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RFID Read/Write Module, Serial (#28440)

Designed in cooperation with Grand Idea Studio (www.grandideastudio.com), the Parallax Radio Frequency Identification (RFID) Read/Write Module provides a low-cost solution to read and write passive RFID transponder tags up to 3 inches away. The RFID transponder tags provide a unique serial number and can store up to 116 bytes of user data, which can be password protected to allow only authorized access.

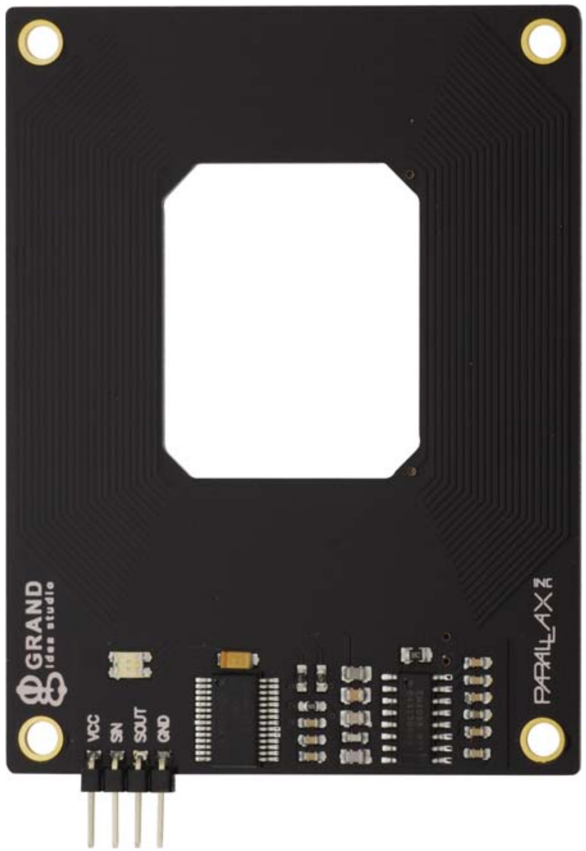
The RFID Read/Write Module can be used in a wide variety of hobbyist and commercial applications, including access control, user identification, robotics navigation, inventory tracking, payment systems, car immobilization, and manufacturing automation.

Features

- Low-cost method for reading and writing passive, 125 kHz RFID transponder tags
- Up to 116 bytes of user data storage on a single tag
- Optional security features prevent tag from being read or written without password
- Bi-color LED for visual indication of status

Key Specifications

- Power requirements: +5 VDC; < 10 mA idle, approx. 100-200 mA active
- Communication: asynchronous serial 9600 bps, (8N1); 5 V TTL-level, non-inverted
- Dimensions: 3.25 x 2.45 in (8.26 x 6.2 cm)



RFID Tag Compatibility

The RFID Read/Write Module works exclusively with the EM Microelectronics EM4x50 1kbit R/W transponder tags. A variety of different tag types and styles exist, with the most popular ones made available from Parallax.

Each tag contains a unique, read-only serial number (one of 2^{32}, or 4,294,967,296 possible combinations) and 116 bytes of user data area stored in a non-volatile EEPROM (Electrically Erasable Read Only Memory). The user data area can be optionally secured with a 32-bit password to allow only authorized read and write operations.

The RFID Read/Write Module provides, with a single command, legacy support for the EM Microelectronics EM4100 read-only tags that are used with Parallax's RFID Card Reader Serial (#28140) and USB (#28340).

