with the uploaded real-time data has been removed.
11. Uploaded real-time data is now uploaded in long-integer (32bit) format as (value)*65536.
12. The minimum real-time upload interval has been shortened to 0.04 seconds for both averaged and raw AFR data upload. The AFRecorder display is not disabled during real-time data upload.
13. The AFRecorder keypad is automatically disabled when "connected."
14. The index offset formerly used with the "Change Value" command has been removed. The indices listed in the "Change Value" section are now the same for both uploaded and downloaded data.

Background

The AFRecorder 4800 may be operated under remote control using a standard RS232 serial port. Available remote operating modes include two types of real-time data upload.

The AFRecorder front panel keypad is disabled while under remote control. To initiate remote control of the AFRecorder, a command is issued over the serial port. No operations using the front panel are necessary. The external computer may take control of the AFRecorder at any time except during power-on initialization. The serial port parameters are 9600 baud, no parity, 8 data bits, and 1 stop bit.

The AFRecorder stores setup and calibration data in an Electrically Erasable Programmable Read Only Memory (EEPROM). EEPROM values may be altered by the external computer, one at

a time, using simple command strings along with the new value. New EEPROM values downloaded from the external computer do not affect the operation of the AFRecorder until an initialization is performed. An initialization is performed after power-on, if real-time data upload is requested, or if a recording session is started.

Data in the EEPROM is stored either as one byte "selections" or as four byte floating-point "values". An example of a "selection" is the choice of AFR units. An example of a "value" is one of the sensor calibration constants. Changing these parameters using the external computer is equivalent to changing them using the front panel keypad.

The serial port remote control code in the AFRecorder was designed to be used with a PC as the external computer. A PC (Intel) stores multi-byte data types with the low byte first. The AFRecorder (Motorola) stores multi-byte data types with the high byte first. In order to make interfacing to a PC easier, the AFRecorder accepts multi-byte data included in download commands in Intel format. However, data uploaded from the AFRecorder to an external computer is in Motorola format. Therefore, a floating-point number sent by the AFRecorder to a PC must undergo a byte reversal before use as shown in the code fragment below. In most applications, a serial port interrupt routine will be used to create a buffer of received characters. The data bytes may then be taken from the buffer and placed in the union variable in reversed order directly, so as to avoid the need for a "reversing" operation.

```
/* C Code showing translation of an AFRecorder floating-point data value to PC format */

typedef union {
    float fl;
    unsigned char uc[4];
} FloatData;

FloatData afrfloat;

unsigned char uchar;
.
.

/* Assume that a floating-point data value from the AFRecorder is contained in "afrfloat" */

uchar = afrfloat.uc[0];
afrfloat.uc[0] = afrfloat.uc[3];
afrfloat.uc[3] = uchar;
uchar = afrfloat.uc[1];
afrfloat.uc[1] = afrfloat.uc[2];
afrfloat.uc[2] = uchar;
.

/* Use the data */
```

Serial Port Commands

When the AFRecorder is being operated under remote control, it is said to be "connected." When "connected", the AFRecorder LCD displays will show AFR data (while in measure mode) or serial link information. Some commands, such as the status command, do not require "connection."

All checksums used for commands and responses are one byte (8bits) long and are calculated so that the unsigned 8bit sum of all bytes in the packet is zero. Checksums include all bytes of the packet including the header where applicable.

The host computer must wait for one command to finish before sending another command to the AFRecorder. Any characters sent to the AFRecorder while a command is in progress will be ignored.

Unless otherwise noted in the description of a particular command, the AFRecorder will acknowledge all commands with one of the following two-byte responses:

- <0xD0> <0x30> - Command was correctly received and has been performed.
- <0xD1> <0x2F> - Checksum failure; command was not processed.
- <0xD2> <0x2E> - Serial port timeout; not enough characters received for a valid command.
- <0xD3> <0x2D> - Serial port overrun; command was not processed.
- <0xD4> <0x2C> - AFRecorder not "connected" or not in "idle" state; command not processed.
- <0xD5> <0x2B> - Software in the AFRecorder is the wrong version.
- <0xD6> <0x2A> - Downloaded value is not within the allowed range.

There are three serial port command formats: "Control", "Change Selection", and "Change Value". All three types of commands are eight bytes long and include a checksum.

Control Commands

Some Control commands require prior "connection" to the PC while others do not. The Control command format is:

<0x5F> <command number> <checksum>.

For example, command number 2, the "connect" command (initiate remote control of the AFRecorder), would be sent as:

<0x5F> <0x02> <0x9F>.

