ModbusMaster

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Module Documentation

4.1 ModbusMaster Object Instantiation/Initialization

Functions

- ModbusMaster::ModbusMaster ()

  Constructor.
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- void ModbusMaster::begin ()

  Initialize class object.
- void ModbusMaster::begin (uint16_t)

4.1.1 Detailed Description

4.1.2 Function Documentation

4.1.2.1 ModbusMaster::ModbusMaster (void)

Constructor.

Creates class object using default serial port 0, Modbus slave ID 1.

```
54 {
55   _u8SerialPort = 0;
56   _u8MBSlave = 1;
57 }
```

4.1.2.2 ModbusMaster::ModbusMaster (uint8_t *u8MBSlave*)

This is an overloaded member function, provided for convenience. It differs from the above function only in what argument(s) it accepts.

Creates class object using default serial port 0, specified Modbus slave ID.

Parameters

u8MBSlave	Modbus slave ID (1..255)

```
70 {
71   _u8SerialPort = 0;
72   _u8MBSlave = u8MBSlave;
73 }
```

4.1.2.3 ModbusMaster::ModbusMaster (uint8_t *u8SerialPort,* uint8_t *u8MBSlave*)

This is an overloaded member function, provided for convenience. It differs from the above function only in what argument(s) it accepts.

Creates class object using specified serial port, Modbus slave ID.

Parameters

u8SerialPort	serial port (Serial, Serial1..Serial3)
u8MBSlave	Modbus slave ID (1..255)

```
87 {
88   _u8SerialPort = (u8SerialPort > 3) ? 0 : u8SerialPort;
89   _u8MBSlave = u8MBSlave;
90 }
```

4.1.2.4 void ModbusMaster::begin (void)

Initialize class object.

Sets up the serial port using default 19200 baud rate. Call once class has been instantiated, typically within setup().

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
102 {
103   begin(19200);
104 }
```

4.1.2.5 void ModbusMaster::begin (uint16_t *u16BaudRate*)

This is an overloaded member function, provided for convenience. It differs from the above function only in what argument(s) it accepts.

Sets up the serial port using specified baud rate. Call once class has been instantiated, typically within setup().

Parameters

u16BaudRate	baud rate, in standard increments (300..115200)

```
118 {
119 //  txBuffer = (uint16_t*) calloc(ku8MaxBufferSize, sizeof(uint16_t));
120   _u8TransmitBufferIndex = 0;
121   u16TransmitBufferLength = 0;
122
123   switch(_u8SerialPort)
```

```
124   {
125 #if defined(UBRR1H)
126     case 1:
127       MBSerial = &Serial1;
128       break;
129 #endif
130
131 #if defined(UBRR2H)
132     case 2:
133       MBSerial = &Serial2;
134       break;
135 #endif
136
137 #if defined(UBRR3H)
138     case 3:
139       MBSerial = &Serial3;
140       break;
141 #endif
142
143     case 0:
144     default:
145       MBSerial = &Serial;
146       break;
147   }
148
149   MBSerial->begin(u16BaudRate);
150 #if __MODBUSMASTER_DEBUG__
151   pinMode(4, OUTPUT);
152   pinMode(5, OUTPUT);
153 #endif
154 }
```

4.2 ModbusMaster Buffer Management

Functions

- uint16_t ModbusMaster::getResponseBuffer (uint8_t)

  Retrieve data from response buffer.
- void ModbusMaster::clearResponseBuffer ()

  Clear Modbus response buffer.
- uint8_t ModbusMaster::setTransmitBuffer (uint8_t, uint16_t)

  Place data in transmit buffer.
- void ModbusMaster::clearTransmitBuffer ()

  Clear Modbus transmit buffer.

4.2.1 Detailed Description

4.2.2 Function Documentation

4.2.2.1 uint16_t ModbusMaster::getResponseBuffer (uint8_t *u8Index*)

Retrieve data from response buffer.

See also

ModbusMaster::clearResponseBuffer()

Parameters

u8Index	index of response buffer array (0x00..0x3F)

Returns

value in position u8Index of response buffer (0x0000..0xFFFF)

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
277 {
278   if (u8Index < ku8MaxBufferSize)
279   {
280     return _u16ResponseBuffer[u8Index];
281   }
282   else
283   {
284     return 0xFFFF;
285   }
286 }
```

4.2.2.2 void ModbusMaster::clearResponseBuffer ( )

Clear Modbus response buffer.

See also

ModbusMaster::getResponseBuffer(uint8_t u8Index)

```
296 {
297   uint8_t i;
298
299   for (i = 0; i < ku8MaxBufferSize; i++)
300   {
301     _u16ResponseBuffer[i] = 0;
302   }
303 }
```

4.2.2.3 uint8_t ModbusMaster::setTransmitBuffer (uint8_t *u8Index*, uint16_t *u16Value*)

Place data in transmit buffer.

See also

ModbusMaster::clearTransmitBuffer()

Parameters

u8Index	index of transmit buffer array (0x00..0x3F)
u16Value	value to place in position u8Index of transmit buffer (0x0000..0xFFFF)

Returns

0 on success; exception number on failure

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
316 {
317   if (u8Index < ku8MaxBufferSize)
318   {
319     _u16TransmitBuffer[u8Index] = u16Value;
320     return ku8MBSuccess;
321   }
322   else
323   {
324     return ku8MBIllegalDataAddress;
325   }
326 }
```

4.2.2.4 void ModbusMaster::clearTransmitBuffer ( )

Clear Modbus transmit buffer.

See also

ModbusMaster::setTransmitBuffer(uint8_t u8Index, uint16_t u16Value)

