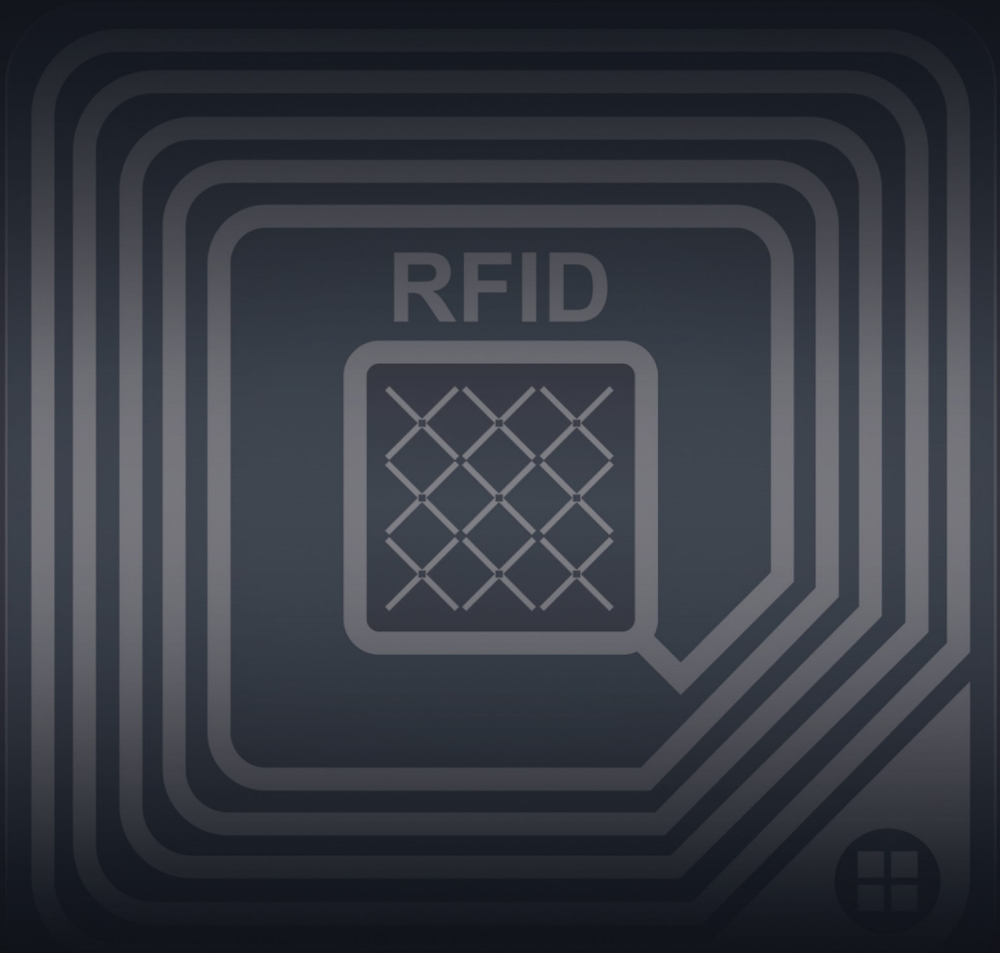
E BLOCKS 2

RFID systems



CP9329

MATRIX

www.matrixtsl.com

EBLOCKS2

CP9329

RFID Systems

Instructor Guide

Contents

About this course

Aims: The principal aim of this course is to introduce the student to the concepts involved in RFID.
On completing this course the student will have learned:

- the basic components of a RFID system;
- common applications for RFID;
- techniques to configure the RFID reader to enable communication with either ICODE or Mifare transponders;

the commands and syntax used to read and write data from and to RFID transponders.

What the student will need:
To complete this course the student will need the following equipment:

- Flowcode software, version 8 or later

E-blocks2 boards including:

a PIC or Arduino Uno processor, BL0011 or BL0055
an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
an LED E-blocks2 (BL0167)
an LCD E-blocks2 (BL0169)
a Keypad E-blocks2 (BL0138)
ICODE RFID transponders
Mifare RFID transponders.

Using this course:
This course presents the student with a number of tasks listed in the exercises in the following text. All the information needed to complete the labs is contained in the notes.

Before starting any exercises, the student should spend some time familiarising him/herself with the material on this course so that (s)he knows where to look when stuck.

Time: If you undertake all of the exercises on this course then it will take you around twelve hours.
Course conventions:

In this course we will use the following conventions:

The main font type is Arial 11 point.

All acronyms will be fully spelt out the first time they are mentioned.
For example
EPROM (Electrically Programmable Read Only Memory)

Matrix products are capitalised on the first word.
For example:
Multiprogrammer,
Prototype board,
Flowcode

Flowcode menu instructions will be fully capitalised.
For example:

- FILE...OPEN

Section	Notes for instructors	Timing (minutes)
1. Introduction to RFID		
1.1 The RFID system	Students familiarise themselves with the hardware components that make up a typical RFID system. They can use websites such as www.rfid.co.uk, or use a wider internet search to learn more about hardware specifications and costs.	10 - 30
1.2 RFID applications	This section outlines areas of use for RFID technology. Students should be encouraged to explore some of these applications through an internet search.	10 - 30
2. RFID system components		
2.1 Reader	Examples or photographs of a range of RFID readers could be made available for students to examine.	5
2.2 Transponders	Again, examples or photographs of the different types of transponder could be provided. Students could use the internet to find information about devices and operating frequencies, and their relative advantages.	5 - 20
3. Anatomy of a passive RFID transponder		
3.1 Transponder communication	Implicit in this section is knowledge about electrical resonance. Students may need support with, or encouragement to research into, this topic. Equally important is the concept of Load Modulation. More information can be obtained from sources such as the RFID handbook (Wiley & Sons).	10 - 30
3.2 The structure of a transponder	Students need familiarity with types of electronic memory, and with interpreting memory maps. This may require intervention by the Instructor.	5 - 20

Section	Notes for instructors	Timing (minute
4. The RFID reader module		
4.1 Host communication	The text refers to the following RS232 signals – TXD, RXD and CTS. Depending on previous experience and desired outcome, it may be beneficial for the Instructor to provide more information about the RS232 protocol at this point. The protocol is now also known as the EIA/TIA232 protocol, (and has been further extended into EIA/TIA 422 and 485 protocols). Alternatively, the students could be directed to web-sites such as Wikipedia (http://en.wikipedia.org/wiki/RS-232) or http://www.inetdaemon.com/tutorials/wan/serial/eia/eia232.shtml.	5 - 20
4.2 Command sequences	The role of the status byte as an acknowledgment and in fault-finding should be emphasised here	5
4.3 Reader module configuration	A datasheet for the RWD-MICODE reader module can be found on the ibtechnology website - (www.ibtechnology.co.uk)	5 - 20
4.4 Transponder type selection	The student should appreciate that the Initialise macro, reading the Protocol selected on the Properties page of the RFID component, controls location 3 and hence transponder type selection.	5
4.5 Authorised UID list	The exercises in this course do not use this function	5

Section	Notes for instructors	Timing (minutes)
5. The RFID E-blocks2		
5.1 Connecting the RFID E-blocks2	The students will be required to build up the system from individual E-blocks2 using the port mapping table provided	5
5.2 RFID E-blocks2 configuration	E-blocks2 boards have defined connections for all signals. For more information, see the E-blocks2 datasheet.	10 – 20

Section	Notes for instructors	Timing (minutes)
6. Using ICODE mode		
6.1 Overview	The important ideas here are: data is stored in the ICODE memory in 4-byte blocks; the UID for these transponders is eight bytes long, and so occupies the first two blocks; ICODE tags support multiple transponder operation, so that several transponders can be identified in the RF field and can be in communication with the reader module.	5
6.2 ICODE mode status byte	The information conveyed in the status byte is invaluable in troubleshooting. Students should be familiar with the significance of bits 1 and 2 in particular.	5
7. Exercise 1 – Reader module communications in ICODE mode		
7.1 Introduction 7.2 Objective 7.3 Requirements 7.4 The Flowcode program in detail 7.4.1 Initialise function 7.4.2 GetRFIDStatus function 7.5 What to do 7.6 Further work	This is the first of a series of practical assignments using Flowcode to control the RFID reader module and its communication with transponder cards. Its aim is to detect the presence of an ICODE transponder. The Flowcode RFID component provides all the functions needed to control the RWD-MICODE reader module. This exercise introduces two of these: the Initialise function which configures the communication link between the host controller and the RFID reader module; the GetRFIDStatus function, which obtains the current value of the reader module status byte. Students design and test a Flowcode program to establish communications between the host controller and the RWD-MICODE reader module. This involves configuring the hardware, including the Flowcode RFID component, and then writing configuration data to the RFID reader module, which then replies with status information, the status byte. Detailed instructions on how to build the Flowcode program are given in the 'What to do' section. It is assumed that students already know how to: add a new variable to a program; add a LED array to the program, and configure its properties; output a the value of a variable to the LEDs; create a program loop incorporating a time delay. A suitable Flowcode program is described in the 'Solutions to Exercises' section.	30

Section	Notes for instructors	Timing (minutes)
8. Exercise 2 – Obtaining the UID from a transponder in ICODE mode		
8.1 Introduction 8.2 Objective 8.3 Requirements 8.4 The Flowcode program in detail 8.4.1 GetRFIDUID function 8.4.2 ReadRFIDUID function 8.5 What to do 8.6 Further work	The aim of this exercise is to write a Flowcode program that will display, on the LCD, the 8-byte UID of an ICODE transponder in contact with the RFID reader module. This exercise introduces two more functions: the GetRFIDUID function, used to obtain the reader module status byte, and to copy the UID of the transponder into a memory buffer; the ReadRFIDUID function used to access the reader module memory buffer to extract, in this case, each byte of the UID in turn. Detailed instructions on how to build the Flowcode program are given in the 'What to do' section. In addition to the prior knowledge assumed for exercise 1, it is assumed that students already know how to: add a LCD display as an output device, and configure its properties; add a component macro and select the LCD display component call the LCD display 'Start' macro; call the LCD display 'Clear' macro; call the LCD display 'Cursor' macro; call the LCD display 'PrintNumber' macro use a Decision box to test the value of a variable; set up a While loop using an index; increment the index. A suitable Flowcode program is described in the 'Solutions to Exercises' section.	30

Section	Notes for instructors	Timing (minutes)
10. Exercise 4 – Write transponder data in ICODE mode		
10.1 Introduction 10.2 Objective 10.3 Requirements 10.4 The Flowcode program in detail 10.4.1 WriteRFIDBuffer function 10.4.2 WriteRFIDBlock function 10.5 What to do 10.6 Further work	The aim of exercise 4 is to modify the previous Flowcode program to write data from the keypad to a transponder. This time, the 4 bytes of data are written to a memory buffer in the reader module, created by the Flowcode RFID component. Then the contents of buffer can be written to the transponder, along with the transponder's UID learned when the transponder was first detected. This exercise introduces two more functions: the WriteRFIDBuffer function used to write data, one byte at a time, to the reader module memory; the WriteRFIDBlock function used to copy the contents of the buffer to a particular location in the transponder's memory. The WriteRFIDBuffer function must be used four times to transfer all four bytes of data to the reader module memory buffer before the WriteRFIDBlock function is used. Detailed instructions on how to build the Flowcode program are given in the 'What to do' section. In addition to the prior knowledge assumed for earlier exercises, it is assumed that students already know how to: add a Keypad component as an input device; create a variable called 'keyval'; use the Keypad 'GetNumber' macro. A suitable Flowcode program is described in the 'Solutions to Exercises' section.	30

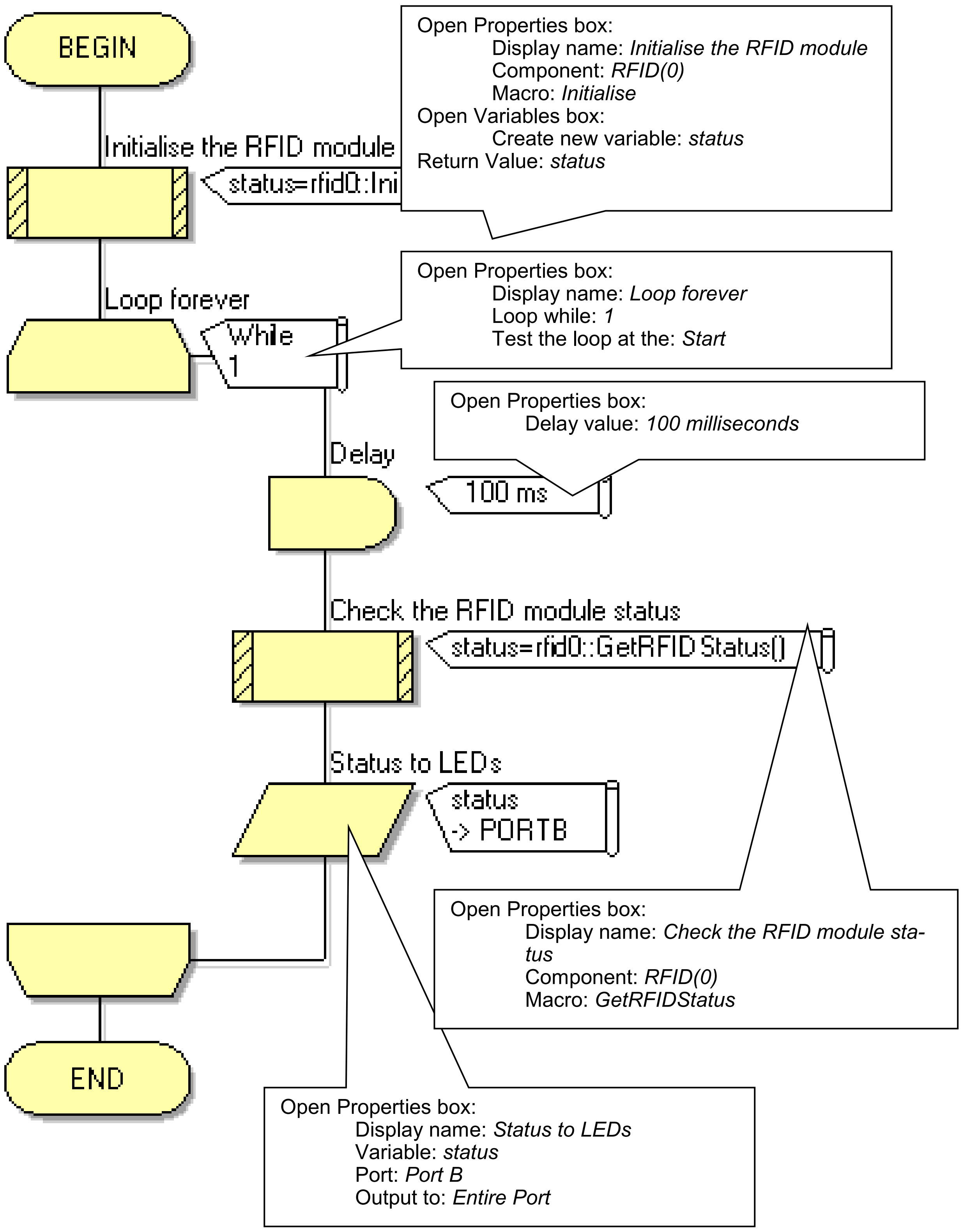
Section	Notes for instructors	Timing (minutes)
11. Using Mifare mode		
11.1 Overview	The important ideas here are: there are three types of Mifare card, 1K, 4K and Ultralight; the first two of these types are compatible, and differ only in their storage capacity, but these are not compatible with Ultralight transponders; data storage can be configured in one of two forms: standard format, where each block stores sixteen bytes of data; 'Value' format, a more secure format used for e-purse applications, incorporating error-checking. three additional commands are available when using the Value format,: Increment – add a 4-byte value to the value in the memory block; Decrement – subtract a 4-byte value from the value in the memory block; Transfer – copy the contents of the memory block to another location. transponder read / write commands require the use of security keys stored in the reader module and transponder;	15
11.2 Mifare mode status byte	As in ICODE mode, the information conveyed is important in troubleshooting. Bits 1 and 2 keep the sam significance, but in addition, bits 3 and 4 identify the type of Mifare card detected.	5
12. Exercise 5 – Reader module communications in Mifare mode		
(This is the Mifare equivalent of exercise 1.)		
12.1 Introduction 12.2 Objective 12.3 Requirements 12.4 The Flowcode program in detail 12.4.1 Initialise function 12.4.2 GetRFIDStatus function 12.5 What to do 12.6 Further work	This exercise has the same aims as exercise 1, but uses Mifare mode. Students could start practical work at this point, and then tackle ICODE mode after completing exercise 9. For that reason, detailed instructions are given on building the Flowcode program. If students are starting practical work here, the instructor should note the assumed prior knowledge of Flowcode programming detailed in the notes for Exercise 1. Students could modify the program developed in Exercise 1, or start a new program for this exercise. A suitable Flowcode program is described in the 'Solutions to Exercises' section.	30