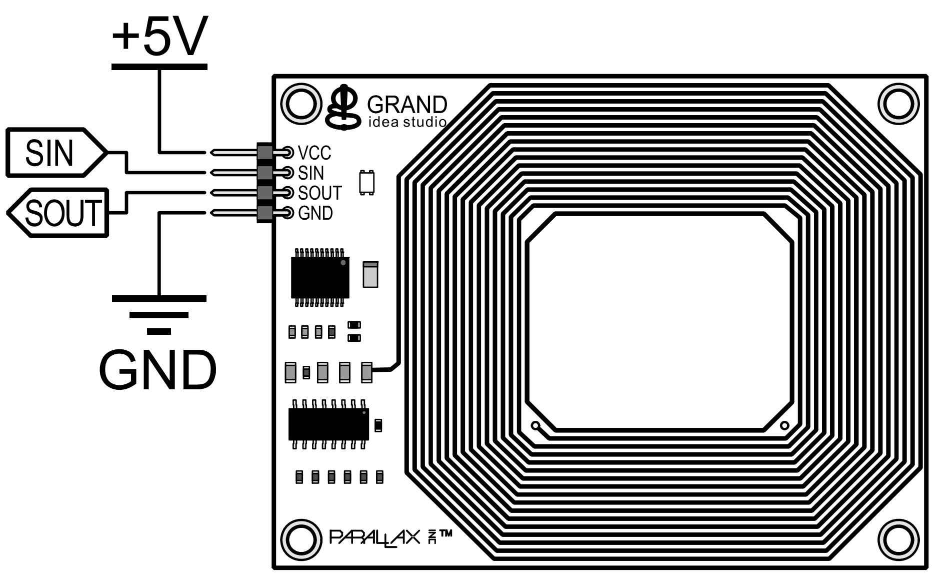
Connections

The RFID Read/Write Module easily interfaces to any host microcontroller using only four connections (VCC, SIN, SOUT, GND).

Pin	Pin Name	Type	Function
1	VCC	P	System power. +5V DC input.
2	SIN	I	Serial input from host. TTL-level interface, 9600 bps, 8 data bits, no parity, 1 stop bit.
3	SOUT	O	Serial output to host. TTL-level interface, 9600 bps, 8 data bits, no parity, 1 stop bit.
4	GROUND	G	System ground. Connect to power supply's ground (GND) terminal.

Note: Type: I = Input, O = Output, P = Power, G = Ground

Use the following example circuit for connecting the Parallax RFID Read/Write Module:



Usage

There are many ways to use the RFID Read/Write Module and associated tags, but the three most common are as follows:

1) Read Only: Read the tag's unique, non-changing 32-bit serial number

2) Read/Write: Read from and write up to 116 bytes of publicly accessible user data on the tag

3) Read/Write (Protected): Read from and write up to 116 bytes of password-protected user data on the tag. In this mode, you must enter the correct 32-bit password in order for read and write operations to be successful.

The RFID Read/Write Module is controlled by the host via a serial communications interface. The unit waits in an idle state until it receives a valid header and command from the host, at which time the module will perform the command and return a status/error byte indicating a success or failure and command-specific data (if any). The module will then re-enter the idle state and wait for the next valid header and command.

A visual indication of the RFID Read/Write Module's state is given with the on-board LED (Light Emitting Diode). When the module is successfully powered-up and is in an idle state, the LED will be GREEN; when the module is in an active state (for example, searching for a valid tag or performing an operation on the tag), the LED will be RED.

The face of the tag should be held parallel to the front or back face of the antenna (where the majority of RF energy is emitted). If the tag is held sideways (for example, perpendicular to the antenna), you'll either get no reading or a poor reading distance. Only one transponder tag should be held up to the antenna at any time. The use of multiple tags at one time will cause tag collisions and the reader may not detect any of them. The tags available in the Parallax store have a read distance of approximately 3 inches. Actual distance may vary slightly depending on the size of the transponder tag and environmental conditions of the application.

Communication Protocol

The RFID Read/Write Module is controlled by the host via a standard, asynchronous serial communications interface configured at 9600 bps, 8 data bits, no parity, 1 stop bit, and least significant bit first (8N1). The serial data expected and transmitted by the RFID Read/Write Module is 5V TTL-level, non-inverted.