The valid Control commands and their functions are as follows:

- 1: (0x01). Upload status. Returns a status byte and a checksum byte:
 - <0xA0> <0x60> - Initializing
 - <0xA1> <0x5F> - Sensor warm-up period
 - <0xA2> <0x5E> - Measure mode
 - <0xA3> <0x5D> - Local control menus
 - <0xA5> <0x5B> - Remote control "idle"
 - <0xA6> <0x5A> - Recording
 - <0xA7> <0x59> - Performing an Air Calibration
- 2: (0x02). Start remote operation ("connect" command). This command should be issued first, before any other commands are used.
- 6: (0x06). Hard reset of AFRecorder (watchdog timer reset). This command is not acknowledged. The AFRecorder will be disconnected after this command is performed.

The following commands require prior "connection" (Control command 2):

- 7: (0x07). Terminate remote operation and return to local mode ("disconnect" command).
- 8: (0x08). Upload all current AFRecorder EEPROM selections. There are a total of 17 individual one byte selection values in the EEPROM. The 17 bytes of data are uploaded followed by a one byte (8 bit) checksum, for a total of 18 bytes. A listing of the function of the relevant EEPROM values is given below in the "Change Selection Command" section.
- 9: (0x09). Upload all current AFRecorder EEPROM constants. There are 77 individual four byte floating-point constant values in the EEPROM. The 308 bytes of data are uploaded followed by a one byte (8 bit) checksum, for a total of 309 bytes. An array of the 77 uploaded constants (with the array index starting at zero) may be matched to the descriptions listed in the "Change Value Command" section.

- 17: (0x11). Put AFRecorder in real-time data upload mode ("Real-time on" command). The data is sent as <Left Channel AFR value> <Right Channel AFR value> <Left Channel %O₂ value> <Right Channel %O₂ value> <checksum>. If the data for one of the sensors is invalid, one of the limit values is uploaded (see the instruction manual for limit values). This command is not acknowledged.

The sensor data is uploaded in four-byte long-integer format. The uploaded value is scaled by 65536. The host computer must divide the uploaded value by 65536 to obtain the desired data value. For example: Original Data = ((float)(uploaded long value))/65536.

Real-time data upload will start when the AFRecorder has completed necessary calculations and the "Allow real-time data upload" command (Control command 19) has been sent to the AFRecorder. To start real-time data upload, send command 17 followed by command 19.

Note that while in real-time upload mode, the AFRecorder will ignore all commands except Control commands 6, 7, 18, 19, 20, and 23.

There are two types of real-time data upload modes: "standard" and "fast-response". In standard mode, the AFR data is averaged in the same way as the front panel display. In fast-response mode, the AFR data is not averaged. Fast-response mode is enabled or disabled using commands 21 and 22. The fast-response mode flag must be set to the desired state before command 17 is sent to the AFRecorder.

The range of allowed data upload rates is from 0.04 to 60.0 seconds, in increments of 0.02 seconds. The data rate is set using the "Change Value" command described below.

- 18: (0x12). Halt real-time data upload ("real-time off" command). This command will cause the AFRecorder to exit measure mode, stop real-time data upload if in progress, and enter the "idle" state to await commands from the host computer. The AFRecorder must be in "idle" state to process most commands.
- 19: (0x13). Allow real-time data upload. Command 19 is required to start real-time data upload, and must be sent to the AFRecorder after command 17. While real-time data is being sent to the host computer, commands 19 and 20 may be used to temporarily suspend and restart real-time data upload without affecting other AFRecorder functions. Data is always uploaded in complete data packets. Using commands 19 and 20 will not result in a partial data packet being sent to the host computer. Commands 19 and 20 may be used to avoid buffer overflow problems in data acquisition or display programs. This command is not acknowledged.
- 20: (0x14). Suspend real-time data upload. This command is not acknowledged.
- 21: (0x15). Set "fast-response" real-time flag. The data uploaded in this mode is not averaged, but is a "snapshot" of the AFR value at the time of data upload. For use, see Control command 17.
- 22: (0x16). Clear "fast-response" real-time flag.

- 23: (0x17). Reset AFRecorder. Equivalent to pressing the "SYS" key on the front panel during stand-alone operation. Will terminate a recording session or real-time data upload. This command is not acknowledged.
- 25: (0x19). Perform an Air Calibration on the Left Channel. Before an Air Calibration can be performed, the AFR sensor must be warmed up and the AFRecorder must be in "idle" mode (as indicated by a status byte of <A5>, see Control command number 1, above). Be sure that the sensor is warmed up, and use command 18 if necessary to halt real-time operation and return the AFRecorder to idle mode before starting an Air Calibration.