Section	Notes for instructors	Timing (minutes)
13. Exercise 6 – Obtaining the UID from a Mifare Classic transponder		
(This is the Mifare equivalent of exercise 2.)		
13.1 Introduction 13.2 Objective 13.3 Requirements 13.4 The Flowcode program in detail 13.4.1 GetRFIDUID function 13.4.2 ReadRFIDUID function 13.5 What to do 13.6 Further work	This exercise has the same aim as exercise 2, to display the UID of a transponder, but using Mifare mode This exercise uses the functions: the GetRFIDUID function, used to copy the UID of the transponder into a memory buffer; the ReadRFIDUID function used to access each byte of the UID in turn. Instructors are reminded that students are expected to: add a LCD display as an output device, and configure its properties; add a component macro and select the LCD display component call the LCD display 'Start' macro; call the LCD display 'Clear' macro; call the LCD display 'Cursor' macro; call the LCD display 'PrintNumber' macro use a Decision box to test the value of a variable; set up a While loop using an index; increment the index. Students could build a new program for this exercise or modify the program developed in Exercise 2, by ignoring the programming steps printed in italics. A suitable Flowcode program is described in the 'Solutions to Exercises' section.	30

Section	Notes for instructors	Timing (minutes)
14. Exercise 7 – Using security keys		
(This is the Mifare equivalent of exercise 3, but with substantial modification.)		
14.1 Introduction	This exercise introduces the enhanced security features of Mifare transponders, but otherwise follows the program structure of exercise 3. The last block of each sector of Mifare memory is known as the Sector Trailer Block, and contains security data, in the form of two security keys and four access bits, for that block. The access bits control whether access to the block is read only, write only or read-and-write, and determines which of the two keys is in force. This exercise uses the functions: StoreRFIDKey function to create a new key value; ReadRFIDBlock function to transfer data from the transponder memory to the reader module memory buffer; ReadRFIDBuffer function to transfer it to the LCD display. Instructors are reminded that students are expected to: use the LCD display 'PrintAscii' macro to display text on the LCD screen. Students could build a new program for this exercise or modify the program developed in Exercise 3, by ignoring the programming steps printed in italics. A suitable Flowcode program is described in the 'Solutions to Exercises' section.	30
14.1.1 Security features		
14.2 Objective		
14.3 Requirements		
14.4 The Flowcode program in detail		
14.4.1 Default keys		
14.4.2 StoreRFIDKey function		
14.4.3 ReadRFIDBlock function		
14.5 What to do		
14.6 Further work		

Section	Notes for instructors	Timing (minutes)
15. Exercise 8 - Write data to a Mifare transponder		
(This is the Mifare equivalent of exercise 4.)		
15.1 Introduction	This exercise has the same aim as exercise 4 and has substantially the same program structure.	30
15.2 Objective	Students could build a new program for this exercise or could modify the program developed in Exercise 4, by ignoring the programming steps printed in italics.	
15.3 Requirements	A suitable Flowcode program is described in the 'Solutions to Exercises' section.	
15.4 The Flowcode program in detail		
15.4.1 GetRFIDUID function		
15.4.2 ReadRFIDUID function		
15.5 What to do		
15.6 Further work		

Section	Notes for instructors	Timing (minutes)
16. Exercise 9 – Using Value format		
16.1 Introduction 16.1.1 The FormatRFIDValue function 16.1.2 The IncrementRFIDValue function 16.1.3 The DecrementRFIDValue function 16.1.4 The TransferRFIDValue function 16.2 Objective 16.3 Requirements 16.4 The Flowcode program in detail 16.5 What to do 16.6 Further work	Mifare classic transponders can use 16-byte memory blocks to store 4-byte (32-bit) numeric value using a special 'Value' format that allow three extra commands, increment, decrement and transfer, to be used on them. This exercise builds on the program used in Exercise 8 to explore two of these commands, using the IncrementRFIDValue and DecrementRFIDValue macros. To permit this, the data stored on the transponder must be written in Value format. This is achieved using the FormatRFIDValue macro. The aim of the main program is simply to explore using these new commands and data format. The Further work section outlines a very practical application for this technology, in part 3. Suitable Flowcode programs are described in the 'Solutions to Exercises' section.	30



Open Properties box:
Display name: *Initialise the RFID module*
Component: *RFID(0)*
Macro: *Initialise*
Open Variables box:
Create new variable: *status*
Return Value: *status*

Open Properties box:
Display name: *Loop forever*
Loop while: *1*
Test the loop at the: *Start*

Open Properties box:
Delay value: *100 milliseconds*

Open Properties box:
Display name: *Check the RFID module status*
Component: *RFID(0)*
Macro: *GetRFIDStatus*

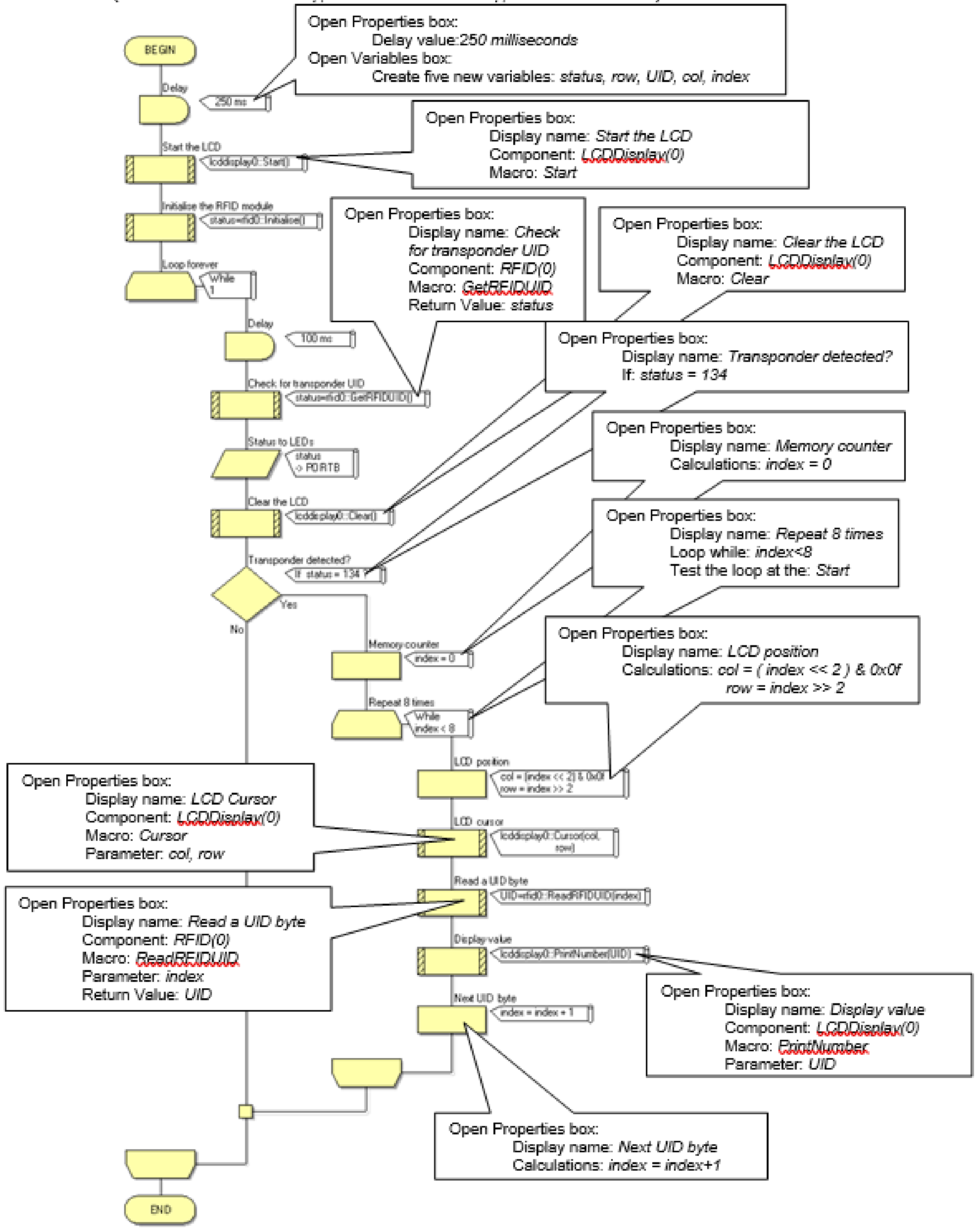
Open Properties box:
Display name: *Status to LEDs*
Variable: *status*
Port: *Port B*
Output to: *Entire Port*

Exercise 2
(Additional to the configuration information given in exercise 1)

E BLOCKS2

Exercise 2

(Additional to the configuration information given in exercise 1)



Open Properties box:
Delay value:*250 milliseconds*
Open Variables box:
Create five new variables: *status, row, UID, col, index*

Open Properties box:
Display name: *Start the LCD*
Component: *LCDDisplay(0)*
Macro: *Start*

Open Properties box:
Display name: *Check for transponder UID*
Component: *RFID(0)*
Macro: *GetRFIDUID*
Return Value: *status*

Open Properties box:
Display name: *Clear the LCD*
Component: *LCDDisplay(0)*
Macro: *Clear*

Open Properties box:
Display name: *Transponder detected?*
If: *status = 134*

Open Properties box:
Display name: *Memory counter*
Calculations: *index = 0*

Open Properties box:
Display name: *Repeat 8 times*
Loop while: *index<8*
Test the loop at the: *Start*

Open Properties box:
Display name: *LCD position*
Calculations: *col = (index << 2) & 0x0f*
row = index >> 2

Open Properties box:
Display name: *LCD Cursor*
Component: *LCDDisplay(0)*
Macro: *Cursor*
Parameter: *col, row*

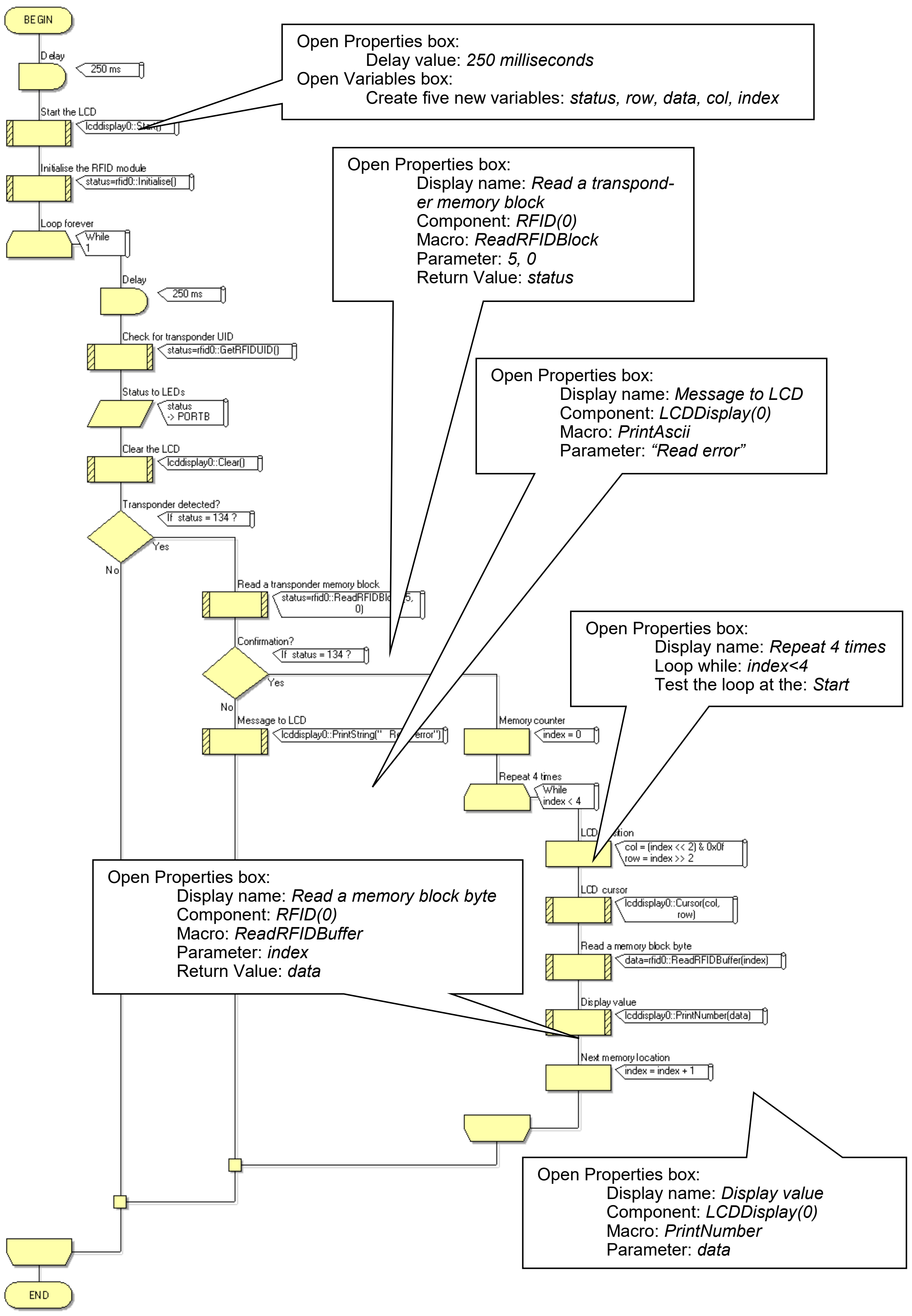
Open Properties box:
Display name: *Read a UID byte*
Component: *RFID(0)*
Macro: *ReadRFIDUID*
Parameter: *index*
Return Value: *UID*

Open Properties box:
Display name: *Display value*
Component: *LCDDisplay(0)*
Macro: *PrintNumber*
Parameter: *UID*

Open Properties box:
Display name: *Next UID byte*
Calculations: *index = index+1*

Exercise 3

(Additional to the configuration information given in previous exercises)



Open Properties box:
    Delay value: *250 milliseconds*
Open Variables box:
    Create five new variables: *status, row, data, col, index*

Open Properties box:
    Display name: *Read a transponder memory block*
    Component: *RFID(0)*
    Macro: *ReadRFIDBlock*
    Parameter: *5, 0*
    Return Value: *status*

Open Properties box:
    Display name: *Message to LCD*
    Component: *LCDDisplay(0)*
    Macro: *PrintAscii*
    Parameter: *“Read error”*

Open Properties box:
    Display name: *Repeat 4 times*
    Loop while: *index<4*
    Test the loop at the: *Start*

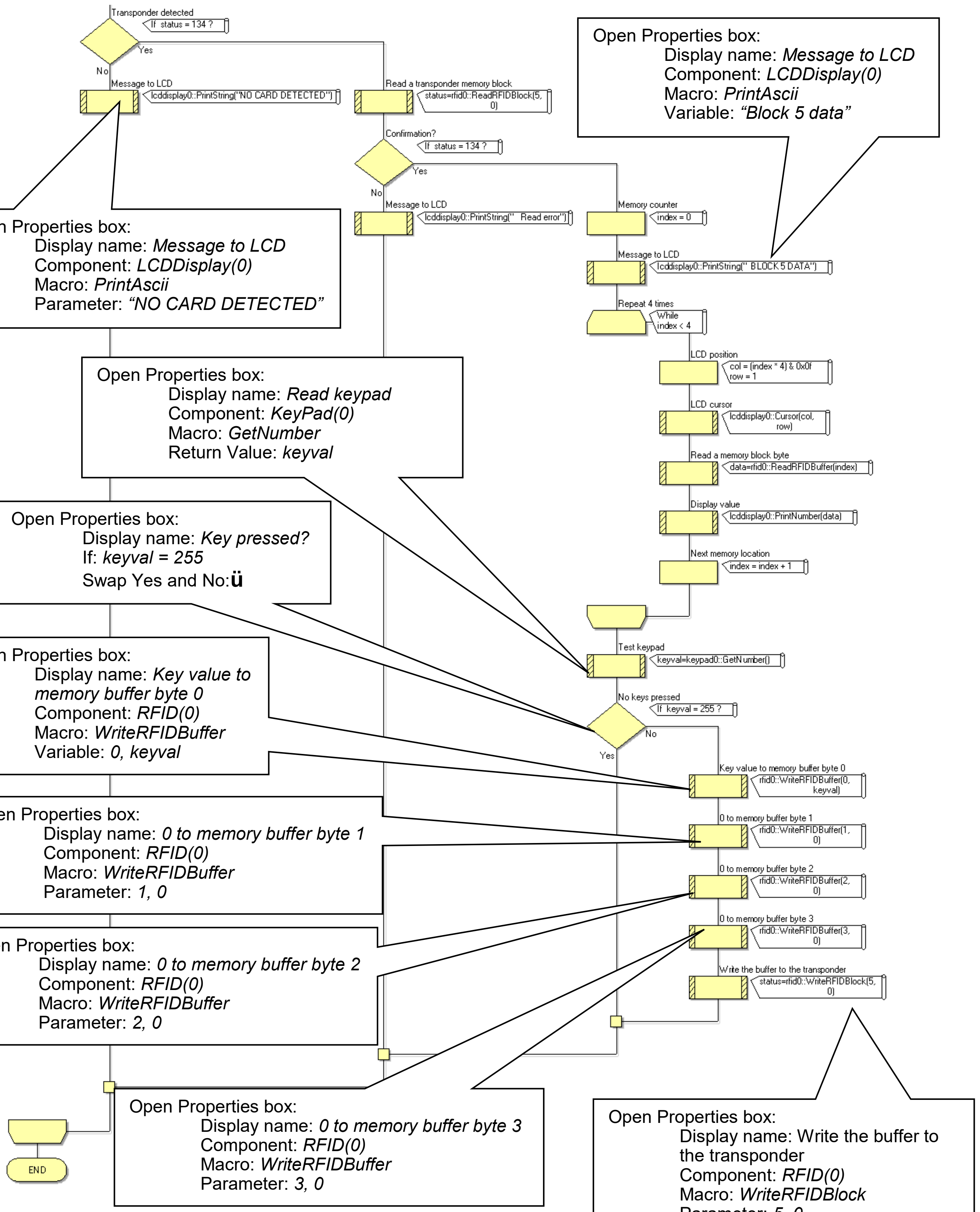
Open Properties box:
    Display name: *Read a memory block byte*
    Component: *RFID(0)*
    Macro: *ReadRFIDBuffer*
    Parameter: *index*
    Return Value: *data*