```
336 {
337   uint8_t i;
338
339   for (i = 0; i < ku8MaxBufferSize; i++)
340   {
341     _u16TransmitBuffer[i] = 0;
342   }
343 }
```

4.3 Modbus Function Codes for Discrete Coils/Inputs

Functions

- uint8_t ModbusMaster::readCoils (uint16_t, uint16_t)

  Modbus function 0x01 Read Coils.
- uint8_t ModbusMaster::readDiscreteInputs (uint16_t, uint16_t)

  Modbus function 0x02 Read Discrete Inputs.
- uint8_t ModbusMaster::writeSingleCoil (uint16_t, uint8_t)

  Modbus function 0x05 Write Single Coil.
- uint8_t ModbusMaster::writeMultipleCoils (uint16_t, uint16_t)

  Modbus function 0x0F Write Multiple Coils.

4.3.1 Detailed Description

4.3.2 Function Documentation

4.3.2.1 uint8_t ModbusMaster::readCoils (uint16_t *u16ReadAddress*, uint16_t *u16BitQty*)

Modbus function 0x01 Read Coils.

This function code is used to read from 1 to 2000 contiguous status of coils in a remote device. The request specifies the starting address, i.e. the address of the first coil specified, and the number of coils. Coils are addressed starting at zero.

The coils in the response buffer are packed as one coil per bit of the data field. Status is indicated as 1=ON and 0=OFF. The LSB of the first data word contains the output addressed in the query. The other coils follow toward the high order end of this word and from low order to high order in subsequent words.

If the returned quantity is not a multiple of sixteen, the remaining bits in the final data word will be padded with zeros (toward the high order end of the word).

Parameters

u16ReadAddress	address of first coil (0x0000..0xFFFF)
u16BitQty	quantity of coils to read (1..2000, enforced by remote device)

Returns

0 on success; exception number on failure

Examples:

examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
370 {
371   _u16ReadAddress = u16ReadAddress;
372   _u16ReadQty = u16BitQty;
373   return ModbusMasterTransaction(ku8MBReadCoils);
374 }
```

4.3.2.2 uint8_t ModbusMaster::readDiscreteInputs (uint16_t *u16ReadAddress*, uint16_t *u16BitQty*)

Modbus function 0x02 Read Discrete Inputs.

This function code is used to read from 1 to 2000 contiguous status of discrete inputs in a remote device. The request specifies the starting address, i.e. the address of the first input specified, and the number of inputs. Discrete inputs are addressed starting at zero.

The discrete inputs in the response buffer are packed as one input per bit of the data field. Status is indicated as 1=ON; 0=OFF. The LSB of the first data word contains the input addressed in the query. The other inputs follow toward the high order end of this word, and from low order to high order in subsequent words.

If the returned quantity is not a multiple of sixteen, the remaining bits in the final data word will be padded with zeros (toward the high order end of the word).

Parameters

u16ReadAddress	address of first discrete input (0x0000..0xFFFF)
u16BitQty	quantity of discrete inputs to read (1..2000, enforced by remote device)

Returns

0 on success; exception number on failure

```
402 {
403   _u16ReadAddress = u16ReadAddress;
404   _u16ReadQty = u16BitQty;
405   return ModbusMasterTransaction(ku8MBReadDiscreteInputs);
406 }
```

4.3.2.3 uint8_t ModbusMaster::writeSingleCoil (uint16_t *u16WriteAddress,* uint8_t *u8State*)

Modbus function 0x05 Write Single Coil.

This function code is used to write a single output to either ON or OFF in a remote device. The requested ON/OFF state is specified by a constant in the state field. A non-zero value requests the output to be ON and a value of 0 requests it to be OFF. The request specifies the address of the coil to be forced. Coils are addressed starting at zero.

Parameters

u16WriteAddress	address of the coil (0x0000..0xFFFF)
u8State	0=OFF, non-zero=ON (0x00..0xFF)

Returns

0 on success; exception number on failure

```
474 {
475   _u16WriteAddress = u16WriteAddress;
476   _u16WriteQty = (u8State ? 0xFF00 : 0x0000);
477   return ModbusMasterTransaction(ku8MBWriteSingleCoil);
478 }
```

4.3.2.4 uint8_t ModbusMaster::writeMultipleCoils (uint16_t *u16WriteAddress,* uint16_t *u16BitQty*)

Modbus function 0x0F Write Multiple Coils.

This function code is used to force each coil in a sequence of coils to either ON or OFF in a remote device. The request specifies the coil references to be forced. Coils are addressed starting at zero.

The requested ON/OFF states are specified by contents of the transmit buffer. A logical '1' in a bit position of the buffer requests the corresponding output to be ON. A logical '0' requests it to be OFF.

Parameters

u16WriteAddress	address of the first coil (0x0000..0xFFFF)
u16BitQty	quantity of coils to write (1..2000, enforced by remote device)

Returns

0 on success; exception number on failure

```
521 {
522   _u16WriteAddress = u16WriteAddress;
523   _u16WriteQty = u16BitQty;
524   return ModbusMasterTransaction(ku8MBWriteMultipleCoils);
525 }
```

4.4 Modbus Function Codes for Holding/Input Registers

Functions

- uint8_t ModbusMaster::readHoldingRegisters (uint16_t, uint16_t)

  Modbus function 0x03 Read Holding Registers.
- uint8_t ModbusMaster::readInputRegisters (uint16_t, uint8_t)

  Modbus function 0x04 Read Input Registers.
- uint8_t ModbusMaster::writeSingleRegister (uint16_t, uint16_t)

  Modbus function 0x06 Write Single Register.
- uint8_t ModbusMaster::writeMultipleRegisters (uint16_t, uint16_t)

  Modbus function 0x10 Write Multiple Registers.
- uint8_t ModbusMaster::maskWriteRegister (uint16_t, uint16_t, uint16_t)

  Modbus function 0x16 Mask Write Register.
- uint8_t ModbusMaster::readWriteMultipleRegisters (uint16_t, uint16_t, uint16_t, uint16_t)

  Modbus function 0x17 Read Write Multiple Registers.

4.4.1 Detailed Description

4.4.2 Function Documentation

4.4.2.1 uint8_t ModbusMaster::readHoldingRegisters (uint16_t *u16ReadAddress*, uint16_t *u16ReadQty*)

Modbus function 0x03 Read Holding Registers.

This function code is used to read the contents of a contiguous block of holding registers in a remote device. The request specifies the starting register address and the number of registers. Registers are addressed starting at zero.

The register data in the response buffer is packed as one word per register.