To communicate with the RFID Read/Write Module, the user must first send a three-byte header string of !RW (in ASCII), followed by the desired single-byte command (in hexadecimal). Certain commands require additional data to be sent along with the command. A status/error byte and a varying number of data bytes will be returned depending on the command called.

Command Set

0x01: RFID_Read

Read data from a specified address

Input: Address location (1 byte), valid locations are 1-33 decimal

Output: Status byte (1 byte) + data (4 bytes)

Example:

```
SEROUT RFID_TX, Baud, ["!RW", RFID_Read, ADDR_Serial]   ' Read tag's serial number
SERIN  RFID_RX, Baud, [err, STR data\4]                 ' Get status byte & data bytes
```

0x02: RFID_Write

Write data to a specified address

Input: Address location (1 byte), valid locations are 3-31 decimal + data (4 bytes)

Output: Status byte (1 byte)

Example:

```
' Write $FEEDBEEF to address 3 (User Data Area)
SEROUT RFID_TX, Baud, ["!RW", RFID_Write, 3, $FE, $ED, $BE, $EF]
SERIN RFID_RX, Baud, [err]  ' Get status byte
```

Note: After writing the specified data to the tag, the RFID Read/Write Module automatically performs a read function to verify that the data has properly been written.

0x03: RFID_Login

Login to the tag (required to use password protection features)

Input: Password (4 bytes), default = 0x00000000

Output: Status byte (1 byte)

Example:

```
' Login to tag with password
SEROUT RFID_TX, Baud, ["!RW", RFID_Login, $00, $00, $00, $00]
SERIN RFID_RX, Baud, [err]                                    ' Get status byte
```

0x04: RFID_SetPass

Change the tag's password

Input: Current password (4 bytes) + new password (4 bytes)

Output: Status byte (1 byte)

Example:

```
' Change password from current ($00000000) to new ($FEEDBEEF)
SEROUT RFID_TX, Baud, ["!RW", RFID_SetPass, REP $00\4, $FE, $ED, $BE, $EF]
SERIN RFID_RX, Baud, [err]  ' Get status byte
```

0x05: RFID_Protect

Enable (lock) or disable (unlock) the tag's password protection.

Input: Mode (1 byte), 0x00 to unlock, 0x01 to lock

Output: Status byte (1 byte)

Example:

```
SEROUT RFID_TX, Baud, ["!RW", RFID_Protect, 1]  ' Lock the tag
SERIN RFID_RX, Baud, [err]                      ' Get status byte
```

Note: When the tag is locked, a successful login using the RFID_Login command is required before you can enable/disable password protection, change the tag's password, or read/write to the tag. If the tag is locked and you are not successfully logged in, the RFID_Read command will return four bytes of 0x00 in place of the actual user data and the RFID_Write command will return an error.

0x06: RFID_Reset

Log out and reset the tag.

Input: None

Output: Status byte (1 byte)

Example:

```
SEROUT RFID_TX, Baud, ["!RW", RFID_Reset]       ' Reset the tag
SERIN RFID_RX, Baud, [err]                      ' Get status byte
```

Note: All user data will remain stored on the tag. You will need to re-login using RFID_Login if you want to access a locked tag after calling this command. You can also reset the tag by removing it from the proximity of the RFID Read/Write Module.

0x0F: RFID_ReadLegacy

Read the 40-bit unique serial number from an EM Microelectronics EM4100 read-only tag (used with Parallax's RFID Card Reader Serial, #28140, and USB, #28340).

Input: None

Output: Header (1 byte) + data (10 bytes) + footer (1 byte)

Example:

```
SEROUT RFID_TX, Baud, ["!RW", RFID_ReadLegacy]        ' Read EM4100 unique serial #
SERIN RFID_RX, Baud, [header, STR data\10, footer]    ' Get header, data, and footer
```

Note: The header and footer are used to identify that a correct string has been received from the reader (they correspond to a line feed and carriage return characters, respectively). The middle ten bytes are the tag's unique ID sent in a printable ASCII string. For example, for a tag with a valid ID of 0F0184F07A, the following bytes would be sent: 0x0A, 0x30, 0x46, 0x30, 0x31, 0x38, 0x34, 0x46, 0x30, 0x37, 0x41, 0x0D.