Open Properties box:
    Display name: *Display value*
    Component: *LCDDisplay(0)*
    Macro: *PrintNumber*
    Parameter: *data*

Exercise 4

(Additional to the configuration information given in previous exercises)

Program above here identical to exercise 3, except that variables are: *status, keyval, row, data, col, index*


Transponder detected
If status = 134 ?
Yes
No
Message to LCD
lcddisplay0::PrintString("NO CARD DETECTED")
Read a transponder memory block
status=rfid0::ReadRFIDBlock(5, 0)
Confirmation?
If status = 134 ?
Yes
No
Message to LCD
lcddisplay0::PrintString("   Read error")
Memory counter
index = 0
Message to LCD
lcddisplay0::PrintString(" BLOCK 5 DATA")
Repeat 4 times
While index < 4
LCD position
col = (index * 4) & 0x0f
row = 1
LCD cursor
lcddisplay0::Cursor(col, row)
Read a memory block byte
data=rfid0::ReadRFIDBuffer(index)
Display value
lcddisplay0::PrintNumber(data)
Next memory location
index = index + 1
Test keypad
keyval=keypad0::GetNumber()
No keys pressed
If keyval = 255 ?
No
Yes
Key value to memory buffer byte 0
rfid0::WriteRFIDBuffer(0, keyval)
0 to memory buffer byte 1
rfid0::WriteRFIDBuffer(1, 0)
0 to memory buffer byte 2
rfid0::WriteRFIDBuffer(2, 0)
0 to memory buffer byte 3
rfid0::WriteRFIDBuffer(3, 0)
Write the buffer to the transponder
status=rfid0::WriteRFIDBlock(5, 0)
END

Open Properties box:
Display name: *Message to LCD*
Component: *LCDDisplay(0)*
Macro: *PrintAscii*
Variable: *"Block 5 data"*

Open Properties box:
Display name: *Message to LCD*
Component: *LCDDisplay(0)*
Macro: *PrintAscii*
Parameter: *"NO CARD DETECTED"*

Open Properties box:
Display name: *Read keypad*
Component: *KeyPad(0)*
Macro: *GetNumber*
Return Value: *keyval*

Open Properties box:
Display name: *Key pressed?*
If: *keyval = 255*
Swap Yes and No:ü

Open Properties box:
Display name: *Key value to memory buffer byte 0*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Variable: *0, keyval*

Open Properties box:
Display name: *0 to memory buffer byte 1*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Parameter: *1, 0*

Open Properties box:
Display name: *0 to memory buffer byte 2*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Parameter: *2, 0*

Open Properties box:
Display name: *0 to memory buffer byte 3*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Parameter: *3, 0*

Open Properties box:
Display name: Write the buffer to the transponder
Component: *RFID(0)*
Macro: *WriteRFIDBlock*
Parameter: *5, 0*
Return Value: *status*

Exercise 5

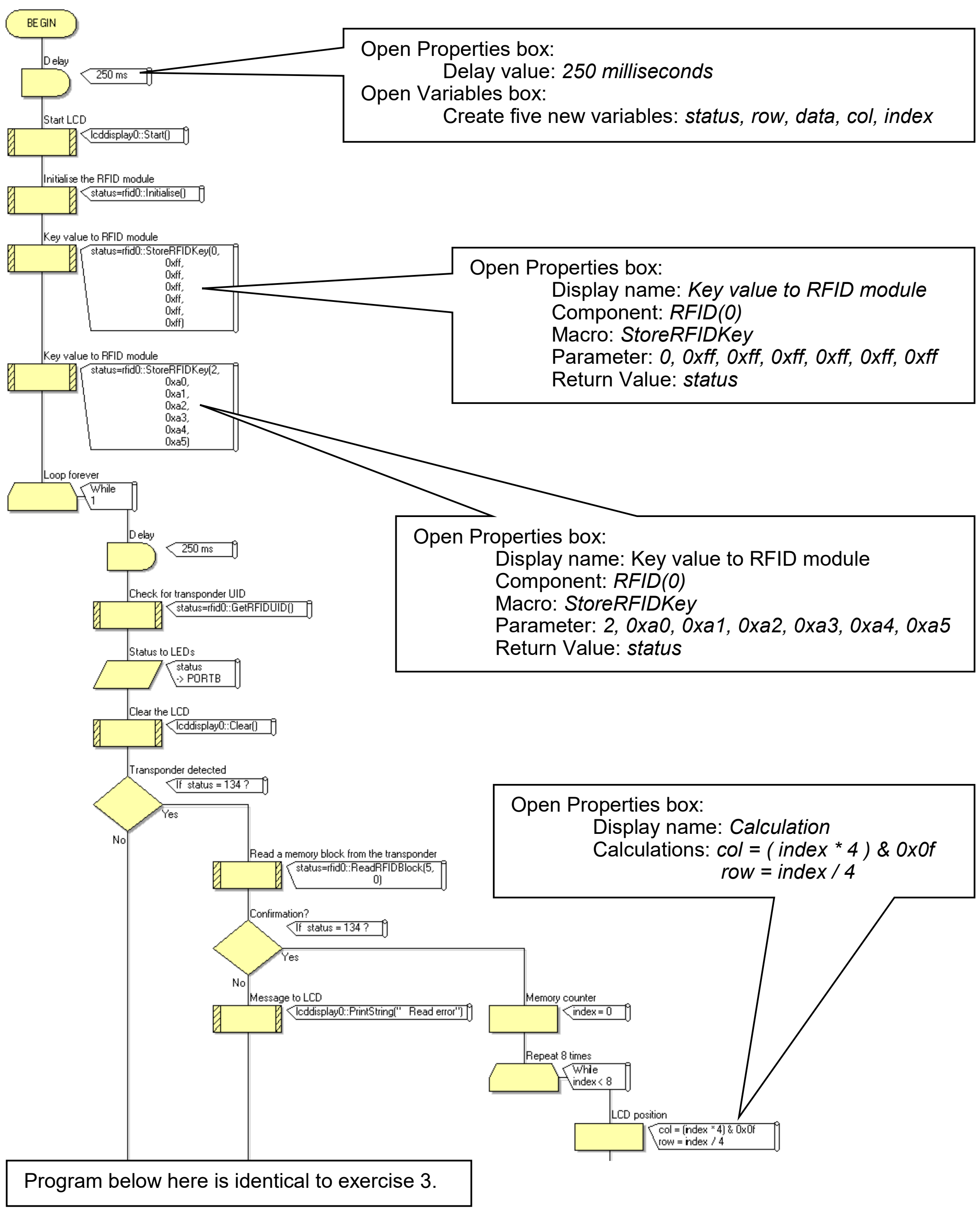
The Flowcode flowchart is identical to that for Exercise 1.
Open the RFID component RFID(0) Properties box, and select the *Mifare 1K/4K* protocol.

Exercise 6

The Flowcode flowchart is identical to that for Exercise 2.
Open the RFID component RFID(0) Properties box, and select the *Mifare 1K/4K* protocol.

Exercise 7

The Flowcode flowchart is identical to that for Exercise 3.
Open the RFID component RFID(0) Properties box, and select the *Mifare 1K/4K* protocol.



Open Properties box:
Delay value: *250 milliseconds*
Open Variables box:
Create five new variables: *status, row, data, col, index*

Open Properties box:
Display name: *Key value to RFID module*
Component: *RFID(0)*
Macro: *StoreRFIDKey*
Parameter: *0, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff*
Return Value: *status*

Open Properties box:
Display name: Key value to RFID module
Component: *RFID(0)*
Macro: *StoreRFIDKey*
Parameter: *2, 0xa0, 0xa1, 0xa2, 0xa3, 0xa4, 0xa5*
Return Value: *status*

Open Properties box:
Display name: *Calculation*
Calculations: *col = (index * 4) & 0x0f*
row = index / 4

Program below here is identical to exercise 3.

Exercise 8

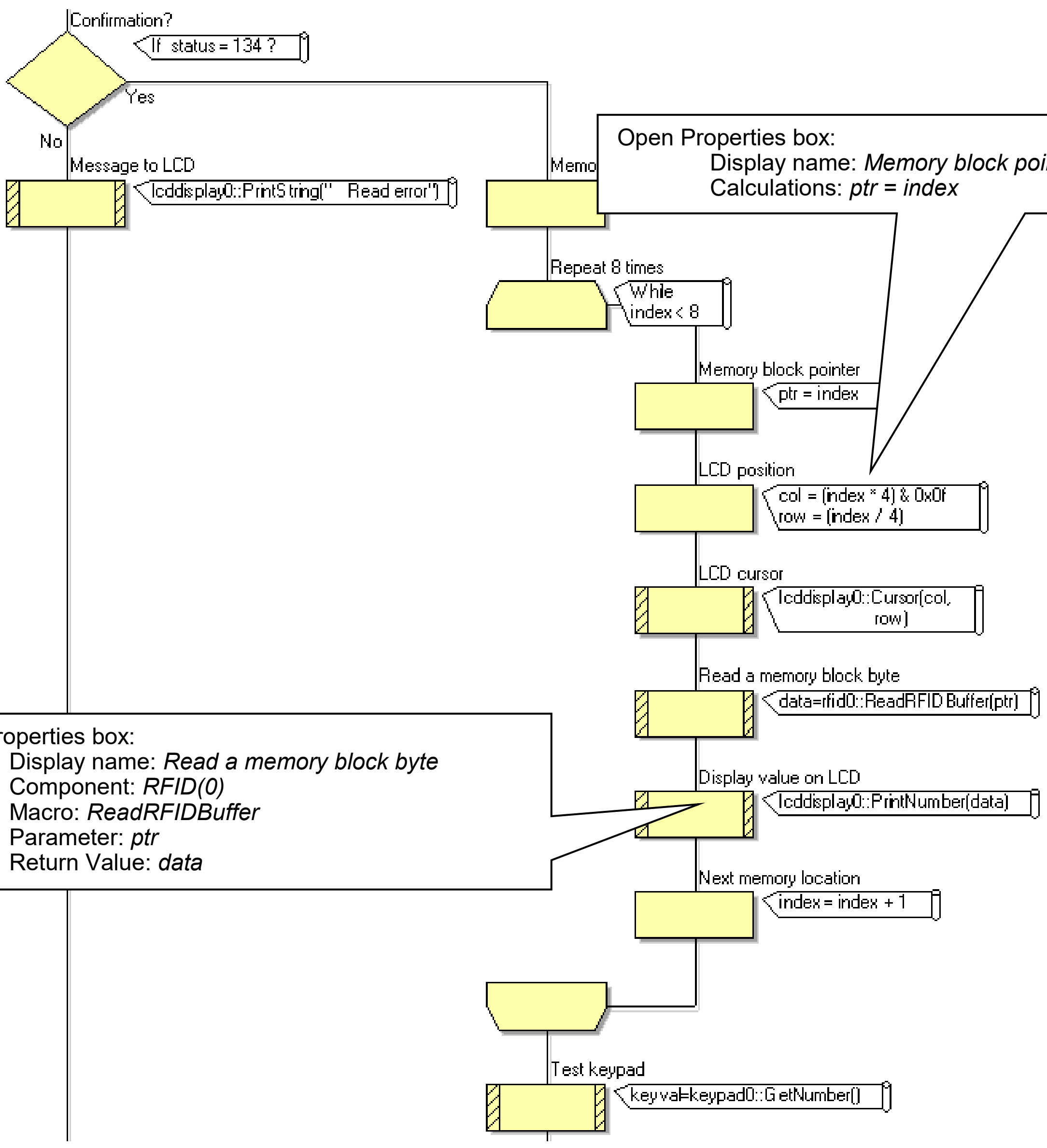
The Flowcode flowchart is identical to that for Exercise 4.
Open the RFID component RFID(0) Properties box, and select the *Mifare 1K/4K* protocol.

Exercise 9

The Flowcode flowchart from exercise 8 can be extended to meet the requirements of this exercise.

The first modification is shown in the following diagram. It introduces an offset pointer to allow the ReadRFIDBuffer macro to read any consecutive eight of the sixteen bytes in the block. To begin with, there is no offset, and the macro reads the first eight bytes.

Program above here identical to exercise 8, except that variables are: *status, keyval, row,* ***ptr****, data, col, index*



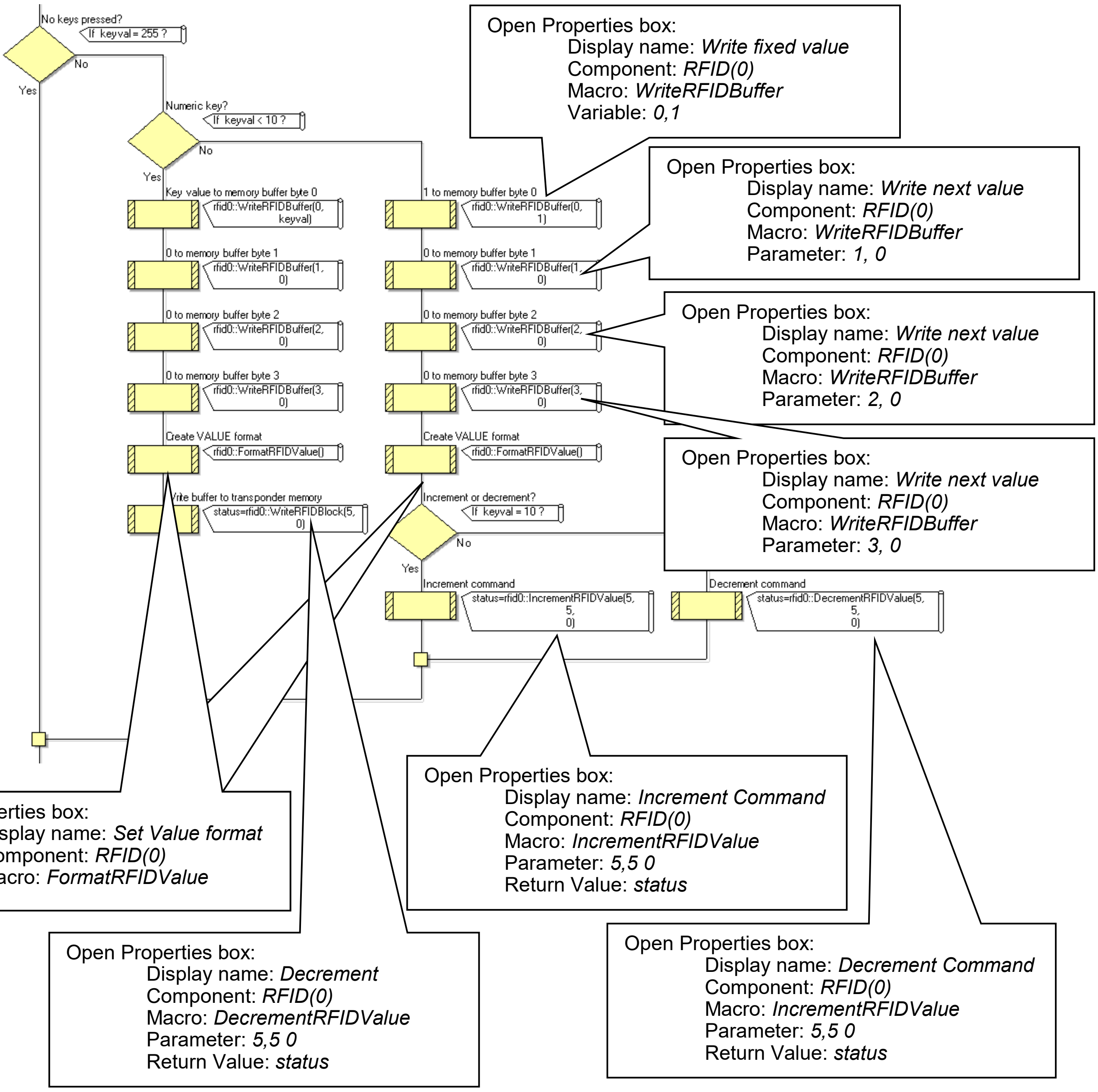
Open Properties box:
Display name: *Memory block pointer*
Calculations: *ptr = index*

Open Properties box:
Display name: *Read a memory block byte*
Component: *RFID(0)*
Macro: *ReadRFIDBuffer*
Parameter: *ptr*
Return Value: *data*

The other changes happen to the section of the program after the test to see if a key has been pressed. If the key pressed is 0 to 9, then the behaviour is the same as in Exercise 8, the value of the key pressed is transferred to the tag. One difference is the addition of a Component Macro, which calls the FormatRFIDValue macro, to write the data to the tag in Value format.