Parameters

u16ReadAddress	address of the first holding register (0x0000..0xFFFF)
u16ReadQty	quantity of holding registers to read (1..125, enforced by remote device)

Returns

0 on success; exception number on failure

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
427 {
428   _u16ReadAddress = u16ReadAddress;
429   _u16ReadQty = u16ReadQty;
430   return ModbusMasterTransaction(
      ku8MBReadHoldingRegisters);
431 }
```

4.4.2.2 uint8_t ModbusMaster::readInputRegisters (uint16_t *u16ReadAddress*, uint8_t *u16ReadQty*)

Modbus function 0x04 Read Input Registers.

This function code is used to read from 1 to 125 contiguous input registers in a remote device. The request specifies the starting register address and the number of registers. Registers are addressed starting at zero.

The register data in the response buffer is packed as one word per register.

Parameters

u16ReadAddress	address of the first input register (0x0000..0xFFFF)
u16ReadQty	quantity of input registers to read (1..125, enforced by remote device)

Returns

0 on success; exception number on failure

Examples:

examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
452 {
453   _u16ReadAddress = u16ReadAddress;
454   _u16ReadQty = u16ReadQty;
455   return ModbusMasterTransaction(ku8MBReadInputRegisters);
456 }
```

4.4.2.3 uint8_t ModbusMaster::writeSingleRegister (uint16_t *u16WriteAddress*, uint16_t *u16WriteValue*)

Modbus function 0x06 Write Single Register.

This function code is used to write a single holding register in a remote device. The request specifies the address of the register to be written. Registers are addressed starting at zero.

Parameters

u16WriteAddress	address of the holding register (0x0000..0xFFFF)
u16WriteValue	value to be written to holding register (0x0000..0xFFFF)

Returns

0 on success; exception number on failure

Examples:

examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
495 {
496   _u16WriteAddress = u16WriteAddress;
497   _u16WriteQty = 0;
498   _u16TransmitBuffer[0] = u16WriteValue;
499   return ModbusMasterTransaction(ku8MBWriteSingleRegister);
500 }
```

4.4.2.4 uint8_t ModbusMaster::writeMultipleRegisters (uint16_t *u16WriteAddress*, uint16_t *u16WriteQty*)

Modbus function 0x10 Write Multiple Registers.

This function code is used to write a block of contiguous registers (1 to 123 registers) in a remote device.

The requested written values are specified in the transmit buffer. Data is packed as one word per register.

Parameters

u16WriteAddress	address of the holding register (0x0000..0xFFFF)
u16WriteQty	quantity of holding registers to write (1..123, enforced by remote device)

Returns

0 on success; exception number on failure

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
549 {
550   _u16WriteAddress = u16WriteAddress;
551   _u16WriteQty = u16WriteQty;
552   return ModbusMasterTransaction(
      ku8MBWriteMultipleRegisters);
553 }
```

4.4.2.5 uint8_t ModbusMaster::maskWriteRegister (uint16_t *u16WriteAddress*, uint16_t *u16AndMask*, uint16_t *u16OrMask*)

Modbus function 0x16 Mask Write Register.

This function code is used to modify the contents of a specified holding register using a combination of an AND mask, an OR mask, and the register's current contents. The function can be used to set or clear individual bits in the register.

The request specifies the holding register to be written, the data to be used as the AND mask, and the data to be used as the OR mask. Registers are addressed starting at zero.

The function's algorithm is:

Result = (Current Contents && And_Mask) || (Or_Mask && (~And_Mask))

Parameters

u16WriteAddress	address of the holding register (0x0000..0xFFFF)
u16AndMask	AND mask (0x0000..0xFFFF)
u16OrMask	OR mask (0x0000..0xFFFF)

Returns

0 on success; exception number on failure

```
587 {
588   _u16WriteAddress = u16WriteAddress;
589   _u16TransmitBuffer[0] = u16AndMask;
590   _u16TransmitBuffer[1] = u16OrMask;
591   return ModbusMasterTransaction(ku8MBMaskWriteRegister);
592 }
```

4.4.2.6 uint8_t ModbusMaster::readWriteMultipleRegisters (uint16_t *u16ReadAddress*, uint16_t *u16ReadQty*, uint16_t *u16WriteAddress*, uint16_t *u16WriteQty*)

Modbus function 0x17 Read Write Multiple Registers.

This function code performs a combination of one read operation and one write operation in a single MODBUS transaction. The write operation is performed before the read. Holding registers are addressed starting at zero.

The request specifies the starting address and number of holding registers to be read as well as the starting address, and the number of holding registers. The data to be written is specified in the transmit buffer.

Parameters

u16ReadAddress	address of the first holding register (0x0000..0xFFFF)
u16ReadQty	quantity of holding registers to read (1..125, enforced by remote device)
u16WriteAddress	address of the first holding register (0x0000..0xFFFF)
u16WriteQty	quantity of holding registers to write (1..121, enforced by remote device)

Returns

0 on success; exception number on failure

Examples:

examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
617 {
618   _u16ReadAddress = u16ReadAddress;
619   _u16ReadQty = u16ReadQty;
620   _u16WriteAddress = u16WriteAddress;
621   _u16WriteQty = u16WriteQty;
622   return ModbusMasterTransaction(
      ku8MBReadWriteMultipleRegisters);
623 }
```

4.5 Modbus Function Codes, Exception Codes

Variables

- static const uint8_t ModbusMaster::ku8MBIllegalFunction = 0x01

  Modbus protocol illegal function exception.
- static const uint8_t ModbusMaster::ku8MBIllegalDataAddress = 0x02

  Modbus protocol illegal data address exception.
- static const uint8_t ModbusMaster::ku8MBIllegalDataValue = 0x03

  Modbus protocol illegal data value exception.
- static const uint8_t ModbusMaster::ku8MBSlaveDeviceFailure = 0x04

  Modbus protocol slave device failure exception.
- static const uint8_t ModbusMaster::ku8MBSuccess = 0x00

  ModbusMaster success.
- static const uint8_t ModbusMaster::ku8MBInvalidSlaveID = 0xE0

  ModbusMaster invalid response slave ID exception.
- static const uint8_t ModbusMaster::ku8MBInvalidFunction = 0xE1

  ModbusMaster invalid response function exception.
- static const uint8_t ModbusMaster::ku8MBResponseTimedOut = 0xE2

  ModbusMaster response timed out exception.
- static const uint8_t ModbusMaster::ku8MBInvalidCRC = 0xE3

  ModbusMaster invalid response CRC exception.

4.5.1 Detailed Description

4.5.2 Variable Documentation

4.5.2.1 const uint8_t ModbusMaster::ku8MBIllegalFunction = 0x01 [static]

Modbus protocol illegal function exception.

The function code received in the query is not an allowable action for the server (or slave). This may be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the server (or slave) is in the wrong state to process a request of this type, for example because it is unconfigured and is being asked to return register values.

4.5.2.2 const uint8_t ModbusMaster::ku8MBIllegalDataAddress = 0x02 [static]

Modbus protocol illegal data address exception.

The data address received in the query is not an allowable address for the server (or slave). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, the ADU addresses the first register as 0, and the last one as 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 4, then this request will successfully operate (address-wise at least) on registers 96, 97, 98, 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 5, then this request will fail with Exception Code 0x02 "Illegal Data Address" since it attempts to operate on registers 96, 97, 98, 99 and 100, and there is no register with address

1.

Examples:

examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

4.5.2.3 const uint8_t ModbusMaster::ku8MBIllegalDataValue = 0x03 [static]

Modbus protocol illegal data value exception.

A value contained in the query data field is not an allowable value for server (or slave). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the MODBUS protocol is unaware of the significance of any particular value of any particular register.

4.5.2.4 const uint8_t ModbusMaster::ku8MBSlaveDeviceFailure = 0x04 [static]

Modbus protocol slave device failure exception.

An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.

4.5.2.5 const uint8_t ModbusMaster::ku8MBSuccess = 0x00 [static]

ModbusMaster success.

Modbus transaction was successful; the following checks were valid:

- slave ID
- function code
- response code
- data
- CRC

Examples:

examples/Basic/Basic.pde.

4.5.2.6 const uint8_t ModbusMaster::ku8MBInvalidSlaveID = 0xE0 [static]

ModbusMaster invalid response slave ID exception.

The slave ID in the response does not match that of the request.

4.5.2.7 const uint8_t ModbusMaster::ku8MBInvalidFunction = 0xE1 [static]

ModbusMaster invalid response function exception.

The function code in the response does not match that of the request.

4.5.2.8 const uint8_t ModbusMaster::ku8MBResponseTimedOut = 0xE2 [static]

ModbusMaster response timed out exception.

The entire response was not received within the timeout period, ModbusMaster::ku8MBResponseTimeout.

4.5.2.9 const uint8_t ModbusMaster::ku8MBInvalidCRC = 0xE3 [static]

ModbusMaster invalid response CRC exception.

The CRC in the response does not match the one calculated.

4.6 "util/crc16.h": CRC Computations

Functions

- static uint16_t crc16_update (uint16_t crc, uint8_t a)

  Processor-independent CRC-16 calculation.

4.6.1 Detailed Description

```
#include "util/crc16.h"
```

This header file provides functions for calculating cyclic redundancy checks (CRC) using common polynomials. Modified by Doc Walker to be processor-independent (removed inline assembler to allow it to compile on SAM3X8E processors).

References:

Jack Crenshaw's "Implementing CRCs" article in the January 1992 issue of *Embedded Systems Programming*. This may be difficult to find, but it explains CRC's in very clear and concise terms. Well worth the effort to obtain a copy.

4.6.2 Function Documentation

4.6.2.1 static uint16_t crc16_update (uint16_t *crc*, uint8_t *a*) [static]

Processor-independent CRC-16 calculation.

Polynomial: x^16 + x^15 + x^2 + 1 (0xA001)
Initial value: 0xFFFF

This CRC is normally used in disk-drive controllers.

Parameters

uint16_t	crc (0x0000..0xFFFF)
uint8_t	a (0x00..0xFF)

Returns

calculated CRC (0x0000..0xFFFF)

```
72 {
73   int i;
74
75   crc ^= a;
76   for (i = 0; i < 8; ++i)
77   {
78     if (crc & 1)
79       crc = (crc >> 1) ^ 0xA001;
80     else
81       crc = (crc >> 1);
82   }
83
84   return crc;
85 }
```

4.7 "util/word.h": Utility Functions for Manipulating Words

Functions

- static uint16_t lowWord (uint32_t ww)
  Return low word of a 32-bit integer.
- static uint16_t highWord (uint32_t ww)
  Return high word of a 32-bit integer.

4.7.1 Detailed Description

```
#include "util/word.h"
```

This header file provides utility functions for manipulating words.

4.7.2 Function Documentation

4.7.2.1 static uint16_t lowWord (uint32_t *ww*) [inline], [static]

Return low word of a 32-bit integer.

Parameters

uint32_t	ww (0x00000000..0xFFFFFFFF)

Returns

low word of input (0x0000..0xFFFF)

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
47 {
48   return (uint16_t) ((ww) & 0xFFFF);
49 }
```

4.7.2.2 static uint16_t highWord (uint32_t *ww*) [inline], [static]

Return high word of a 32-bit integer.

Parameters

uint32_t	ww (0x00000000..0xFFFFFFFF)

Returns

high word of input (0x0000..0xFFFF)

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

```
59 {
60   return (uint16_t) ((ww) >> 16);
61 }
```

Chapter 5

Class Documentation

5.1 ModbusMaster Class Reference

Arduino class library for communicating with Modbus slaves over RS232/485 (via RTU protocol).

`#include <ModbusMaster.h>`

Public Member Functions

- ModbusMaster ()
  Constructor.
- ModbusMaster (uint8_t)
- ModbusMaster (uint8_t, uint8_t)
- void begin ()
  Initialize class object.
- void begin (uint16_t)
- void idle (void(∗)())
  Set idle time callback function (cooperative multitasking).
- uint16_t getResponseBuffer (uint8_t)
  Retrieve data from response buffer.
- void clearResponseBuffer ()
  Clear Modbus response buffer.
- uint8_t setTransmitBuffer (uint8_t, uint16_t)
  Place data in transmit buffer.
- void clearTransmitBuffer ()
  Clear Modbus transmit buffer.
- void **beginTransmission** (uint16_t)
- uint8_t **requestFrom** (uint16_t, uint16_t)
- void **sendBit** (bool)
- void **send** (uint8_t)
- void **send** (uint16_t)
- void **send** (uint32_t)
- uint8_t **available** (void)
- uint16_t **receive** (void)
- uint8_t readCoils (uint16_t, uint16_t)

Modbus function 0x01 Read Coils.