Error Checking

The RFID Read/Write Module responds to each command with a single-byte status/error code in hexadecimal format followed by any returned data, if applicable. In most standard implementations, the user will repeatedly call the desired function until the ERR_OK status byte is returned, indicating that the function successfully completed with no errors.

For scenarios where more error checking is desired, the RFID Read/Write Module provides detailed error code values:

Value	Name	Description
0x01	ERR_OK	No Errors
0x02	ERR_LIW	Could not find a Listen Window (LIW) from the tag
0x03	ERR_NAK	Received a No Acknowledge (NAK), possible communication error or invalid command/data
0x04	ERR_NAK_OLDPW	Received a No Acknowledge (NAK) sending the current password during the RFID SetPass command, possible incorrect password
0x05	ERR_NAK_NEWPW	Received a No Acknowledge (NAK) sending the new password during the RFID SetPass command
0x06	ERR_LIW_NEWPW	Could not find a Listen Window (LIW) from the tag after setting the new password during the RFID SetPass command
0x07	ERR_PARITY	Parity error when reading data from the tag

Tag Details

The RFID Read/Write Module works exclusively with the EM Microelectronics-Marin SA EM4x50 1kbit R/W transponder tags at 125kHz. A variety of different tag types and styles exist with the most popular ones made available from Parallax.

The memory map and corresponding address locations for the EM4x50 tag are shown below. Each address holds a 32-bit (4 byte) value.

Address (decimal)	Register	Description
0	ADDR_Password	Password (not readable)
1	ADDR_Protect	Protection word
2	ADDR_Control	Control word
3-31	User Data Area	Non-volatile EEPROM storage area for user data (116 bytes)
32	ADDR_Serial	Device serial number (unique, read-only)
33	ADDR_DeviceID	Device identification (used to identify tag family, read-only)

The User Data Area can be optionally secured using a 32-bit password to allow only authorized read and write operations. This password is stored in *ADDR_Password* and can be changed by the user via the RFID_SetPass command with knowledge of the current password. For security reasons, it cannot be read. As such, if your tag is password-protected and you forget the tag's password, you will be unable to retrieve the contents of the User Data Area.

ADDR_Protect and *ADDR_Control* are modified directly by the RFID Read/Write Module and, in normal scenarios, should not be changed by the user.

ADDR_Serial is a unique, read-only serial number with one of 2^{32}, or 4,294,967,296, possible values. It cannot be changed by the user.

ADDR_DeviceID is a read-only value used to identify the specific tag family (for example, EM4150). The 32-bit value contains a family code, version code, reserved/unused bits, and a checksum value. It cannot be changed by the user.

Further details of the EM4x50 tag can be found at:
www.emmicroelectronic.com/Products.asp?IdProduct=159

Electrical Characteristics

At V_{CC} = +5.0V and T_A = 25ºC unless otherwise noted

Parameter	Symbol	Test Conditions	Specification			Unit
			Min.	Typ.	Max.	
Supply Voltage	V_{CC}	---	4.5	5.0	5.5	V
Supply Current, Idle	I_{IDLE}	---	---	9.4	---	mA
Supply Current, Active	I_{CC}	---	---	108	200	mA
Input LOW voltage	V_{IL}	+4.5V <= V_{CC} +5.5V	---	---	0.8	V
Input HIGH voltage	V_{IH}	+4.5V <= V_{CC} +5.5V	2.0	---	---	V
Output LOW voltage	V_{OL}	V_{CC} = +4.5V	---	---	0.6	V
Output HIGH voltage	V_{OH}	V_{CC} = +4.5V	V_{cc} - 0.7	---	---	V

Absolute Maximum Ratings

Condition	Value
Operating Temperature	-40ºC to +85ºC
Storage Temperature	-55ºC to +125ºC
Supply Voltage (V_{CC})	+4.5V to +5.5V
Ground Voltage (V_{SS})	0V
Voltage on any pin with respect to V_{SS}	-0.3V to +7.0V

NOTICE: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

RFID Technology Overview

Material in this section is based on information provided by the RFID Journal (www.rfidjournal.com).