If the Ü or # key is pressed, then the program follows a new path. This is shown in the next diagram. First of all, four bytes of fixed data is written to the reader memory buffer.
Then a Component Macro calls the FormatRFIDValue macro to write the data to the tag in Value format. This allows the Increment and Decrement operations to take place.

Another Decisions box is added to find out if the Ü key or the # key has been pressed. If it was the Ü key, then the data stored on the tag is incremented (but stored in the same place.) If the # key has been pressed, then the data is decremented.



No keys pressed?
If keyval = 255 ?
No
Yes
Numeric key?
If keyval < 10 ?
No
Yes
Key value to memory buffer byte 0
rfid0::WriteRFIDBuffer(0, keyval)
0 to memory buffer byte 1
rfid0::WriteRFIDBuffer(1, 0)
0 to memory buffer byte 2
rfid0::WriteRFIDBuffer(2, 0)
0 to memory buffer byte 3
rfid0::WriteRFIDBuffer(3, 0)
Create VALUE format
rfid0::FormatRFIDValue()
Write buffer to transponder memory
status=rfid0::WriteRFIDBlock(5, 0)
1 to memory buffer byte 0
rfid0::WriteRFIDBuffer(0, 1)
0 to memory buffer byte 1
rfid0::WriteRFIDBuffer(1, 0)
0 to memory buffer byte 2
rfid0::WriteRFIDBuffer(2, 0)
0 to memory buffer byte 3
rfid0::WriteRFIDBuffer(3, 0)
Create VALUE format
rfid0::FormatRFIDValue()
Increment or decrement?
If keyval = 10 ?
No
Yes
Increment command
status=rfid0::IncrementRFIDValue(5, 5, 0)
Decrement command
status=rfid0::DecrementRFIDValue(5, 5, 0)

Open Properties box:
Display name: *Write fixed value*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Variable: *0,1*

Open Properties box:
Display name: *Write next value*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Parameter: *1, 0*

Open Properties box:
Display name: *Write next value*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Parameter: *2, 0*

Open Properties box:
Display name: *Write next value*
Component: *RFID(0)*
Macro: *WriteRFIDBuffer*
Parameter: *3, 0*

Open Properties box:
Display name: *Increment Command*
Component: *RFID(0)*
Macro: *IncrementRFIDValue*
Parameter: *5,5 0*
Return Value: *status*

Open Properties box:
Display name: *Set Value format*
Component: *RFID(0)*
Macro: *FormatRFIDValue*

Open Properties box:
Display name: *Decrement*
Component: *RFID(0)*
Macro: *DecrementRFIDValue*
Parameter: *5,5 0*
Return Value: *status*

Open Properties box:
Display name: *Decrement Command*
Component: *RFID(0)*
Macro: *IncrementRFIDValue*
Parameter: *5,5 0*
Return Value: *status*

Command Syntax for both ICODE and Mifare modes

Obtain the status byte

Operation	ICODE card	Mifare card
Send	ASCII ‘S’ = 01010011$_2$ = 83$_{10}$ = 0x53	
Receive	Status byte	

This command is accomplished by the GetRFIDStatus macro.

Obtain the card UID

Operation	ICODE card	Mifare card	
		1K/4K	Ultralight
Send	ASCII ‘U’ = 01010101$_2$ = 85$_{10}$ = 0x55		
Receive	Status byte		
Data is returned only if the status byte shows a card is present and communicating.			
Receive	UID byte 0 (Least significant)	UID byte 0 (Least significant)	UID byte 0 (Least significant)
Receive	UID byte 1	UID byte 1	UID byte 1
Receive	UID byte 2	UID byte 2	UID byte 2
Receive	UID byte 3	UID byte 3	UID byte 3
Receive	UID byte 4	0x00	UID byte 4
Receive	UID byte 5	0x00	UID byte 5
Receive	UID byte 6	0x00	UID byte 6
Receive	UID byte 7		

This command is accomplished by the GetRFIDUID macro.

Read data from an ICODE card Read data from a Mifare card

Operation	ICODE card		Operation	ICODE card
Send	ASCII ‘R’ = 01010010$_2$ = 82$_{10}$ = 0x52		Send	ASCII ‘R’ = 01010010$_2$ = 82$_{10}$ = 0x52
Send	Block address (0 to 27)		Send	Block address (0 to 255)
Send	UID byte 0 (Least significant)		Send	T x x KKKKK (see below)
Send	UID byte 1		Receive	Status byte
Send	UID byte 2		If successful:	
Send	UID byte 3		Receive	Data byte 0 (Least significant)
Send	UID byte 4		Receive	Data byte 1
Send	UID byte 5		Receive	Data byte 2
Send	UID byte 6		Receive	Data byte 3
Send	UID byte 7		Receive	Data byte 4
Receive	Status byte		Receive	Data byte 5
If successful			Receive	Data byte 6
: Receive	Data byte 0 (Least significant)		Receive	Data byte 7
Receive	Data byte 1		Receive	Data byte 8
Receive	Data byte 2		Receive	Data byte 9
Receive	Data byte 3		Receive	Data byte 10
			Receive	Data byte 11
			Receive	Data byte 12
			Receive	Data byte 13
			Receive	Data byte 14
			Receive	Data byte 15

T = Key type (0 = Key A, 1 = Key B)
K = Key code number (0 – 31)

The Read command is accomplished by the ReadRFIDBlock macro.

Write data to an ICODE card **Write data to a Mifare card**

Operation	ICODE card		Operation	ICODE card
Send	ASCII ‘W’ = 01010111_2 = 87_{10} = 0x57		Send	ASCII ‘W’ = 01010111_2 = 87_{10} = 0x57
Send	Block address (0 to 27)		Send	Block address (0 to 255)
Send	UID byte 0 (Least significant)		Send	T x x KKKKK (see below)
Send	UID byte 1		Send	Data byte 0 (Least significant)
Send	UID byte 2		Send	Data byte 1
Send	UID byte 3		Send	Data byte 2
Send	UID byte 4		Send	Data byte 3
Send	UID byte 5		Send	Data byte 4
Send	UID byte 6		Send	Data byte 5
Send	UID byte 7		Send	Data byte 6
Send	Data byte 0 (Least significant)		Send	Data byte 7
Send	Data byte 1		Send	Data byte 8
Send	Data byte 2		Send	Data byte 9
Send	Data byte 3		Send	Data byte 10
			Send	Data byte 11
Receive	Status byte		Send	Data byte 12
			Send	Data byte 13
			Send	Data byte 14
			Send	Data byte 15
			Receive	Status byte

T = Key type (0 = Key A, 1 = Key B)
K = Key code number (0 – 31)

This command is accomplished by the WriteRFIDBlock macro.

Additional commands for Mifare mode

Default Keys

Mifare transponders are supplied by the manufacturers with default (transport) setting for all the keys and access bits. These settings allow full access, (read and write access) to the memory using key A for each operation.

The transport key settings depend on the manufacturer of the Mifare transponder.
The most common values are:

Key A	0x A0, A1, A2, A3, A4, A5 i.e.160_{10}, 161_{10}, 162_{10}, 163_{10}, 164_{10}, 165_{10}
Key B	0x B0, B1, B2, B3, B4, B5 i.e. 176_{10}, 177_{10}, 178_{10}, 179_{10}, 180_{10}, 181_{10}

or

Key A	0x FF, FF, FF, FF, FF, FF i.e. 255_{10}, 255_{10}, 255_{10}, 255_{10}, 255_{10}, 255_{10}
Key B	0xFF, FF, FF, FF, FF, FF i.e. 255_{10}, 255_{10}, 255_{10}, 255_{10}, 255_{10}, 255_{10}

Store a new Key value

Operation	**Mifare card**
Send	ASCII 'K' = 01001011_2 = 75_{10} = 0x4B
Send	x x x KKKKK (see below)
Send	Key byte 0
Send	Key byte 1
Send	Key byte 2
Send	Key byte 3
Send	Key byte 4
Send	Key byte 5
Receive	Status byte

K = Key code number (0 – 31)

This command is accomplished by the StoreRFIDKey macro.

The RWD-MICODE reader module contains a memory array that allows up to thirty-two 6-byte keys to be stored.

Increment an integer

The command adds a 4-byte number to the contents found in the source block. The result is stored in the destination block (which must be within the same sector).

Operation	Mifare card
Send	ASCII 'I' = 01001001_2 = 73_{10} = 0x49
Send	Source block address (0 to 255)
Send	T x x KKKKK (see below)
Send	Destination block address (0 to 255)
Send	Number byte 0
Send	Number byte 1
Send	Number byte 2
Send	Number byte 3
Receive	Status byte

T = Key type (0 = Key A, 1 = Key B)
K = Key code number (0 – 31)

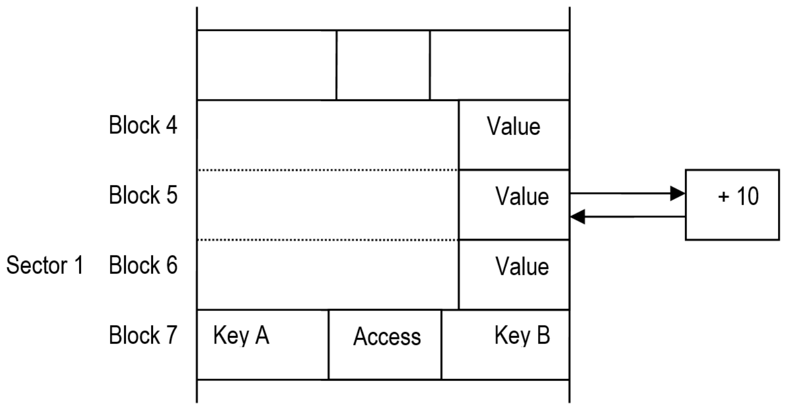
This command is accomplished by the IncrementRFIDValue macro.

Example

Add 10 to the value currently stored in transponder memory block 5.
Use the key stored at location 1 as Key A.
Store the result to the same memory block.

To do this:

Send	'I'	
Send	5	<source memory block>
Send	1	<key location (Key A)>
Send	5	<destination memory block (same as source)>
Send	10	<value byte0>
Send	0	<value byte1>
Send	0	<value byte2>
Send	0	<value byte3>
Receive	<status>	



Decrement an integer

The command subtracts a 4-byte number from the contents found in the source block. The result is stored in the destination block (which must be within the same sector).

Operation	Mifare card
Send	ASCII 'D' = 01000100_2 = 68_{10} = 0x44
Send	Source block address (0 to 255)
Send	T x x KKKKK (see below)
Send	Destination block address (0 to 255)
Send	Number byte 0
Send	Number byte 1
Send	Number byte 2
Send	Number byte 3
Receive	Status byte

T = Key type (0 = Key A, 1 = Key B)
K = Key code number (0 – 31)

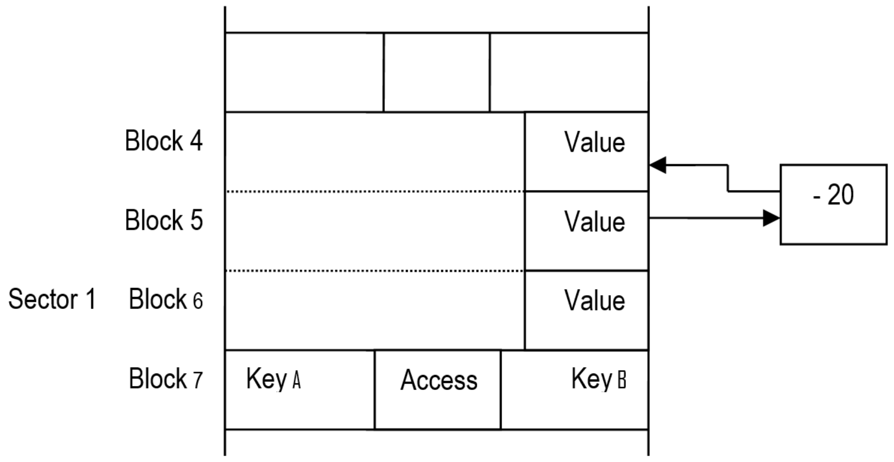
This command is accomplished by the DecrementRFIDValue macro.

Example:

Copy the value currently stored in transponder memory block 5 to transponder memory block 4.
Subtract 20 from the copied value as it is written.
Use the data key at storage location 1 as Key B.

To do this:

Send	'D'	
Send	5	<source memory block>
Send	129	<key location (Key B = 1 + 128)>
Send	4	<destination memory block (same as source)>
Send	20	<value byte0>
Send	0	<value byte1>
Send	0	<value byte2>
Send	0	<value byte3>
Receive	<status>	



Transfer(copy) a value

The 4-byte number found in the source block is copied to the destination block (which must be within the same sector).

Operation	Mifare card
Send	ASCII ‘T’ = 01010100_2 = 84_{10} = 0x54
Send	Source block address (0 to 255)
Send	T x x KKKKK (see below)
Send	Destination block address (0 to 255)
Receive	Status byte

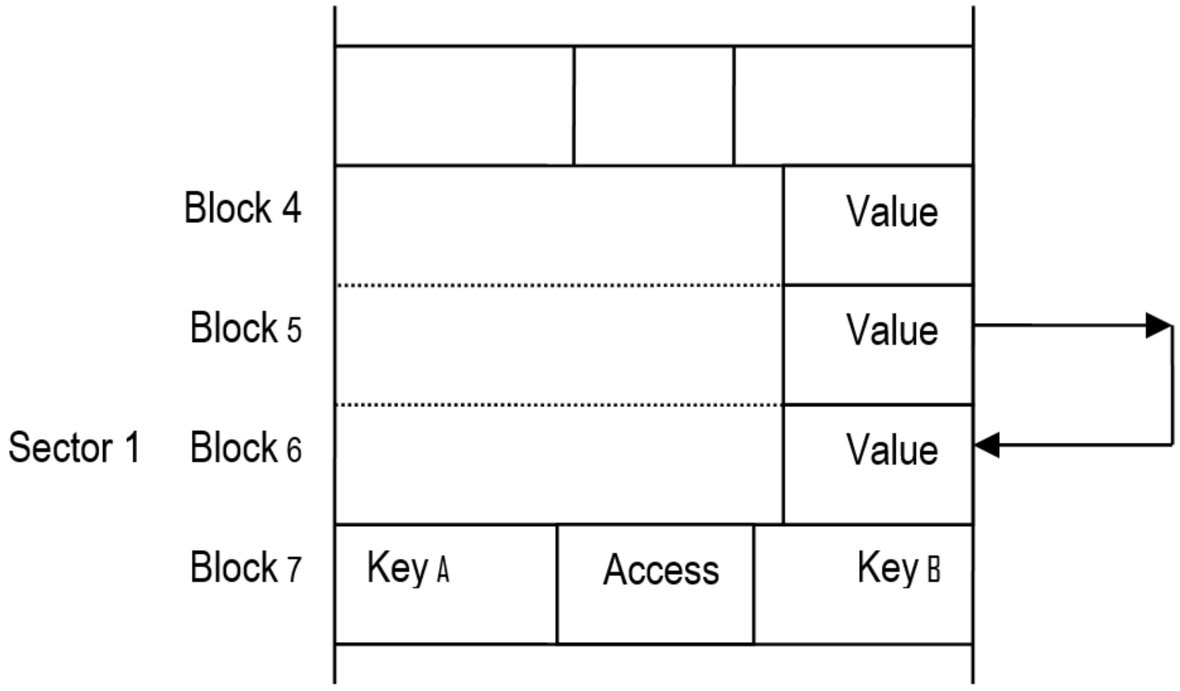
T = Key type (0 = Key A, 1 = Key B)
K = Key code number (0 – 31)

This command is accomplished by the TransferRFIDValue macro.

Example:

Copy the value currently stored in transponder memory block 5 to transponder memory block 6.
Do not change the value.
Use the data key at storage location 3 as Key A.