- uint8_t readDiscreteInputs (uint16_t, uint16_t)

  Modbus function 0x02 Read Discrete Inputs.
- uint8_t readHoldingRegisters (uint16_t, uint16_t)

  Modbus function 0x03 Read Holding Registers.
- uint8_t readInputRegisters (uint16_t, uint8_t)

  Modbus function 0x04 Read Input Registers.
- uint8_t writeSingleCoil (uint16_t, uint8_t)

  Modbus function 0x05 Write Single Coil.
- uint8_t writeSingleRegister (uint16_t, uint16_t)

  Modbus function 0x06 Write Single Register.
- uint8_t writeMultipleCoils (uint16_t, uint16_t)

  Modbus function 0x0F Write Multiple Coils.
- uint8_t **writeMultipleCoils** ()
- uint8_t writeMultipleRegisters (uint16_t, uint16_t)

  Modbus function 0x10 Write Multiple Registers.
- uint8_t **writeMultipleRegisters** ()
- uint8_t maskWriteRegister (uint16_t, uint16_t, uint16_t)

  Modbus function 0x16 Mask Write Register.
- uint8_t readWriteMultipleRegisters (uint16_t, uint16_t, uint16_t, uint16_t)

  Modbus function 0x17 Read Write Multiple Registers.
- uint8_t **readWriteMultipleRegisters** (uint16_t, uint16_t)

Static Public Attributes

- static const uint8_t ku8MBIllegalFunction = 0x01

  Modbus protocol illegal function exception.
- static const uint8_t ku8MBIllegalDataAddress = 0x02

  Modbus protocol illegal data address exception.
- static const uint8_t ku8MBIllegalDataValue = 0x03

  Modbus protocol illegal data value exception.
- static const uint8_t ku8MBSlaveDeviceFailure = 0x04

  Modbus protocol slave device failure exception.
- static const uint8_t ku8MBSuccess = 0x00

  ModbusMaster success.
- static const uint8_t ku8MBInvalidSlaveID = 0xE0

  ModbusMaster invalid response slave ID exception.
- static const uint8_t ku8MBInvalidFunction = 0xE1

  ModbusMaster invalid response function exception.
- static const uint8_t ku8MBResponseTimedOut = 0xE2

  ModbusMaster response timed out exception.
- static const uint8_t ku8MBInvalidCRC = 0xE3

  ModbusMaster invalid response CRC exception.

Private Member Functions

- uint8_t ModbusMasterTransaction (uint8_t u8MBFunction)

  Modbus transaction engine.

Private Attributes

- uint8_t _u8SerialPort

  serial port (0..3) initialized in constructor
- uint8_t _u8MBSlave

  Modbus slave (1..255) initialized in constructor.
- uint16_t _u16BaudRate

  baud rate (300..115200) initialized in begin()
- uint16_t _u16ReadAddress

  slave register from which to read
- uint16_t _u16ReadQty

  quantity of words to read
- uint16_t _u16ResponseBuffer [ku8MaxBufferSize]

  buffer to store Modbus slave response; read via GetResponseBuffer()
- uint16_t _u16WriteAddress

  slave register to which to write
- uint16_t _u16WriteQty

  quantity of words to write
- uint16_t _u16TransmitBuffer [ku8MaxBufferSize]

  buffer containing data to transmit to Modbus slave; set via SetTransmitBuffer()
- uint16_t * **txBuffer**
- uint8_t **_u8TransmitBufferIndex**
- uint16_t **u16TransmitBufferLength**
- uint16_t * **rxBuffer**
- uint8_t **_u8ResponseBufferIndex**
- uint8_t **_u8ResponseBufferLength**
- void(* **_idle**)()

Static Private Attributes

- static const uint8_t ku8MaxBufferSize = 64

  size of response/transmit buffers
- static const uint8_t ku8MBReadCoils = 0x01

  Modbus function 0x01 Read Coils.
- static const uint8_t ku8MBReadDiscreteInputs = 0x02

  Modbus function 0x02 Read Discrete Inputs.
- static const uint8_t ku8MBWriteSingleCoil = 0x05

  Modbus function 0x05 Write Single Coil.
- static const uint8_t ku8MBWriteMultipleCoils = 0x0F

  Modbus function 0x0F Write Multiple Coils.
- static const uint8_t ku8MBReadHoldingRegisters = 0x03

  Modbus function 0x03 Read Holding Registers.
- static const uint8_t ku8MBReadInputRegisters = 0x04

  Modbus function 0x04 Read Input Registers.
- static const uint8_t ku8MBWriteSingleRegister = 0x06

  Modbus function 0x06 Write Single Register.
- static const uint8_t ku8MBWriteMultipleRegisters = 0x10

  Modbus function 0x10 Write Multiple Registers.

- static const uint8_t ku8MBMaskWriteRegister = 0x16

  Modbus function 0x16 Mask Write Register.
- static const uint8_t ku8MBReadWriteMultipleRegisters = 0x17

  Modbus function 0x17 Read Write Multiple Registers.
- static const uint8_t ku8MBResponseTimeout = 200

  Modbus timeout [milliseconds].

5.1.1 Detailed Description

Arduino class library for communicating with Modbus slaves over RS232/485 (via RTU protocol).

Examples:

examples/Basic/Basic.pde, and examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde.

5.1.2 Member Function Documentation

5.1.2.1 void ModbusMaster::idle (void(*)() *idle*)

Set idle time callback function (cooperative multitasking).

This function gets called in the idle time between transmission of data and response from slave. Do not call functions that read from the serial buffer that is used by ModbusMaster. Use of i2c/TWI, 1-Wire, other serial ports, etc. is permitted within callback function.

See also

ModbusMaster::ModbusMasterTransaction()

```
263 {
264   _idle = idle;
265 }
```

5.1.2.2 uint8_t ModbusMaster::ModbusMasterTransaction (uint8_t *u8MBFunction*) [private]

Modbus transaction engine.