The response to this command is one floating-point number followed by a checksum byte. The response is either the sensor age factor (a value between 0.5 and 1.5) or an error code (greater than 100.0). Note that the response will be transmitted after the calibration, which takes several seconds. The error codes are:

- 101.0: The AFR sensors are disabled.
- 201.0: The AFR sensor is not warmed up.
- 301.0: The AFR sensor output voltage shows significant variation. Either the sensor is not in still air or it may be defective.
- 401.0: The AFR sensor output voltage is very low. There is no AFR sensor attached to the AFRecorder, the AFR sensor is not in air, the AFR sensor is defective, or the AFR sensor wiring is defective.
- 501.0: The AFR sensor output voltage is unusually high. Verify that the correct AFR sensor calibration constants are entered into the AFRecorder. If the calibration constants are correct, the sensor may be defective.
- 601.0: The AFR sensor Age Factor indicates a significantly aged sensor. Verify that the correct AFR sensor calibration constants are entered into the AFRecorder, and that the sensor is in air. If the calibration constants are correct and the sensor is in air, the sensor should be replaced.
- 26: (0x1A). Perform an Air Calibration on the Right Channel. Action is similar to command 25.
- 27: (0x1B). Enable AFR sensors. This command will apply power to the AFR sensors allowing them to make AFR measurements after a warm-up period of less than one minute. **The AFR sensors will quickly become very hot and may cause a fire or personal injury. The user must insure that the sensors are in a safe location before issuing this command.**

28: (0x1C). Disable AFR sensors.

The following commands relate to recording functions:

12: (0x0C). Start a recording session. This command is equivalent to placing the unit in measure mode and then pressing the "REC" button on the front panel.

13: (0x0D). Upload recorded data units used in the last recording session. The response to this command is a single byte followed by a checksum byte. Responses are 1 for AFR units, 2 for Phi, 3 for Lambda and 4 for %O₂.

14: (0x0E). Upload recorded data interval used in the last recording session. The response to this command is one floating-point number followed by a checksum byte.

15: (0x0F). Upload number of recorded data points. The value is a single long (32bit) integer followed by a checksum byte. If there is no recorded data, the AFRecorder will return a value of zero.

16: (0x10). Upload recorded AFR data. The data is sent in floating-point format as:

<all Left Channel AFR data> <all Right Channel AFR data> <checksum>.

The total number of points recorded (sum from both sensors) is available using command 15. The number of bytes received will be (number of points recorded)*(4) + (1 for checksum byte).

Change Selection Command

A "Change Selection" command to the AFRecorder consists of a header, an index, the one byte value, and the checksum byte. A total of five bytes must be sent. The index is an array index, **starting at zero**, in the 17 byte selection list in the EEPROM. Any indices not listed below should never be changed by the external computer. The Change Selection command requires prior "connection" to the PC. Changing a selection using this command is equivalent to changing the selection using the front-panel keypad. Changes to selections made using this command will remain even if the AFRecorder is turned off.

The "Change Selection" command format is:

<0x5F> <0x37> <index> <selection> <checksum>.

The valid index values and selections are:

Index	Function	Valid Values
3 (0x03)	AFR Display units	1=AFR, 2=Phi, 3=Lambda, 4=% O ₂
4 (0x04)	AFR Analog output units	1=AFR, 2=Phi, 3=Lambda, 4=% O ₂
5 (0x05)	Simulated EGO units	1=AFR, 2=Phi, 3=Lambda
8 (0x08)	Left display size	1=Small, 2=Large
9 (0x09)	Right display size	1=Small, 2=Large
10 (0x0A)	Display update rate	1=Slow, 2=Med, 3=Fast
11 (0x0B)	Left large display type	1=AFR, 2=DEV, 3=DIF, 4=AVG
12 (0x0C)	Right large display type	1=AFR, 2=DEV, 3=DIF, 4=AVG
13 (0x0D)	ICC Left	0=Disabled, 1=Enabled
14 (0x0E)	ICC Right	0=Disabled, 1=Enabled
15 (0x0F)	Hydrogen Fuel	0=Disabled, 1=Enabled
16 (0x10)	Key beeping enable	0=Disabled, 1=Enabled

Change Value Command

A "Change Value" command to the AFRecorder consists of a header, an index, the four byte floating-point value and a one-byte checksum. A total of eight bytes must be sent. **Remember to send the floating-point value to the AFRecorder in Intel format.** Indices not listed below should never be changed by the external computer. The Change Value command requires prior "connection" to the PC. Changing a value using this command is equivalent to changing the value using the front-panel keypad. Changes made using this command will remain if the AFRecorder is turned off.

The "Change Value" command format is:

<0x5F> <0x41> <index> <value 1> <value 2> <value 3> <value 4> <checksum>.