Send	'T'	
Send	5	<source memory block>
Send	3	<key location>
Send	6	<destination memory block (same as source)>
Receive	<status>	



RS-232 is a telecommunications standard dating from the 1960's, defined originally for use in teletypewriters and still in widespread use. For example, it is the basis for data transfer from a computer's 9-pin serial and 25-pin parallel ports.

It appears in a number of different forms, such as EIA/TIA232, RS-232D, V.24, V.28, X20, and X21. It is used in both asynchronous data transfer and synchronous links such as HDLC, Frame Relay and X.25.

Scope
It includes not only electrical specifications, and definitions of the signals used, but also pin outs for a range of connectors such as 9 and 25 pin D-type connectors and RJ45 connectors.

In its native form, voltage levels are -15 to -3V for a 1 (mark), and +3 to +15V for a 0 (space). TTL based RS232 is suitable for short range serial communications at TTL/CMOS logic voltage levels. Converter chips are available to provide an interface between logic level and full RS232 voltage systems (as used in the EB-015 E-blocks2).

Jargon!

Devices which use serial cables for their communication are split into two categories, DCE (Data Communications Equipment) and DTE (Data Terminal Equipment.)
Data Communications Equipment includes devices such as an analogue modem, TA adapter (on an ISDN line), CSU/DSU (Channel Service Unit / Data Service Unit – a digital modem, in effect) etc., while Data Terminal Equipment is often a computer or router. Usually, the DCE device controls the flow of data between the DCE and the DTE by providing synchronisation signals or timing signals. The DTE device is also known as the data terminal, whereas the DCE device is the data set.

Confusion can arise over the pin descriptions TD (Transmit Data) and RD (Receive Data). In reality, both pins may 'transmit' data and 'receive' data at times, depending on whether they are located on the DTE or the DCE device. The solution is to look at these pins from the viewpoint of the DTE device. The DTE device transmits data on the TD line. When the DCE device receives this data, it receives it on the TD line as well! When the modem or CSU/DSU receives data from the outside world and sends it to the DTE, it sends it on the RD line because from the viewpoint of the DTE, the data is being received!

Signalling overview

Data is transmitted and received by the data terminal on pins 2 and 3, (TD and RD) respectively.

The Data Set Ready (DSR) and Data Terminal Ready (DTR) signals become active usually when the respective devices are powered up. They enable these devices to check each other's status.

Data Carrier Detect (DCD) indicates that a good carrier is being received from a remote modem.

Request To Send (RTS) signal from data terminal and Clear To Send (CTS) signal from the data set are used for flow control. If either device is busy, it can block the arrival of further data by taking the respective signal low. The DTE device can transmit only when it senses that the CTS line is active. When the DTE has finished its transmission, it drops the RTS signal.

The Carrier Detect (CD) and the Ring Indicator (RI) lines are only useful in connections to a modem and telephone line.

CP9329

RFID Systems

Student Guide

Contents

Introduction to RFID

1.1 The RFID system

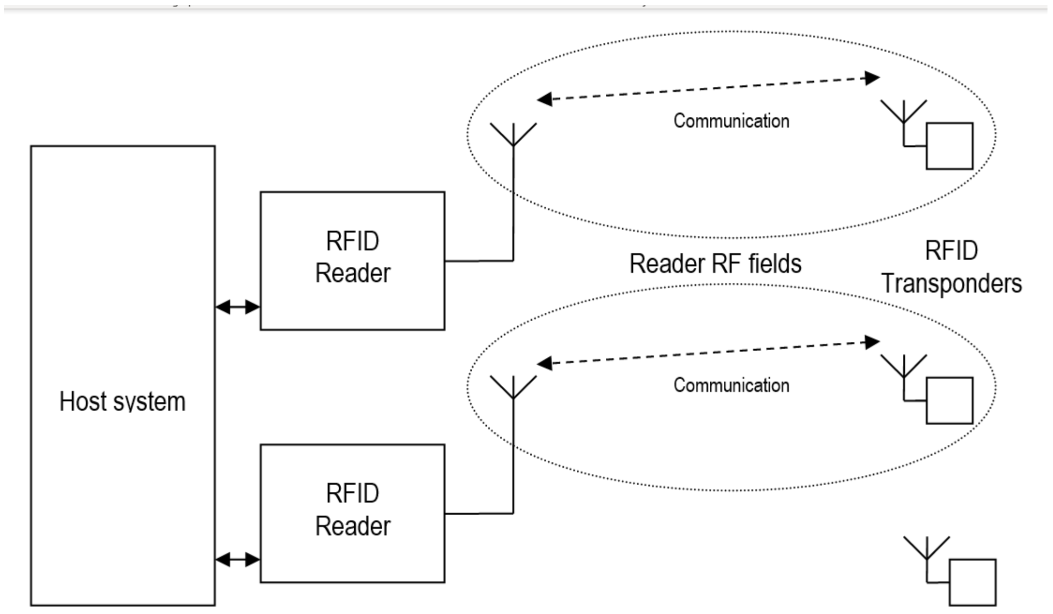
Radio **F**requency **Id**entification (RFID) technology has been under development for many years. The recent increase in applications is the result of the development of small, low-cost, low-power, logic devices which can be integrated into inexpensive (or even disposable) transponders (also known as tags).

These logic devices provide the processing power that allows the use of sophisticated communication protocols, permitting the secure transfer of a tag's identity and data.

On-board memory allows information to be stored in the transponder indefinitely, and changed as required.

The low power consumption of many types of tags allows the entire logic circuit to be powered by electricity generated in the tag's antenna when it intercepts radio waves transmitted by a reading device. Consequently, these tags do not require any type of internal power supply, such as a battery, decreasing their cost and size, and increasing their operating life almost indefinitely.

The main components of an RFID system are the **readers**, **transponders** (tags) and the **host system**.



1.2 RFID applications

The use of broadcast radio frequency signalling means that RFID can work in environments where other systems would have problems such as dirty environments where there is dirt and grease, in bad weather conditions where there is rain, snow and ice, or where there is obscuring substances such as paint that would render barcodes and other optical recognition systems unusable.

RFID applications focus on the task of monitoring the location, movement and identification of objects or people. It is useful because it allows tagged items to be identified and tracked as they move past readers. It works without human intervention and without physical contact between the readers and tags. It does not require line of sight to operate.

Typically, a manufacturer may add a RFID tag to a carton of newly made goods. A RFID-enabled printer can create an adhesive label containing the RFID tag, programmed by the printer, but also showing a bar code and / or text, describing the contents. The carton, and others are then loaded on a pallet to facilitate transport. It is useful to monitor the contents of the pallet throughout its journey to the customer.

Traditionally, this was done either by reading the labels or by scanning the bar codes on each carton. With RFID tags, this process can be automated, allowing inspection at any point by passing the pallet through a RFID-enabled portal, where a RFID reader reads the tags as they pass through. Typically several hundred tags can be read each second, whereas bar-coded items each had to be positioned in front of a scanner.

RFID tags also offer some data storage on the tag itself, whereas barcode technology does not. This enables environmental details such as temperature to be recorded and updated as the tagged goods are transported.

Similarly RFID tags can be added to baggage at airports so that they can be identified and sorted. This monitoring can take place even as the baggage moves at speed down a conveyor belt, using RFID readers on the belt itself.

Large shipping containers, used to transport goods by road, rail and sea, can be monitored in the same way, using RFID techniques that allow communication over longer range, i.e. tens of metres.

‘Chipping’ of dogs and cats, where the RFID device is implanted in the animal, and the use of ear tags in animal husbandry, is used for identification and for the control of automated feeding. Bar-coding is not as durable. The barcode must be stuck to a relatively flat surface on the outside of the object, and is subject to wear-and –tear.

People can be admitted quickly to secured areas by using contactless RFID tags, rather than by using slower techniques such as keypad-operated combination locks.

More sophisticated tags, which can store more data, can be used in ‘e-purse’ applications, such as automatic fare collection on public transport, automatic vending from machines, road toll charging and even gambling.

RFID system components

2.1 Reader

An RFID reader radiates RF (radio frequency) energy from its antenna and attempts to establish communication with any compatible transponders that are detected.

The reader is usually part of a host system that makes use of the data stored in each transponder. Multiple readers can be used to track the movement of transponders from one location to another.

2.2 Transponder

Transponders are grouped into three main types, passive, semi-active and active.

2.2.1 Passive

Passive transponders have no internal power source. When the antenna of a transponder enters the RF field radiated by a reader transmitting at the correct frequency, it absorbs some of the energy. If sufficient energy is absorbed, the control device within the transponder wakes up and attempts to communicate with the reader.

These types of transponders are small, low-cost, and have an almost unlimited life. They can be used in security tags, tickets and product labels.
Typical communication range is 0.1-0.4m, though some can be up to 1m.

2.2.2 Semi-active

Semi-active transponders contain a small power source for the logic circuits. The antenna circuit is passive and is only powered when sufficient energy is absorbed from the RF field of a reader. As a result, the life of the internal power source is increased.

These types of transponders are larger and more expensive than the passive transponders, and have a limited life (up to 10 years).

The internal power source allows the transponder to gather data when out of range of a reader. Data could include temperature and shock levels when attached to fragile items during transport.

2.2.3 Active

Active transponders contain a power supply that can allow both the logic circuitry and the transmitter/receiver to be active at all times. This usually allows the transponder to detect weaker signals, and transmit stronger signals than either the passive or semi-active transponders.

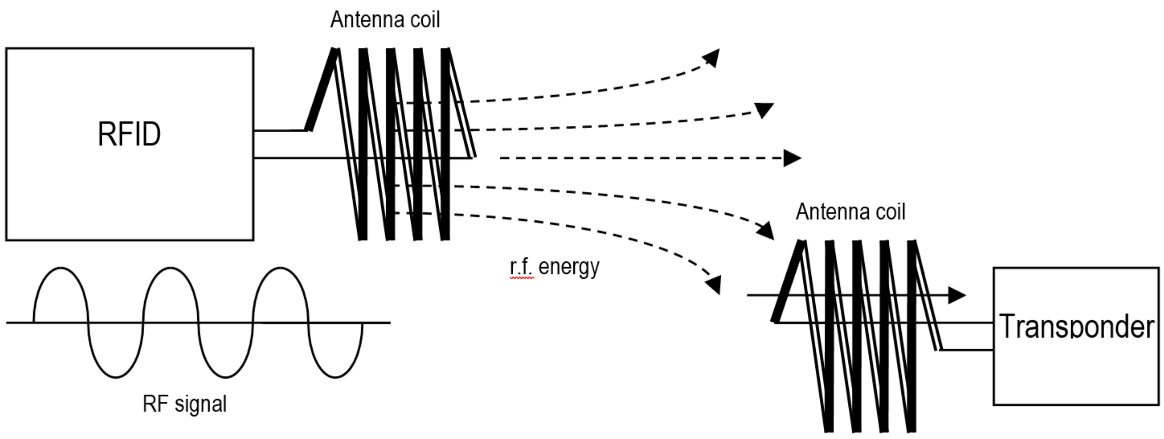
These types of transponders are relatively large and expensive.

The improved transmission and reception performance of these types of transponders makes them suitable for tracking and communicating with large objects, like shipping containers, over longer distances than the other types (typically 20-40m).

3.1 Transponder communications

A passive RFID transponder consists of a low power logic device and an antenna coil. A passive transponder has no internal power supply, so the antenna coil is used as the means of both powering the device and communicating with the reader.

When a transponder enters the RF field of a reader, some of the electromagnetic energy emitted by the reader's antenna is absorbed and generates electricity in the transponder's antenna. This then powers the internal logic. When the logic device wakes up, it starts to communicate with the reader.



The reader can send information to the transponder by varying the amount of RF energy transmitted.

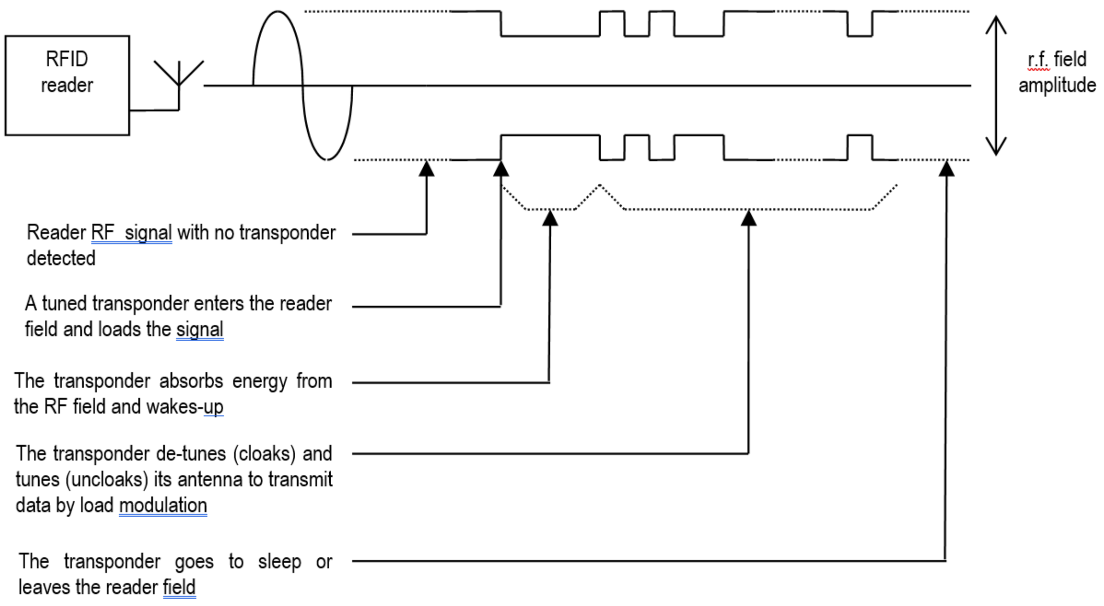
The transponder can send information back to the reader by varying the amount of RF energy absorbed. When the transponder antenna is tuned to the reader's radio frequency it absorbs energy from the RF. Field. The transponder has the ability to change the tuned frequency of its antenna circuit, absorbing no energy when tuned to an alternative frequency. The varying amount of energy absorbed by the transponder can be detected by the reader as changes in the load on the transmitter. This is known as Load Modulation.

When a transponder is de-tuned and absorbing no energy, it cannot be detected by the reader. This condition is referred to as 'cloaked'.

In practice, the amount of load modulation experienced by the reader could be less than 1% of the normal signal amplitude.

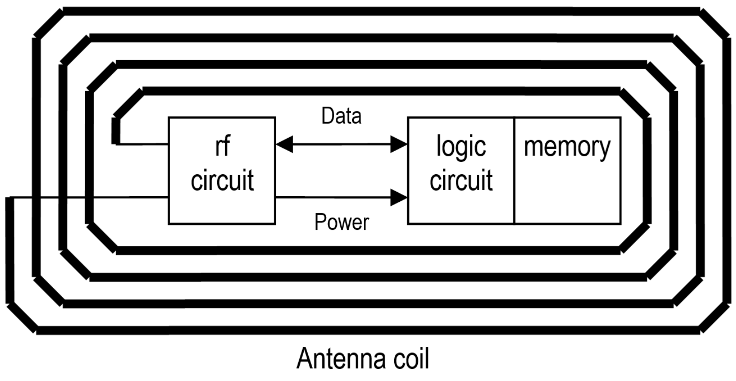
The amount of modulation can also change if the transponder is moved during communications.

The passive RFID transponder is woken up and powered by the RF field of a reader and transmits data by load modulation.


RFID reader
r.f. field amplitude
Reader RF signal with no transponder detected
A tuned transponder enters the reader field and loads the signal
The transponder absorbs energy from the RF field and wakes-up
The transponder de-tunes (cloaks) and tunes (uncloaks) its antenna to transmit data by load modulation
The transponder goes to sleep or leaves the reader field

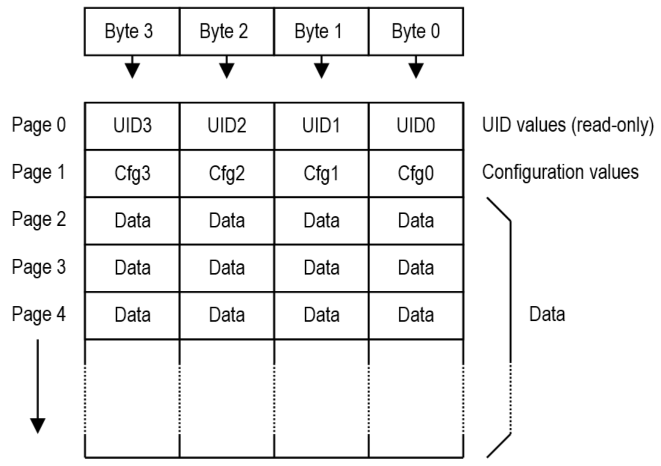
The structure of a transponder

The logic device in the transponder contains the RF interface circuit, a power control circuit, system control logic, and non-volatile memory (memory that does not lose data when the power is removed – for at least 10 years).