Sequence:

- assemble Modbus Request Application Data Unit (ADU), based on particular function called
- transmit request over selected serial port
- wait for/retrieve response
- evaluate/disassemble response
- return status (success/exception)

Parameters

u8MBFunction	Modbus function (0x01..0xFF)

Returns

0 on success; exception number on failure

```
649 {
650   uint8_t u8ModbusADU[256];
651   uint8_t u8ModbusADUSize = 0;
652   uint8_t i, u8Qty;
653   uint16_t u16CRC;
654   uint32_t u32StartTime;
655   uint8_t u8BytesLeft = 8;
656   uint8_t u8MBStatus = ku8MBSuccess;
657 
658   // assemble Modbus Request Application Data Unit
659   u8ModbusADU[u8ModbusADUSize++] = _u8MBSlave;
660   u8ModbusADU[u8ModbusADUSize++] = u8MBFunction;
661 
662   switch(u8MBFunction)
663   {
664     case ku8MBReadCoils:
665     case ku8MBReadDiscreteInputs:
666     case ku8MBReadInputRegisters:
667     case ku8MBReadHoldingRegisters:
668     case ku8MBReadWriteMultipleRegisters:
669       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16ReadAddress);
670       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16ReadAddress);
671       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16ReadQty);
672       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16ReadQty);
673       break;
674   }
675 
676   switch(u8MBFunction)
677   {
678     case ku8MBWriteSingleCoil:
679     case ku8MBMaskWriteRegister:
680     case ku8MBWriteMultipleCoils:
681     case ku8MBWriteSingleRegister:
682     case ku8MBWriteMultipleRegisters:
683     case ku8MBReadWriteMultipleRegisters:
684       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16WriteAddress);
685       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16WriteAddress);
686       break;
687   }
688 
689   switch(u8MBFunction)
690   {
691     case ku8MBWriteSingleCoil:
692       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16WriteQty);
693       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16WriteQty);
694       break;
695 
696     case ku8MBWriteSingleRegister:
697       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16TransmitBuffer[0]);
698       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16TransmitBuffer[0]);
699       break;
700 
701     case ku8MBWriteMultipleCoils:
702       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16WriteQty);
703       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16WriteQty);
704       u8Qty = (_u16WriteQty % 8) ? ((_u16WriteQty >> 3) + 1) : (
    _u16WriteQty >> 3);
705       u8ModbusADU[u8ModbusADUSize++] = u8Qty;
706       for (i = 0; i < u8Qty; i++)
707       {
708         switch(i % 2)
709         {
710           case 0: // i is even
711             u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16TransmitBuffer[i >> 1]);
712             break;
713 
714           case 1: // i is odd
715             u8ModbusADU[u8ModbusADUSize++] = highByte(_u16TransmitBuffer[i >> 1]);
716             break;
717         }
```

```
718       }
719       break;
720
721     case ku8MBWriteMultipleRegisters:
722     case ku8MBReadWriteMultipleRegisters:
723       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16WriteQty);
724       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16WriteQty);
725       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16WriteQty << 1);
726
727       for (i = 0; i < lowByte(_u16WriteQty); i++)
728       {
729         u8ModbusADU[u8ModbusADUSize++] = highByte(_u16TransmitBuffer[i]);
730         u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16TransmitBuffer[i]);
731       }
732       break;
733
734     case ku8MBMaskWriteRegister:
735       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16TransmitBuffer[0]);
736       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16TransmitBuffer[0]);
737       u8ModbusADU[u8ModbusADUSize++] = highByte(_u16TransmitBuffer[1]);
738       u8ModbusADU[u8ModbusADUSize++] = lowByte(_u16TransmitBuffer[1]);
739       break;
740   }
741
742   // append CRC
743   u16CRC = 0xFFFF;
744   for (i = 0; i < u8ModbusADUSize; i++)
745   {
746     u16CRC = crc16_update(u16CRC, u8ModbusADU[i]);
747   }
748   u8ModbusADU[u8ModbusADUSize++] = lowByte(u16CRC);
749   u8ModbusADU[u8ModbusADUSize++] = highByte(u16CRC);
750   u8ModbusADU[u8ModbusADUSize] = 0;
751
752   // transmit request
753   for (i = 0; i < u8ModbusADUSize; i++)
754   {
755 #if defined(ARDUINO) && ARDUINO >= 100
756     MBSerial->write(u8ModbusADU[i]);
757 #else
758     MBSerial->print(u8ModbusADU[i], BYTE);
759 #endif
760   }
761
762   u8ModbusADUSize = 0;
763   MBSerial->flush();
764
765   // loop until we run out of time or bytes, or an error occurs
766   u32StartTime = millis();
767   while (u8BytesLeft && !u8MBStatus)
768   {
769     if (MBSerial->available())
770     {
771 #if __MODBUSMASTER_DEBUG__
772       digitalWrite(4, true);
773 #endif
774       u8ModbusADU[u8ModbusADUSize++] = MBSerial->read();
775       u8BytesLeft--;
776 #if __MODBUSMASTER_DEBUG__
777       digitalWrite(4, false);
778 #endif
779     }
780     else
781     {
782 #if __MODBUSMASTER_DEBUG__
783       digitalWrite(5, true);
784 #endif
785       if (_idle)
786       {
787         _idle();
788       }
789 #if __MODBUSMASTER_DEBUG__
790       digitalWrite(5, false);
791 #endif
792     }
793
794     // evaluate slave ID, function code once enough bytes have been read
795     if (u8ModbusADUSize == 5)
796     {
797       // verify response is for correct Modbus slave
798       if (u8ModbusADU[0] != _u8MBSlave)
```

```
799       {
800         u8MBStatus = ku8MBInvalidSlaveID;
801         break;
802       }
803
804       // verify response is for correct Modbus function code (mask exception bit 7)
805       if ((u8ModbusADU[1] & 0x7F) != u8MBFunction)
806       {
807         u8MBStatus = ku8MBInvalidFunction;
808         break;
809       }
810
811       // check whether Modbus exception occurred; return Modbus Exception Code
812       if (bitRead(u8ModbusADU[1], 7))
813       {
814         u8MBStatus = u8ModbusADU[2];
815         break;
816       }
817
818       // evaluate returned Modbus function code
819       switch(u8ModbusADU[1])
820       {
821         case ku8MBReadCoils:
822         case ku8MBReadDiscreteInputs:
823         case ku8MBReadInputRegisters:
824         case ku8MBReadHoldingRegisters:
825         case ku8MBReadWriteMultipleRegisters:
826           u8BytesLeft = u8ModbusADU[2];
827           break;
828
829         case ku8MBWriteSingleCoil:
830         case ku8MBWriteMultipleCoils:
831         case ku8MBWriteSingleRegister:
832         case ku8MBWriteMultipleRegisters:
833           u8BytesLeft = 3;
834           break;
835
836         case ku8MBMaskWriteRegister:
837           u8BytesLeft = 5;
838           break;
839       }
840     }
841     if (millis() > (u32StartTime + ku8MBResponseTimeout))
842     {
843       u8MBStatus = ku8MBResponseTimedOut;
844     }
845   }
846
847   // verify response is large enough to inspect further
848   if (!u8MBStatus && u8ModbusADUSize >= 5)
849   {
850     // calculate CRC
851     u16CRC = 0xFFFF;
852     for (i = 0; i < (u8ModbusADUSize - 2); i++)
853     {
854       u16CRC = crc16_update(u16CRC, u8ModbusADU[i]);
855     }
856
857     // verify CRC
858     if (!u8MBStatus && (lowByte(u16CRC) != u8ModbusADU[u8ModbusADUSize - 2] ||
859       highByte(u16CRC) != u8ModbusADU[u8ModbusADUSize - 1]))
860     {
861       u8MBStatus = ku8MBInvalidCRC;
862     }
863   }
864
865   // disassemble ADU into words
866   if (!u8MBStatus)
867   {
868     // evaluate returned Modbus function code
869     switch(u8ModbusADU[1])
870     {
871       case ku8MBReadCoils:
872       case ku8MBReadDiscreteInputs:
873         // load bytes into word; response bytes are ordered L, H, L, H, ...
874         for (i = 0; i < (u8ModbusADU[2] >> 1); i++)
875         {
876           if (i < ku8MaxBufferSize)
877           {
878             _u16ResponseBuffer[i] = word(u8ModbusADU[2 * i + 4], u8ModbusADU[2 * i + 3]);
879           }
```

```
880
881           _u8ResponseBufferLength = i;
882         }
883
884         // in the event of an odd number of bytes, load last byte into zero-padded word
885         if (u8ModbusADU[2] % 2)
886         {
887           if (i < ku8MaxBufferSize)
888           {
889             _u16ResponseBuffer[i] = word(0, u8ModbusADU[2 * i + 3]);
890           }
891
892           _u8ResponseBufferLength = i + 1;
893         }
894         break;
895
896       case ku8MBReadInputRegisters:
897       case ku8MBReadHoldingRegisters:
898       case ku8MBReadWriteMultipleRegisters:
899         // load bytes into word; response bytes are ordered H, L, H, L, ...
900         for (i = 0; i < (u8ModbusADU[2] >> 1); i++)
901         {
902           if (i < ku8MaxBufferSize)
903           {
904             _u16ResponseBuffer[i] = word(u8ModbusADU[2 * i + 3], u8ModbusADU[2 * i + 4]);
905           }
906
907           _u8ResponseBufferLength = i;
908         }
909         break;
910     }
911   }
912
913   _u8TransmitBufferIndex = 0;
914   u16TransmitBufferLength = 0;
915   _u8ResponseBufferIndex = 0;
916   return u8MBStatus;
917 }
```