Radio Frequency Identification (RFID) is a generic term for non-contacting technologies that use radio waves to automatically identify people or objects. There are several methods of identification, but the most common is to store a unique serial number that identifies a person or object on a microchip that is attached to an antenna. The combined antenna and microchip are called an "RFID transponder" or "RFID tag" and work in combination with an "RFID reader" (sometimes called an "RFID interrogator").

An RFID system consists of a reader and one or more tags. The reader's antenna is used to transmit radio frequency (RF) energy. Depending on the tag type, the energy is "harvested" by the tag's antenna and used to power up the internal circuitry of the tag. The tag will then modulate the electromagnetic waves generated by the reader in order to transmit its data back to the reader. The reader receives the modulated waves and converts them into digital data.

There are two major types of tag technologies. "Passive tags" are tags that do not contain their own power source or transmitter. When radio waves from the reader reach the chip's antenna, the energy is converted by the antenna into electricity that can power up the microchip in the tag (typically via inductive coupling). The tag is then able to send back any information stored on the tag by modulating the reader's electromagnetic waves. "Active tags" have their own power source and transmitter. The power source, usually a battery, is used to run the microchip's circuitry and to broadcast a signal to a reader. Due to the fact that passive tags do not have their own transmitter and must reflect their signal to the reader, the reading distance is much shorter than with active tags. However, active tags are typically larger, more expensive, and require occasional service.

Frequency refers to the size of the radio waves used to communicate between the RFID system components. Just as you tune your radio to different frequencies in order to hear different radio stations, RFID tags and readers have to be tuned to the same frequency in order to communicate effectively. RFID systems typically use one of the following frequency ranges: low frequency (or LF, around 125 and 134.2 kHz), high frequency (or HF, around 13.56 MHz), ultra-high frequency (or UHF, around 868 and 928 MHz), or microwave (around 2.45 and 5.8 GHz).

The read range of a tag ultimately depends on many factors: the frequency of RFID system operation, the power of the reader, and interference from other RF devices. Balancing a number of engineering trade-offs (antenna size vs. reading distance vs. power vs. manufacturing cost), the Parallax RFID Read/Write Module's antenna was designed specifically for use with low-frequency (125 kHz) passive tags.