In simple transponders, the memory is a small amount of factory programmed ROM (read-only memory). As an example, 4 bytes (32 bits) of data are sufficient to allow the storage of a UID (**U**nique **Id**entification number,) with approximately 4.3 billion (2^{32}) variations. In many applications, all that is required is to detect a transponder and use its UID to confirm the identity of a person, or animal or the location of an asset.

More advanced transponders have larger amounts of memory (up to 4kB) that can be written to, as well as read. This is usually in the form of EEPROM (Electrically Erasable, Programmable, Read Only Memory). The memory is usually split into small groups (**pages**), which may be combined into larger groups (**blocks**), and groups of blocks (**sectors**). The use of pages, blocks and sectors can allow sections of memory to be reserved for special functions by the manufacturer, or configured for special modes of operation by the user.



Simple RFID transponder memory map

4. The RFID reader module

4.1 Host communications

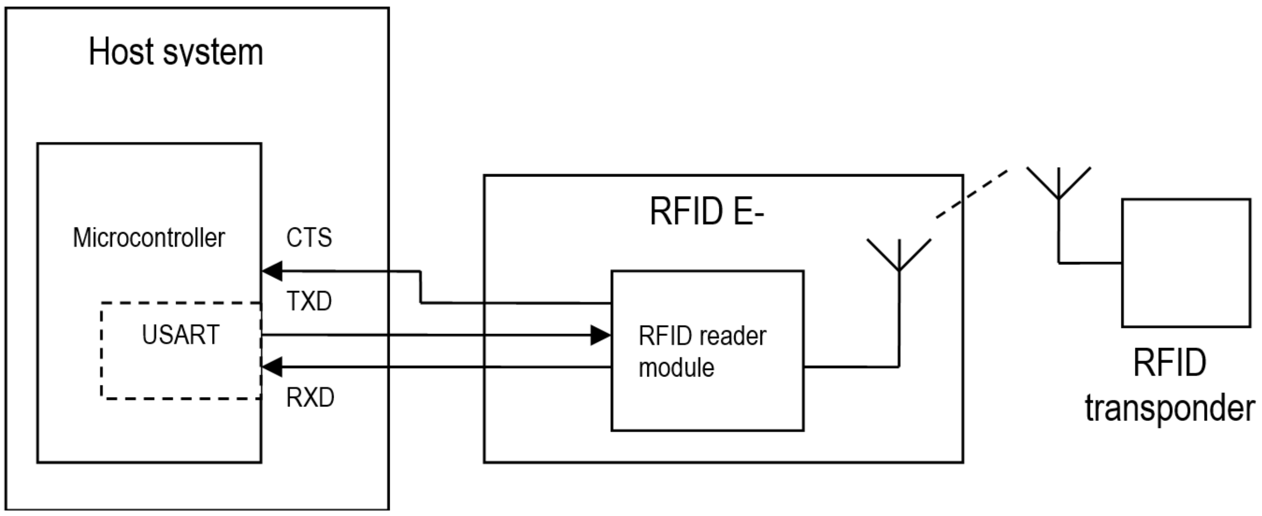
Communication between the reader module and the host system uses a logic level RS-232 serial interface, using the Transmit Data (TXD) and Receive Data (RXD) lines. This is compatible with the Universal Asynchronous Receiver / Transmitter (UART, USART, AUSART etc.) contained in many microcontroller devices.

(The Instructor Guide for the RFID course provides more information about the RS232 protocol.)

The RFID reader module also requires the equivalent of the RS-232 CTS (Clear To Send) signal to be connected. This allows the RFID reader module to stop the host system from transmitting to it when it is too busy to accept the data. The opposite is not provided! – there is no provision of a signal to allow the host system to suspend transmissions from the RFID reader! As a result, the host system must be ready to receive all data transmitted by the reader, whenever it happens.

However, the RFID reader will only transmit data back to the host system in response to a request from the host. The format of any data returned by the RFID reader module is clearly defined by the request. The recommended way to request data is to send the command and then to concentrate on receiving and storing the data until the transaction has been completed.

This means that operations like writing to the LCD, or executing a delay loop, should not be carried out when reading data back from the RFID reader module. The delays involved might cause the host to miss some of the data.

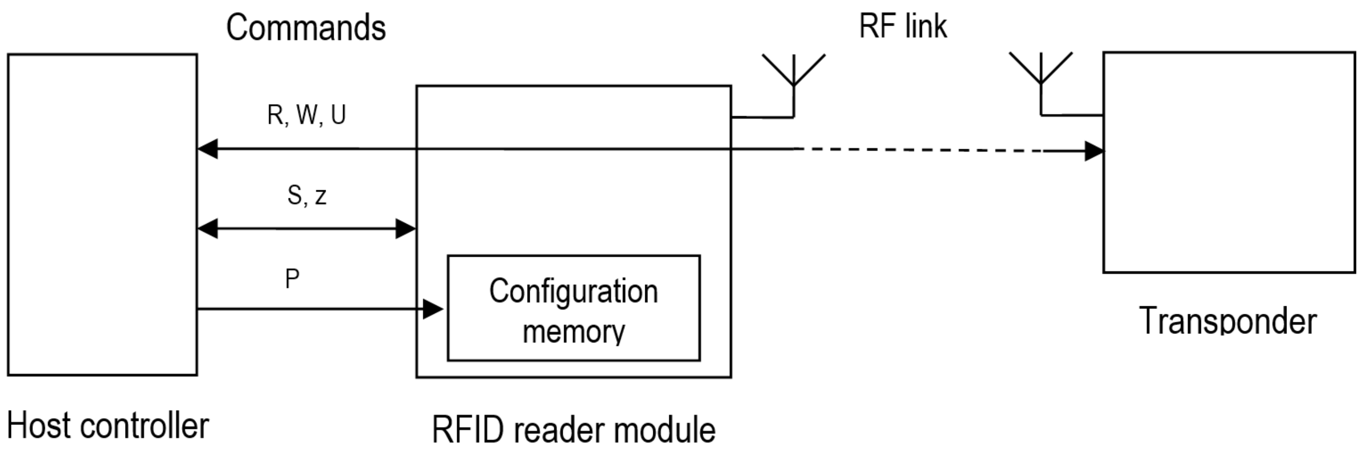


The RFID reader module responds to commands sent from the host system. Commands can target either a particular RFID transponder detected by the reader, or the status and memory of the RFID reader module itself.

Every command causes a status byte to be returned, indicating the current condition of the reader module. In some cases, data will also be returned.

The main commands are:

S = Return the reader module status only
z = Return the reader module and firmware identification as a text string
P = Program the reader module's internal memory
W = Write a block of data to a transponder
R = Read a block of data from the transponder
U = Read the transponder UID



These common commands are supported for both ICODE and Mifare transponders, though there are differences in the data format for each transponder type. The Mifare transponders, and reader module when in Mifare mode, support some extra commands. The extra commands will be introduced in the Mifare section.

Using Flowcode, these commands are embedded in the following Component Macros:

Command	Use
Initialise	Initialises the RFID reader module, and selects the type of transponder to detect
GetRFIDStatus	Returns the current value of the reader module status byte
GetRFIDUID	Returns the status byte and copies the UID into memory
ReadRFIDUID	Reads each byte of the UID in turn from the memory
ReadRFIDBlock	Reads data from a specific block of the transponder memory
ReadRFIDBuffer	Reads a single byte from a block of data stored in the reader memory buffer
WriteRFIDBuffer	Writes a single byte of data into a specific location in the memory buffer
WriteRFIDBlock	Writes 4 bytes of data from the memory buffer to a specific location in the transponder memory

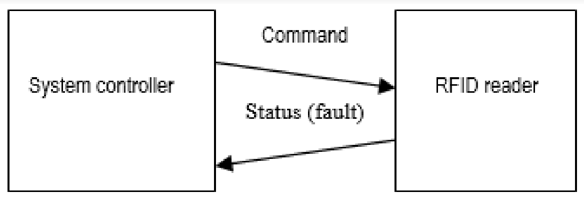
Command sequences

Each command sent to the reader module causes a ‘status’ byte to be returned, indicating the outcome of the command and the condition of the reader module.

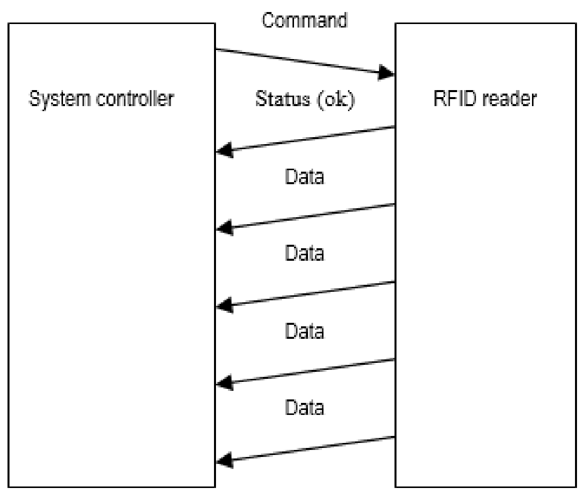
When a command requesting data is sent to the RFID reader module, the reader module will first return the status byte and then, provided the status byte indicates no errors, the data will be returned. If an error is detected, no data will be returned.

When the command sent to the RFID reader module contains data, the status byte will be returned after the module has received all the expected data.

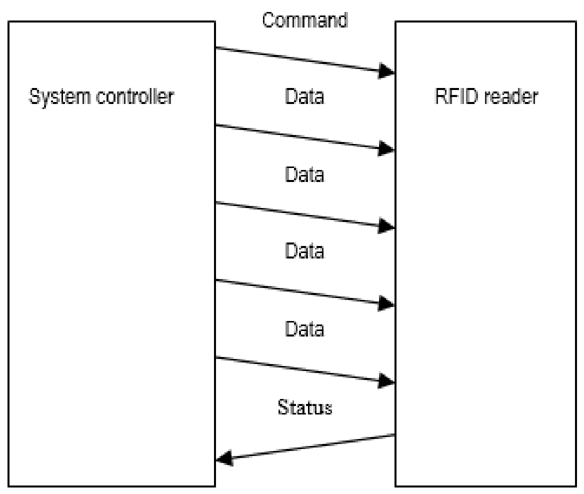
Failed read command.
Status returned, but no data.



Successful read command.
Status returned, followed by data



Data write command.
Data sent immediately after the command.
Status returned on completion.



4.3 Reader module configuration

The RWD-MICODE module is compatible with two main groups of 13.56MHz transponder types: ICODE and Mifare. The type of transponder to be detected can be selected by programming a location (location 3) in the RFID reader's internal memory.

RWD-MICODE RFID reader module internal memory map

Location	
0	Tag polling rate (default = 50 = 100ms)
1	Reserved
2	Reserved
3	Transponder mode (1 = ICODE, 0 = Mifare)
4	Reserved
:	:
11	Reserved
12, 13, 14, 15	Authorised UID list 0
16, 17, 18, 19	Authorised UID list 1
:	:
252, 253, 254, 255	Authorised UID list 60

The polling rate (number of times per second the reader communicates with the transponder,) can be increased when a transponder is detected to make the reader module react more quickly when the transponder leaves its RF field.

4.4 Transponder type selection

Transponder type selection, ICODE or Mifare, is controlled by the number written into location 3 of the reader module memory. The value should be set to 1 for ICODE transponders, and 0 for Mifare transponders.

This operation is carried out by the Flowcode RFID 'Initialise' function, using the selection made in the 'Properties' panel.

4.5 Authorised UID list

The RWD-MICODE module can be configured with an authorised list of UIDs. It then accepts automatically any transponder whose UID appears on this list. All other transponders will fail to communicate fully. (Status bit 1 will remain at zero and transponder-targeted commands will not be executed).

The reader module searches the authorised UID list for a match whenever a transponder is detected. The list search starts from the lowest memory location and ends either at the top of the list or when it reaches a location with all four bytes set to 255.

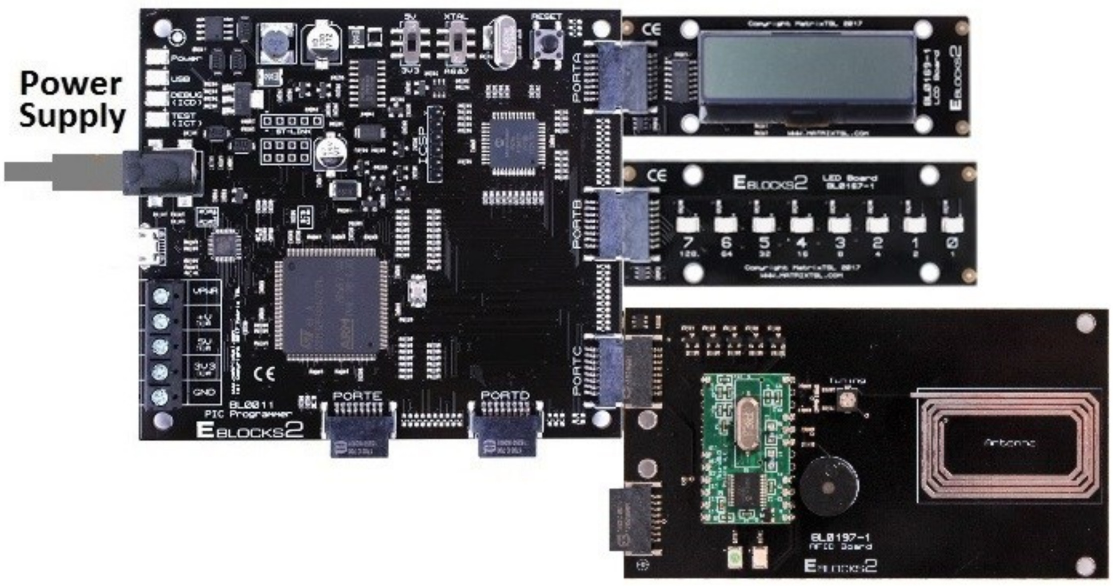
The authorised UID list function is disabled if the four bytes of the lowest list location are set to 255. All transponders of the appropriate type are then accepted.

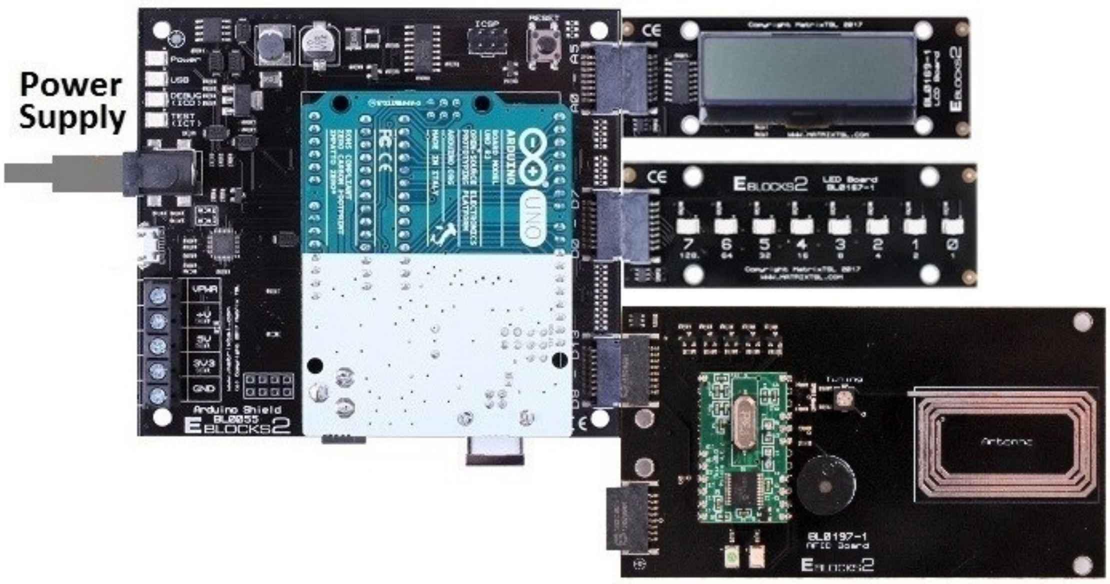
The following exercises do not use the authorised list facility so they include commands to write a value of 255 into locations 12, 13, 14 and 15, the first locations in the Authorised UID list, in the reader module's memory.

5. The RFID E-blocks2 system configuration

5.1 Connecting the RFID E-blocks2 system boards

The RFID E-blocks2 is used to provide the control and antenna interfaces for a variety of RFID reader modules.
To carry out the exercises in this course, the RFID E-blocks2 is fitted with the RWD-MICODE reader module. It operates with a radio frequency of 13.56MHz and uses the antenna built into the circuit board.