The documentation for this class was generated from the following files:

- ModbusMaster.h
- ModbusMaster.cpp

Chapter 6

File Documentation

6.1 crc16.h File Reference

CRC Computations.

Functions

- static uint16_t crc16_update (uint16_t crc, uint8_t a)

  Processor-independent CRC-16 calculation.

6.1.1 Detailed Description

CRC Computations.

6.2 ModbusMaster.cpp File Reference

Arduino library for communicating with Modbus slaves over RS232/485 (via RTU protocol).

```
#include "ModbusMaster.h"
```

6.2.1 Detailed Description

Arduino library for communicating with Modbus slaves over RS232/485 (via RTU protocol).

6.3 ModbusMaster.h File Reference

Arduino library for communicating with Modbus slaves over RS232/485 (via RTU protocol).

```
#include "WProgram.h"
#include "util/crc16.h"
#include "util/word.h"
```

Classes

- class ModbusMaster

  Arduino class library for communicating with Modbus slaves over RS232/485 (via RTU protocol).

Macros

- #define __MODBUSMASTER_DEBUG__ (1)

  Set to 1 to enable debugging features within class:

6.3.1 Detailed Description

Arduino library for communicating with Modbus slaves over RS232/485 (via RTU protocol).

6.3.2 Macro Definition Documentation

6.3.2.1 #define __MODBUSMASTER_DEBUG__ (1)

Set to 1 to enable debugging features within class:

- pin 4 cycles for each byte read in the Modbus response
- pin 5 cycles for each millisecond timeout during the Modbus response

6.4 word.h File Reference

Utility Functions for Manipulating Words.

Functions

- static uint16_t lowWord (uint32_t ww)

  Return low word of a 32-bit integer.
- static uint16_t highWord (uint32_t ww)

  Return high word of a 32-bit integer.

6.4.1 Detailed Description

Utility Functions for Manipulating Words.

Chapter 7

Example Documentation

7.1 examples/Basic/Basic.pde

```
/*

  Basic.pde - example using ModbusMaster library

  This file is part of ModbusMaster.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  along with ModbusMaster.  If not, see <http://www.gnu.org/licenses/>.

  Written by Doc Walker (Rx)
  Copyright © 2009-2013 Doc Walker <4-20ma at wvfans dot net>

*/

#include <ModbusMaster.h>


// instantiate ModbusMaster object as slave ID 2
// defaults to serial port 0 since no port was specified
ModbusMaster node(2);


void setup()
{
  // initialize Modbus communication baud rate
  node.begin(19200);
}


void loop()
{
  static uint32_t i;
  uint8_t j, result;
  uint16_t data[6];

  i++;

  // set word 0 of TX buffer to least-significant word of counter (bits 15..0)
  node.setTransmitBuffer(0, lowWord(i));

  // set word 1 of TX buffer to most-significant word of counter (bits 31..16)
  node.setTransmitBuffer(1, highWord(i));
```

```
  // slave: write TX buffer to (2) 16-bit registers starting at register 0
  result = node.writeMultipleRegisters(0, 2);

  // slave: read (6) 16-bit registers starting at register 2 to RX buffer
  result = node.readHoldingRegisters(2, 6);

  // do something with data if read is successful
  if (result == node.ku8MBSuccess)
  {
    for (j = 0; j < 6; j++)
    {
      data[j] = node.getResponseBuffer(j);
    }
  }
}
```