The valid index values and allowed ranges for the data are:

Index	Function	Valid Values
Real-time Data Rate		
52 (0x34)	Real-time data upload rate	0.04 to 60.0 sec. (0.02 second increments)
Fuel Constants		
43 (0x2B)	Fuel H:C	1.0 to 10.0
44 (0x2C)	Fuel O:C	0.0 to 1.0
45 (0x2D)	Fuel N:C	0.0 to 1.0
AFR Sensor Calibration Constants		
67 (0x43)	Left sensor I ₁	0.10 to 5.00
68 (0x44)	Left sensor I _{O2}	0.01 to 1.00
69 (0x45)	Left sensor I _{CO}	0.01 to 1.00
70 (0x46)	Left sensor I _{H2}	0.01 to 1.00
71 (0x47)	Left sensor I ₂	-1.00 to 1.00
65 (0x41)	Left sensor Age Factor	0.50 to 1.50
72 (0x48)	Right sensor I ₁	0.10 to 5.00
73 (0x49)	Right sensor I _{O2}	0.01 to 1.00
74 (0x4A)	Right sensor I _{CO}	0.01 to 1.00
75 (0x4B)	Right sensor I _{H2}	0.01 to 1.00
76 (0x4C)	Right sensor I ₂	-1.00 to 1.00
66 (0x42)	Right sensor Age Factor	0.50 to 1.50

Engine Calibration (ICC) Constants

46	(0x2E)	Left sensor ICC lean	-10.00 to 10.00
47	(0x2F)	Left sensor ICC stoic	-10.00 to 10.00
48	(0x30)	Left sensor ICC rich	-10.00 to 10.00
49	(0x31)	Right sensor ICC lean	-10.00 to 10.00
50	(0x32)	Right sensor ICC stoic	-10.00 to 10.00
51	(0x33)	Right sensor ICC rich	-10.00 to 10.00

Analog Output Constants

1	(0x01)	Left Channel at 0.0V (AFR)	0.00 to 400.00
2	(0x02)	Left Channel at 0.0V (Phi)	0.00 to 10.00
3	(0x03)	Left Channel at 0.0V (Lambda)	0.00 to 10.00
4	(0x04)	Left Channel at 0.0V (%O ₂)	0.00 to 100.00
5	(0x05)	Left %O ₂ Channel at 0.0V	0.00 to 100.00
6	(0x06)	Left Channel at 5.0V (AFR)	0.00 to 400.00
7	(0x07)	Left Channel at 5.0V (Phi)	0.00 to 10.00
8	(0x08)	Left Channel at 5.0V (Lambda)	0.00 to 10.00
9	(0x09)	Left Channel at 5.0V (%O ₂)	0.00 to 100.00
10	(0x0A)	Left %O ₂ Channel at 5.0V	0.00 to 100.00
11	(0x0B)	Right Channel at 0.0V (AFR)	0.00 to 400.00
12	(0x0C)	Right Channel at 0.0V (Phi)	0.00 to 10.00
13	(0x0D)	Right Channel at 0.0V (Lambda)	0.00 to 10.00
14	(0x0E)	Right Channel at 0.0V (%O ₂)	0.00 to 100.00
15	(0x0F)	Right %O ₂ Channel at 0.0V	0.00 to 100.00
16	(0x10)	Right Channel at 5.0V (AFR)	0.00 to 400.00
17	(0x11)	Right Channel at 5.0V (Phi)	0.00 to 10.00
18	(0x12)	Right Channel at 5.0V (Lambda)	0.00 to 10.00
19	(0x13)	Right Channel at 5.0V (%O ₂)	0.00 to 100.00
20	(0x14)	Right %O ₂ Channel at 5.0V	0.00 to 100.00

Simulated EGO Output Threshold Levels

29	(0x1D)	Left simulated EGO (AFR)	0.00 to 400.00
30	(0x1E)	Left simulated EGO (Phi)	0.00 to 10.00
31	(0x1F)	Left simulated EGO (Lambda)	0.00 to 10.00
32	(0x20)	Right simulated EGO (AFR)	0.00 to 400.00
33	(0x21)	Right simulated EGO (Phi)	0.00 to 10.00
34	(0x22)	Right simulated EGO (Lambda)	0.00 to 10.00

Recording Functions

53	(0x35)	Recording period (interval)	0.02 to 60 sec. (0.02 second increments)
54	(0x36)	Recording duration (minutes)	0 to 5000
55	(0x37)	Recording duration (seconds)	0 to 1000

AFR Offset Values

35	(0x23)	Left Channel offset (AFR)	-2.00 to 2.00
36	(0x24)	Left Channel offset (Phi)	-0.20 to 0.20
37	(0x25)	Left Channel offset (Lambda)	-0.20 to 0.20
38	(0x26)	Left Channel offset (%O ₂)	-2.00 to 2.00
39	(0x27)	Right Channel offset (AFR)	-2.00 to 2.00
40	(0x28)	Right Channel offset (Phi)	-0.20 to 0.20
41	(0x29)	Right Channel offset (Lambda)	-0.20 to 0.20
42	(0x2A)	Right Channel offset (%O ₂)	-2.00 to 2.00