5.2 RFID systems exercises E-blocks2 configuration

	PIC BL0011			Arduino BL0055		
	Port C	Port B	Port A	D8-13 (B)	D0-7 (D)	A0-5 (C)
Exercise 1	BL0197	BL0167		BL0197	BL0167	
Exercise 2	BL0197	BL0167	BL0169	BL0197	BL0167	BL0169
Exercise 3	BL0197	BL0167	BL0169	BL0197	BL0167	BL0169
Exercise 4	BL0197	BL0138	BL0169	BL0197	BL0138	BL0169
Exercise 5	BL0197	BL0167		BL0197	BL0167	
Exercise 6	BL0197	BL0167	BL0169	BL0197	BL0167	BL0169
Exercise 7	BL0197	BL0167	BL0169	BL0197	BL0167	BL0169
Exercise 8	BL0197	BL0138	BL0169	BL0197	BL0138	BL0169
Exercise 9	BL0197	BL0138	BL0169	BL0197	BL0138	BL0169

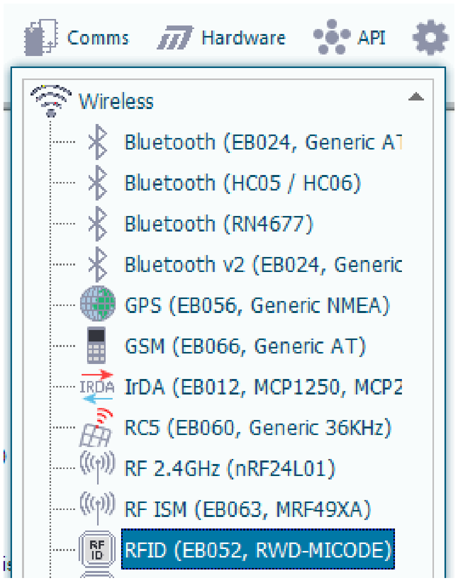
BL0197	RFID E-blocks2 board
BL0167	LED E-blocks2 board
BL0169	LCD E-blocks2 board
BL0138	Keypad E-blocks2 board

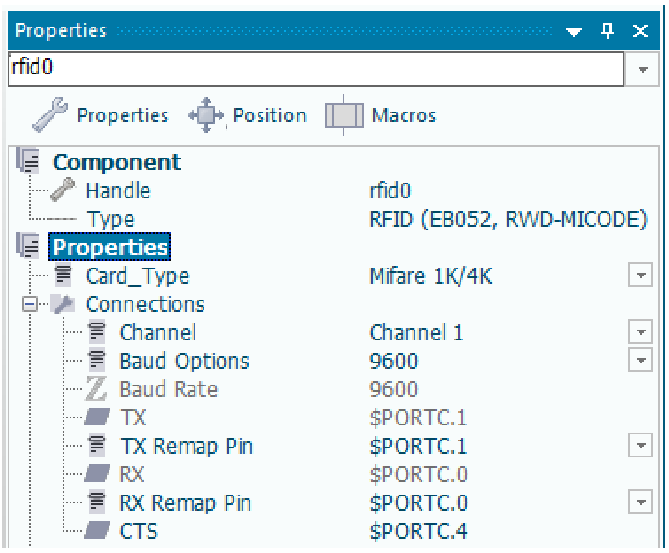
5.3 Microcontroller configuration

Flowcode has specific target devices for the E-blocks2 processors boards used in conjunction with this curriculum. These are named BL0011 for the PIC processor board and BL0055 for the Arduino Uno board. Using these as target devices will pre-configure all processor settings.

5.4 Flowcode RFID component

The RFID component can be found in the Wireless section of the Comms toolbar item. The component properties should be set as shown below.

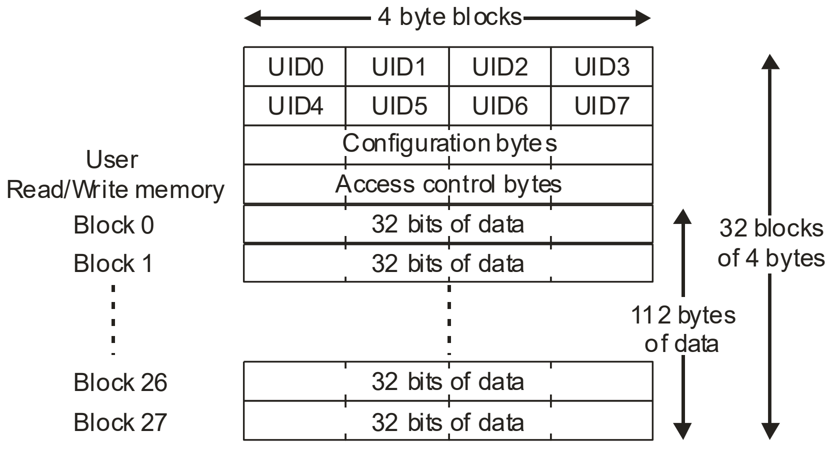



Properties
rfid0
Properties | Position | Macros

Component	
Handle	rfid0
Type	RFID (EB052, RWD-MICODE)
Properties	
Card_Type	Mifare 1K/4K
Connections	
Channel	Channel 1
Baud Options	9600
Baud Rate	9600
TX	$PORTC.1
TX Remap Pin	$PORTC.1
RX	$PORTC.0
RX Remap Pin	$PORTC.0
CTS	$PORTC.4

6.1 Overview

ICODE transponders are relatively simple devices, containing 128 bytes of memory accessible in 4-byte blocks.



They have no in-built security features except for the ability to make individual memory blocks read-only.

One of the main features of the ICODE protocol is the ability of some reading devices (not included in this solution) to detect multiple transponders simultaneously. The UID of an ICODE transponder is 8 bytes long and must be included in each transponder read and write command to identify which transponder the command is directed at, as there could be more than one in communication with the reader module.

The RFID reader module supports a command to report the UID of any transponder being detected. In the case of a multi-transponder system the command would return an inventory of all detected devices.

6.2 ICODE mode status byte

The status byte returned by the RWD-MICODE reader module depends on the transponder type selected and detected.
For ICODE transponders:

ICODE mode RFID reader status byte:

Bit	Value	Significance
7	1	Always
6	1	Internal or antenna fault
5	0	Always
4	0	Always
3	1	RS232 error (System controller communications)
2	1	Transponder communications OK
1	1	Transponder UID accepted
0	1	Reader module memory write error

3

For example:

Binary	Decimal	Status
10000000	= 128	No tags detected. No errors.
10000110	= 134	ICODE tag detected. UID accepted. No errors.
10000001	= 129	No tags detected. Error writing to internal memory.

7. Exercise 1 – Reader module communications in ICODE mode.

7.1 Introduction

The Flowcode RFID component provides all the functions necessary to control the RWD-MICODE reader module.

These include the Initialise function, which configures the communication link between the host controller and the RFID reader module, and the GetRFIDStatus function, which obtains the current value of the reader module status byte.

With correct configuration, it is possible to detect the presence of a compatible RFID transponder.

7.2 Objective

To design and test a Flowcode program to establish communications between the host controller and the RWD-MICODE reader module by:

- connecting and configuring the system hardware;
- configuring the Flowcode RFID component within a simple Flowcode program;
- writing configuration data to the RFID reader module;

obtaining and displaying the status information from the RFID reader module.

7.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- an LED E-blocks2 (BL0167)

an ICODE RFID transponder.

7.4 The Flowcode program in detail

The aim of the program is to:

- Initialise the RFID module using the Initialise function;
- read the module's status byte repeatedly, using the GetRFIDStatus function;

display the status byte value on a bank of LEDs connected to Port B to allow the states of the individual bits to be observed easily.

If bits 1 and 2 are both set to 1, a transponder has been detected and communications has been established.

7.4.1 Initialise function

The Initialise function sends the configuration information required to the reader module using the protocol selected in the component properties panel.

The value returned is the reader module status byte generated when the protocol was selected. This can be used to confirm the presence of the RFID reader module and the successful execution of the command.

Expected outcome:

- Bit 7 = 1 Reader present
- Bit 0 = 0 No memory write error

Bit	Value	Significance
7	1	Always
6	1	Internal or antenna fault
5	0	Always
4	0	Always
3	1	RS232 error (System controller communications)
2	1	Transponder communications OK
1	1	Transponder UID accepted
0	1	Reader module memory write error

A reminder – ICODE mode RFID reader module status byte:

7.4.2 GetRFIDStatus **function**

The GetRFIDStatus function causes the reader module to return the current value of the reader module status byte.

This can be used to detect the presence of a matching transponder.

Expected outcome when a transponder is accessed:
- Bit 7 = 1 Reader present
- Bit 2 = 1 Transponder communications OK

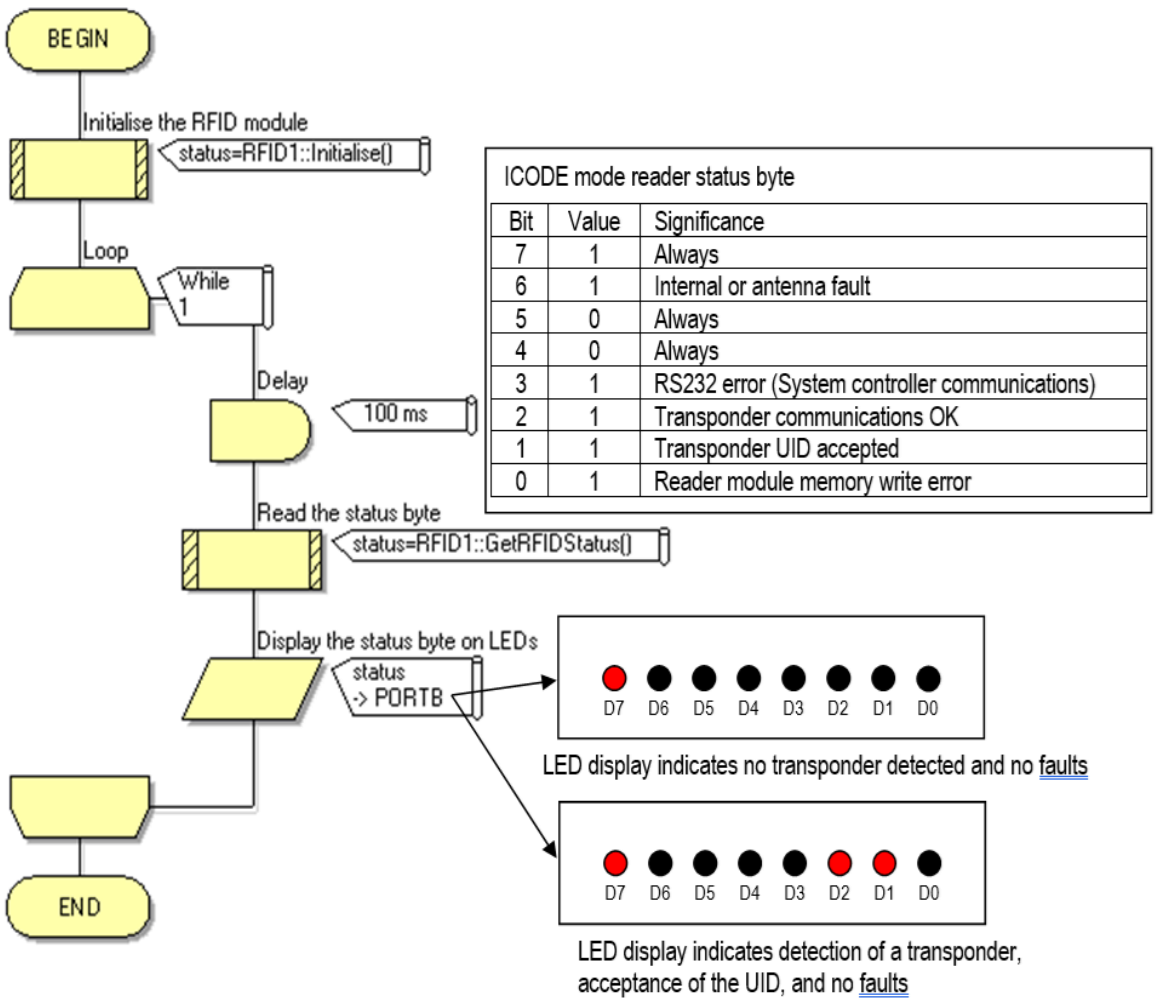
Bit 1 = 1 Transponder UID accepted.

7.5 What to do

1. Write the Flowcode program using the following steps as a guide:

   load the RFID component into a new Flowcode flowchart;
   use the RFID component properties to select the ICODE protocol;
   insert a Component Macro, and select the RFID(0) component and the 'Initialise' macro to Initialise the RFID reader module;
   create a program loop that continuously cycles every 100ms (approximately) and uses the RFID component 'GetRFIDStatus' to read the status of the RFID reader module;
   write the returned status value to the LED port so that the individual bits can be observed.
2. Compile the program and transfer it to the PIC chip.
3. Run and test the program by observing the LEDs to see if the status byte is displayed both when a RFID card is present, and when no card is present.
4. Do not delete this program as it can be modified for use in exercise 5!

The resulting Flowcode program is shown in the next diagram.


BEGIN
Initialise the RFID module
status=RFID1::Initialise()
Loop
While
1
Delay
100 ms
Read the status byte
status=RFID1::GetRFIDStatus()
Display the status byte on LEDs
status
-> PORTB
D7 D6 D5 D4 D3 D2 D1 D0
LED display indicates no transponder detected and no faults
D7 D6 D5 D4 D3 D2 D1 D0
LED display indicates detection of a transponder, acceptance of the UID, and no faults
END

ICODE mode reader status byte

Bit	Value	Significance
7	1	Always
6	1	Internal or antenna fault
5	0	Always
4	0	Always
3	1	RS232 error (System controller communications)
2	1	Transponder communications OK
1	1	Transponder UID accepted
0	1	Reader module memory write error

7.6 Further work

Test the detection range of the reader with the transponder in different orientations (edge first, side first etc.).

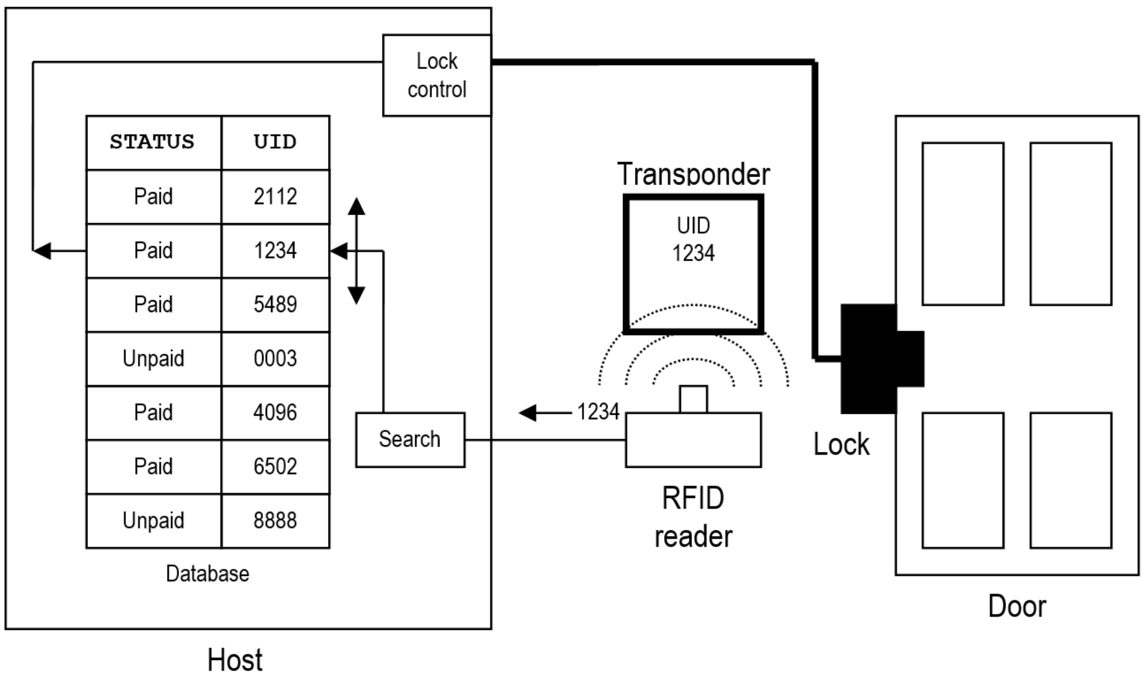
Some transponders are intended to work without being removed from wallets or purses. Place different materials, paper, fabric, plastics and metals – including coins and aluminium foil, between the reader and the transponder and see the effect on detection.

Do not let any metal objects come into contact with the circuit boards or components!

8.1 Introduction

Every RFID transponder is programmed with a **U**nique **Id**entification number that is sent to each reading device that causes the transponder to wake-up. In many practical applications, nothing else is needed. This UID can be used to identify the person or object carrying the transponder. Any data relating to the identity can be retrieved quickly from a database on a local computer, or via a high speed data link, using the UID as a reference.

A typical application is where the transponder, attached to a ticket, is used as a door entry pass for a venue. The central database contains details of membership status, fee payment etc. The host system can use the database information to determine whether or not to release the door lock for the person carrying the ticket.



This exercise uses the GetRFIDUID function to obtain the status byte and copy the UID of the transponder into a memory buffer. It then uses the ReadRFIDUID function to access each byte of the UID in turn.