7.2 examples/PhoenixContact_nanoLC/PhoenixContact_nanoLC.pde

```
/*

  PhoenixContact_nanoLC.pde - example using ModbusMaster library
  to communicate with PHOENIX CONTACT nanoLine controller.

  This file is part of ModbusMaster.

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  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  along with ModbusMaster.  If not, see <http://www.gnu.org/licenses/>.

  Written by Doc Walker (Rx)
  Copyright © 2009-2013 Doc Walker <4-20ma at wvfans dot net>

*/

#include <ModbusMaster.h>

// discrete coils
#define NANO_DO(n)   (0x0000 + n)
#define NANO_FLAG(n) (0x1000 + n)

// discrete inputs
#define NANO_DI(n)   (0x0000 + n)

// analog holding registers
#define NANO_REG(n)  (0x0000 + 2 * n)
#define NANO_AO(n)   (0x1000 + 2 * n)
#define NANO_TCP(n)  (0x2000 + 2 * n)
#define NANO_OTP(n)  (0x3000 + 2 * n)
#define NANO_HSP(n)  (0x4000 + 2 * n)
#define NANO_TCA(n)  (0x5000 + 2 * n)
#define NANO_OTA(n)  (0x6000 + 2 * n)
#define NANO_HSA(n)  (0x7000 + 2 * n)

// analog input registers
#define NANO_AI(n)   (0x0000 + 2 * n)


// instantiate ModbusMaster object, serial port 0, Modbus slave ID 1
ModbusMaster nanoLC(0, 1);


void setup()
{
  // initialize Modbus communication baud rate
  nanoLC.begin(19200);
}
```

```
void loop()
{
  static uint32_t u32ShiftRegister;
  static uint32_t i;
  uint8_t u8Status;

  u32ShiftRegister = ((u32ShiftRegister < 0x01000000) ? (u32ShiftRegister << 4) : 1);
  if (u32ShiftRegister == 0) u32ShiftRegister = 1;
  i++;

  // set word 0 of TX buffer to least-significant word of u32ShiftRegister (bits 15..0)
  nanoLC.setTransmitBuffer(0, lowWord(u32ShiftRegister));

  // set word 1 of TX buffer to most-significant word of u32ShiftRegister (bits 31..16)
  nanoLC.setTransmitBuffer(1, highWord(u32ShiftRegister));

  // set word 2 of TX buffer to least-significant word of i (bits 15..0)
  nanoLC.setTransmitBuffer(2, lowWord(i));

  // set word 3 of TX buffer to most-significant word of i (bits 31..16)
  nanoLC.setTransmitBuffer(3, highWord(i));

  // write TX buffer to (4) 16-bit registers starting at NANO_REG(1)
  // read (4) 16-bit registers starting at NANO_REG(0) to RX buffer
  // data is available via nanoLC.getResponseBuffer(0..3)
  nanoLC.readWriteMultipleRegisters(NANO_REG(0), 4, NANO_REG(1), 4);

  // write lowWord(u32ShiftRegister) to single 16-bit register starting at NANO_REG(3)
  nanoLC.writeSingleRegister(NANO_REG(3), lowWord(u32ShiftRegister));

  // write highWord(u32ShiftRegister) to single 16-bit register starting at NANO_REG(3) + 1
  nanoLC.writeSingleRegister(NANO_REG(3) + 1, highWord(u32ShiftRegister));

  // set word 0 of TX buffer to nanoLC.getResponseBuffer(0) (bits 15..0)
  nanoLC.setTransmitBuffer(0, nanoLC.getResponseBuffer(0));

  // set word 1 of TX buffer to nanoLC.getResponseBuffer(1) (bits 31..16)
  nanoLC.setTransmitBuffer(1, nanoLC.getResponseBuffer(1));

  // write TX buffer to (2) 16-bit registers starting at NANO_REG(4)
  nanoLC.writeMultipleRegisters(NANO_REG(4), 2);

  // read 17 coils starting at NANO_FLAG(0) to RX buffer
  // bits 15..0 are available via nanoLC.getResponseBuffer(0)
  // bit 16 is available via zero-padded nanoLC.getResponseBuffer(1)
  nanoLC.readCoils(NANO_FLAG(0), 17);

  // read (66) 16-bit registers starting at NANO_REG(0) to RX buffer
  // generates Modbus exception ku8MBIllegalDataAddress (0x02)
  u8Status = nanoLC.readHoldingRegisters(NANO_REG(0), 66);
  if (u8Status == nanoLC.ku8MBIllegalDataAddress)
  {
    // read (64) 16-bit registers starting at NANO_REG(0) to RX buffer
    // data is available via nanoLC.getResponseBuffer(0..63)
    u8Status = nanoLC.readHoldingRegisters(NANO_REG(0), 64);
  }

  // read (8) 16-bit registers starting at NANO_AO(0) to RX buffer
  // data is available via nanoLC.getResponseBuffer(0..7)
  nanoLC.readHoldingRegisters(NANO_AO(0), 8);

  // read (64) 16-bit registers starting at NANO_TCP(0) to RX buffer
  // data is available via nanoLC.getResponseBuffer(0..63)
  nanoLC.readHoldingRegisters(NANO_TCP(0), 64);

  // read (64) 16-bit registers starting at NANO_OTP(0) to RX buffer
  // data is available via nanoLC.getResponseBuffer(0..63)
  nanoLC.readHoldingRegisters(NANO_OTP(0), 64);

  // read (64) 16-bit registers starting at NANO_TCA(0) to RX buffer
  // data is available via nanoLC.getResponseBuffer(0..63)
  nanoLC.readHoldingRegisters(NANO_TCA(0), 64);

  // read (64) 16-bit registers starting at NANO_OTA(0) to RX buffer
  // data is available via nanoLC.getResponseBuffer(0..63)
  nanoLC.readHoldingRegisters(NANO_OTA(0), 64);

  // read (8) 16-bit registers starting at NANO_AI(0) to RX buffer
  // data is available via nanoLC.getResponseBuffer(0..7)
  nanoLC.readInputRegisters(NANO_AI(0), 8);
```

```
}
```

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