BASIC Stamp 2 Program

The example program shown below is a simple system-level test to read the tag ID and write a block of data. This .bs2 program, along with a more comprehensive code example demonstrating the full capabilities of the RFID Read/Write Module, is available for download on the product page; search "28440" at www.parallax.com.

```
' =========================================================================
'
'   File...... rfid_rw_test.bs2
'   Purpose... System-level test code for the Parallax RFID Read/Write Module
'   Author.... Joe Grand, Grand Idea Studio, Inc. [www.grandideastudio.com]
'   E-mail.... support@parallax.com
'   Updated... 15 Dec 2009
'
'   {$STAMP BS2}
'   {$PBASIC 2.5}
'
' =========================================================================


' -----[ Program Description ]---------------------------------------------
'
' This program performs a system-level test of the Parallax RFID Read/
' Write Module by:
'
' 1) Reading tag's unique ID
' 2) Writing and verifying a block of data to the tag


' -----[ I/O Definitions ]-------------------------------------------------

RFID_TX      PIN   0              ' Connects to RFID R/W Module SIN
RFID_RX      PIN   1              ' Connects to RFID R/W Module SOUT


' -----[ Constants ]-------------------------------------------------------

#SELECT $STAMP
  #CASE BS2, BS2E, BS2PE
    T9600    CON     84
  #CASE BS2SX, BS2P
    T9600    CON     240
#ENDSELECT

Baud              CON     T9600

' RFID R/W Module Commands
' Number of bytes returned in ()
RFID_Read         CON      $01   ' Read data from specified address,
                                 ' valid locations 1 to 33 (5)
RFID_Write        CON      $02   ' Write data to specified address,
                                 ' valid locations 3 to 31 (1)
RFID_Login        CON      $03   ' Login to tag with password (1)
RFID_SetPass      CON      $04   ' Change tag's password from old to new (1)
RFID_Protect      CON      $05   ' Enable/disable password protection (1)
RFID_Reset        CON      $06   ' Reset tag (1)
RFID_ReadLegacy   CON      $0F   ' Read unique ID from EM4102 read-only tag
                                 ' (for backwards compatibility with Parallax
                                 ' RFID Card Reader, #28140 and #28340) (12)

' Memory map/address locations for EM4x50 tag
' Each address holds/returns a 32-bit (4 byte) value
ADDR_Password     CON      0     ' Password (not readable)
ADDR_Protect      CON      1     ' Protection Word
ADDR_Control      CON      2     ' Control Word
' ADDR 3-31 are User EEPROM area
ADDR_Serial       CON      32    ' Device Serial Number
ADDR_DeviceID     CON      33    ' Device Identification
```

```
' Status/error return codes
ERR_OK           CON     $01   ' No errors
ERR_LIW          CON     $02   ' Did not find a listen window
ERR_NAK          CON     $03   ' Received a NAK, could be invalid command
ERR_NAK_OLDPW    CON     $04   ' Received a NAK sending old password (RFID_SetPass),
                               ' could be incorrect password
ERR_NAK_NEWPW    CON     $05   ' Received a NAK sending new password (RFID_SetPass)
ERR_LIW_NEWPW    CON     $06   ' Did not find a listen window after sending
                               ' old password (RFID_SetPass)
ERR_PARITY       CON     $07   ' Parity error when reading data


' -----[ Variables ]----------------------------------------------------------------

buf      VAR     Byte(12)      ' data buffer

idx      VAR     Byte          ' index
idy      VAR     Byte

' -----[ EEPROM Data ]--------------------------------------------------------------


' -----[ Initialization ]-----------------------------------------------------------

Initialize:
  PAUSE 250  ' let DEBUG open
  DEBUG CLS  ' clear the screen
  DEBUG "Parallax RFID Read/Write Module Test Application", CR,
        "------------------------------------------------", CR, CR


' -----[ Program Code ]-------------------------------------------------------------

Main:
  DEBUG "Reading tag's unique serial number..."
Read_Tag:
  SEROUT RFID_TX, Baud, ["!RW", RFID_Read, ADDR_Serial]   ' Read tag's serial number
  SERIN  RFID_RX, Baud, [STR buf\5]                ' Get status byte and data bytes
  IF buf(0) <> ERR_OK THEN Read_Tag                ' If we get an error, keep trying
                                                   ' until the read is successful
  FOR idx = 1 TO 4                                 ' Print data
    DEBUG HEX2 buf(idx)
  NEXT
  DEBUG CR

  DEBUG "Writing and verifying data to tag..."
Write_Tag:
  SEROUT RFID_TX, Baud, ["!RW", RFID_Write, 3, $FE, $ED, $BE, $EF] ' Write $FEEDBEEF
                                                   ' into address 4 (user EEPROM area)
  SERIN RFID_RX, Baud, [buf(0)]                    ' Wait for status byte
  IF buf(0) <> ERR_OK THEN Write_Tag               ' If we get an error, keep trying
                                                   ' until the write is successful
  DEBUG "Success!", CR

  DEBUG "End of test.", CR
  END

' -----[ End of File ]----------------------------------------------------
```