8.2 Objective

The objective for this exercise is to write a Flowcode program that will display, on the LCD, the 8-byte UID of any ICODE transponder in communication with the RFID reader module.

8.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- an LED E-blocks2 (BL0167)
- an LCD E-blocks2 (BL0169)

an ICODE RFID transponder (several if possible – make a note of the UIDs).

8.4 The Flowcode program in detail

The program will:

- access the reader module's status byte using the Initialise function;
- check that a transponder has been detected, and that there are no errors;
- display each of the eight bytes of the transponder UID, in turn, on the LCD display, using the GetRFIDUID function and the ReadRFIDUID function, whenever a transponder has been detected;

loop back and re-read the status byte repeatedly.

8.4.1 GetRFIDUID function

This causes the reader module to return its status byte and obtain the 8-byte UID of a transponder, if one is available. This 8-byte UID is stored in a memory buffer created by the RFID component. If no transponder is available, or there is a fault, the status byte will indicate this, and so no UID data will be returned.

Data transferred between host controller and reader module by this function:

Send	'U'	ASCII character (decimal value = 85).
Receive	<status>	The value returned is the reader module status byte. This will indicate when a transponder is accessed successfully.

When the status byte indicates that no transponder is available, or there is an error, the command terminates here.

Expected outcome when a transponder is detected, and the UID is transmitted:

- Bit 7 = 1 Reader present
- Bit 2 = 1 Transponder communications ok

Bit 1 = 1 Transponder UID accepted.

When a transponder is available and there are no faults, the UID data is returned to the reader module.

Receive	<UID0>
Receive	<UID1>
Receive	<UID2>
Receive	<UID3>
Receive	<UID4>
Receive	<UID5>
Receive	<UID6>
Receive	<UID7>

8.4.2 ReadRFIDUID function

When the GetRFIDUID function is executed successfully, the 8-byte UID of the transponder is stored in a memory buffer created by the RFID component.

The ReadRFIDUID function reads only one of these bytes. The user specifies which byte to retrieve by adding a parameter with a value from 0 to 7. All 8 bytes must be read individually to retrieve the full UID of the transponder being accessed.

8.5 What to do

1. Write the Flowcode program using the following steps as a guide:

   load the RFID component into a new Flowcode flowchart;
   use the RFID component properties to select the ICODE protocol;
   configure the LCD display, using the Start macro;
   Initialise the RFID module by inserting a Component Macro, selecting the RFID(0) component and selecting the 'Initialise' macro to Initialise the RFID reader module;
   create a program loop that continuously cycles every 100ms (approximately) and uses the RFID macro GetRFIDUID to keep looking for a transponder, and copying its UID;
   test the value of the returned status byte to determine if a transponder has been detected and valid UID data is available(i.e. status byte value in decimal = 134);
   then use the ReadRFIDUID macro to read each of the 8 UID bytes in turn, and display them on the LCD;
   If a transponder cannot be accessed, clear the LCD display and loop back to repeat the process.
2. Compile the program and transfer it to the PIC chip.
3. Run and test the program by observing the LEDs to see if the status byte is displayed when a RFID card is present.
4. Then examine the LCD to check that the eight-byte UID is displayed when a card is present.
5. Check that the LCD screen is cleared when the card is removed.
6. Do not delete this program as it can be modified for use in exercise 6!

8.6 Further work

Modify the program to compare the UID of a detected transponder against a list of UIDs. (Do not include the UIDs of all the available transponders in this list, so that some transponders will not be recognised.)

Remove instruction to display the status byte on the LEDs

Add Decision icons to test for the list of accepted UIDs.

If the UID is recognised, light one of the LEDs to indicate a door lock being released.

If the UID is not recognised, light another LED to indicate a warning alarm.

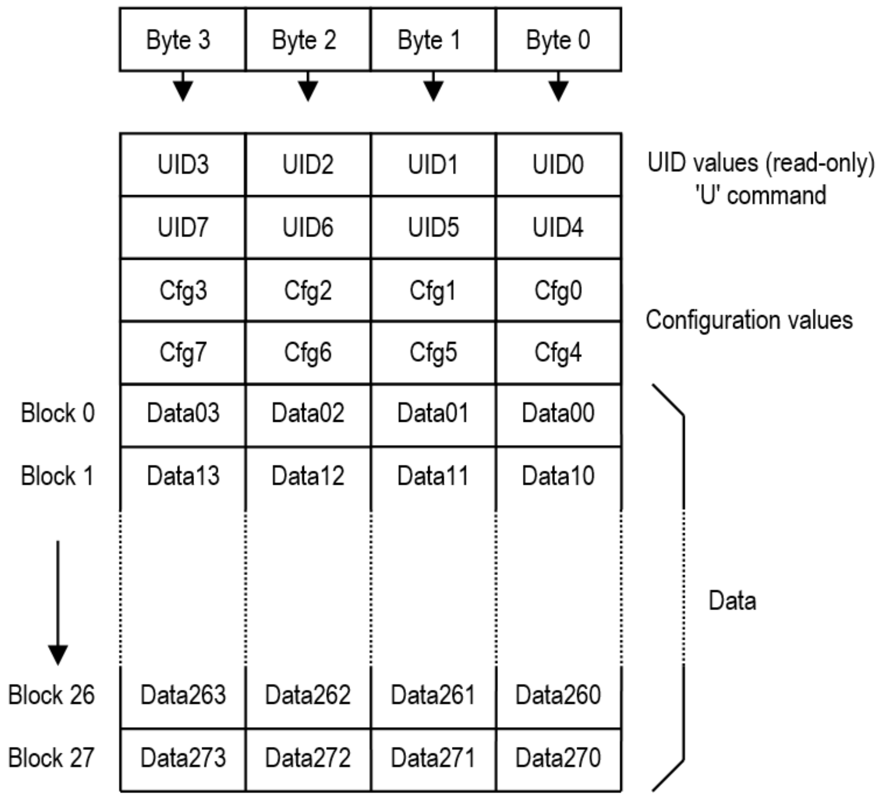
This program now represents the basis of a practical door entry security system. It could be expanded to include additional data with each UID, to specify for each user, permitted times of

9. Exercise 3 – Read transponder data in ICODE mode

9.1 Introduction

The internal memory of ICODE transponders is organised in 32-bit blocks. These are transferred between the host controller and the RFID reader as four 8-bit bytes.

ICODE transponders contain 128 bytes of memory, i.e. 32 x 4 byte blocks. Four of these blocks are reserved for the 8-byte UID and configuration controls. The remaining 28 blocks are available for data storage and have block addresses from 0 to 27.



ICODE transponder memory map

Some ICODE systems are capable of detecting multiple transponders simultaneously using special anti-collision techniques to detect and communicate with each separately. ICODE transponder read and write commands include the full UID of the target transponder to make it clear to which transponder the command applies.

The RFID E-blocks2 does not support the multiple transponder detection facility, but the transponder read and write command formats still require the inclusion of the full UID of the single transponder being detected.

In the previous exercises, the transponder UID was used for identification purposes only. This implies that in a practical situation any data associated with the transponder is accessed from a central database in a computer, rather than from the transponder memory itself. When access to such a computer is impractical, the solution is to carry some, or all, of the required data in the transponder memory itself.

The next exercise uses the ReadRFIDBlock function to return a nominated 4-byte data block of a transponder to the reader module memory, and the ReadRFIDBuffer function to transfer that to the LCD module.

9. Exercise 3 – Read transponder data in ICODE mode

9.2 Objective

To write a Flowcode program that will:

- detect the presence of a particular ICODE transponder;
- read the transponder's UID;
- read data from block 5 of the transponder memory;
- display the 4 bytes of data obtained from block 5 on the LCD.

9.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- an LED E-blocks2 (BL0167)
- an LCD E-blocks2 (BL0169)
- an ICODE RFID transponder (several if possible – make a note of the UIDs)

9.4 The Flowcode program in detail

The program will:

- access the reader module's status byte using the Initialise function;
- check that a transponder has been detected, and that there are no errors, using the GetRFIDUID function;
- copy data from block 5 of the transponder's data memory to the reader module buffer, using the ReadRFIDBlock function;
- display each of the four bytes of the data, in turn, on the LCD display, using the ReadRFIDBuffer function;
- loop back and repeat the process.

9.4.1 ReadRFIDBlock function

The ReadRFIDBlock function causes the reader module to return its status byte and the 4-byte data block of a transponder, if one is available. If no transponder is available, the supplied UID is incorrect, or there is a fault, the status byte will reflect this condition and no block data will be returned.

```
Send      'R'                ASCII character (decimal value = 82).
Send      <block address>    0 to 27
Send      <UID0>   ⎫
             |     ⎬  Send all eight bytes of the UID
Send      <UID7>   ⎭
Receive   <status>
```

If the status value indicates that no transponder is available, or there is an error, the command terminates here.

When a transponder is available and there are no faults, the memory block data is returned to the reader module memory.

```
Receive   <data0>  ⎫
             |     ⎬  Receive four data bytes.
Receive   <data3>  ⎭
```

9.4.2 ReadRFIDBuffer function

If the ReadRFIDBlock function is executed successfully, the 4 bytes of data from the selected block in the transponder are stored in a memory buffer created by the RFID component. The individual bytes of the data block can then be read using the ReadRFIDBuffer' function. The function needs to know which of the 4 bytes to read so a value must be provided (0 to 3).

The value returned by this function is the selected byte of the data block. All 4 bytes must be read individually to retrieve the full block of data.

9.5 What to do

1. Write the Flowcode program using the following steps as a guide:

- configure the reader for ICODE mode (as in previous exercises);
- Initialise the LCD display (as in exercise 2);
- Initialise the RFID module using the 'Initialise' macro (as in previous exercises);
- use the 'GetRFIDUID' macro to attempt to read the UID of a transponder continuously, at 100ms intervals (as in exercise 2);
- use the value of the returned status byte to determine if a transponder has been detected and valid UID data is available (as in exercise 2);

print "No card detected" until a transponder is detected.

When a transponder is detected:

- use the ReadRFIDBlock macro to read the data from block 5 of the transponder memory, using 5 as the address byte and 0 as the Key_type byte in the parameters – the UID that has been read will be automatically included in the command;
- use the value of the returned status byte to determine if the read command has been executed correctly;

if the command has not been executed correctly, print "Read error" on the LCD, and loop back to the beginning of the program.

When the ReadRFIDBlock command has been executed successfully:

- use the ReadRFIDBuffer macro to read each of the four data bytes copied from the transponder memory block, and display them on the LCD;
- then return to the main program loop.

(If a transponder has not previously been used it is likely that the block data values will all be 0 or random values.)

2. Compile the program and transfer it to the PIC chip.

3. Run and test the program by observing the LEDs to see if the status byte is displayed when a RFID card is present. Examine the LCD to check that the data is displayed when a card is present.
4. Do not delete this program as it can be modified for use in exercise 7!

9.6 Further work

- Modify the program to read data from other blocks on the transponder card.

- Find out what happens if you try to access a non-existent block.

- Read data from other transponder cards.

10. Exercise 4 – Write transponder data in ICODE mode

10.1 Introduction

The outcome of the previous exercises is the ability to detect, identify and read data from an ICODE transponder by the RFID reader module. The next step is to modify that program to write blocks of data to the transponder's memory. This will allow information to be stored in memory of a transponder and to be changed when necessary.

The process required to write a block of data to a transponder is the reverse of the read process. After detecting and identifying a transponder, the 4 bytes of data must be written to a memory buffer in the reader module, created by the Flowcode RFID component. Then the contents of buffer can be written to the transponder, along with the transponder's UID – obtained during the identification process.

The Flowcode function, WriteRFIDBuffer copies data, one byte at a time, into a memory buffer. Then the function WriteRFIDBlock, is used to copy the contents of the buffer to a particular location in the transponder's memory.

10.2 Objective

To write a Flowcode program that will modify the previous program by adding the ability to write data from the keypad to a transponder.

10.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- an LCD E-blocks2 (BL0169)
- a Keypad E-blocks2 (BL0138)

an ICODE RFID transponder (several if possible – make a note of the UIDs)

10.4 The Flowcode program in detail

The program will:

- detect the presence of an available ICODE transponder;
- read the transponders UID;
- read data from block 5 of the transponder's memory;
- display the 4 bytes of data on the LCD;
- check to see when a key on the keypad is pressed;
- write the ASCII value of the key pressed to the transponder memory, using the WriteRFIDBuffer and WriteRFIDBlock functions;

check that the new data has been transferred successfully.

10.4.1 **WriteRFIDBuffer function**

The data to be sent to the transponder memory block is first written to a memory buffer in the reader module, created by the RFID component using the WriteRFIDBuffer function. The function needs to know which of the four bytes of the buffer to write to, and so an address (0 to 3) must be provided in the Parameters box of the macro properties.

All 4 bytes should be written individually before the ‘WriteRFIDBlock’ function is executed, otherwise some random data may be sent.

10.4.2 WriteRFIDBlock function

The WriteRFIDBlock function causes the reader module to write four bytes of data from the buffer created by the Flowcode RFID component, to a specified memory block in a transponder.

If no transponder is detected, the supplied UID is incorrect, or there is a fault, the status byte will reflect this and the data will not be transmitted to the transponder.

Data transferred between the host controller and the reader module by this function:

Send	‘W’	ASCII character (decimal value = 87).
Send	<block address>	0 to 27
Send	<UID0>	Send all four bytes of data.
	|	
Send	<UID7>	
Send	<data0>	Send all eight bytes of the UID.
	|	
Send	<data3>	
Receive	<status>	

10.5 What to do

1. Modify the previous Flowcode program using the following steps as a guide, - the steps shown in italics are those already included in the previous program:

- *configure the reader for ICODE mode (as in previous exercises);*
- *Initialise the LCD display (as in exercise 2);*
- *use the ‘GetRFIDUID’ macro to attempt to read the UID of a transponder continuously, at 100ms intervals (as in exercise 2);*
- *use the value of the returned status byte to determine if a transponder has been detected and valid UID data is available (as in exercise 2);*

print “No card detected” until a transponder is detected.

When a transponder is detected:

- *use the ReadRFIDBlock macro to read the data from block 5 of the transponder memory, using 5 as the address byte and 0 as the Key_type byte in the parameters – the UID that has been read will be automatically included in the command;*
- *use the value of the returned status byte to determine if the read command has been executed correctly;*

if the command has not been executed correctly, print “Read error” on the LCD, and loop back to the beginning of the program.

When the ReadRFIDBlock command has been executed successfully:

use the ReadRFIDBuffer macro to read each of the four data bytes copied from the transponder memory block, and display them on the LCD;

Check to see if any key on the keypad has been pressed:

- insert a Component Macro;
- open its properties and select the KeyPad(0) component;
- select the GetNumber macro;

- add a decisions box to check when a key has been pressed – i.e. the 'keyval' variable, returned by the GetNumber macro, is not 255;
if no key has been pressed loop back to the beginning of the program.

When a key has been pressed:

- insert a Component Macro;
- open its properties and select the RFID(0) component;
- select the WriteRFIDBuffer macro, and add address '0' and data 'keyval' to the Parameters box;
- in the same way, insert three more Component Macros with addresses '1', '2' and '3' respectively, and with data '0' for all three;
- insert another Component Macro for the RFID(0) component;
- select the WriteRFIDBuffer macro, and add address '5' and Key_Type '0' to the Properties box, to write the contents of the buffer to block 5 of the transponder memory;
then return to the main program loop.

2. Compile the program and transfer it to the PIC chip.
3. Run and test the program by:

- observing the LEDs to see if the status byte is displayed when a RFID card is present
- examining the LCD to check that data is displayed when a card is present;
pressing a key on the keypad and observing that the value of the key is transferred to the transponder memory and then picked up and displayed on the LCD.

4. Do not delete this program as it can be modified for use in exercise 8!

10.6 Further work

If more than one ICODE transponder is available, introduce each one, in turn, into the reader field to prove that the system is reading and writing the data from each individual tag.

Create a top-up card system:

- Write a program to display continuously on the LCD, the contents of data block 0, when a transponder is present.
- Top-up the card by pressing a key on the keypad. When this happens, write the value '10' to data block 0 of the transponder memory, and set the value in the other three blocks to '0'.
- Whenever the key is not pressed, and the transponder is detected, check whether the value in data block 0 is greater that '0'.
- If it is greater than '0', light an led to indicate that the card has been accepted and then decrement the value stored in data block 0.
- If it is equal to '0', light a different led to show that the transponder has been rejected and that another top-up is required.

11. Using Mifare mode

11.1 Overview

Mifare transponders operate at the same radio frequency as ICODE transponders and can use the same antenna configuration. However, they are **not** compatible with ICODE data transfer. The reader module must be configured differently to set up communications.

There are three main types of Mifare transponders:

Mifare Ultralight
Mifare 1k
Mifare 4k

The Mifare 1k and 4k transponders are compatible with each other but not with Ultralight cards. The 1k and 4k have different amounts of memory (1024 and 4096 bytes respectively) and are known as Mifare Classic to distinguish them from the Ultralight type.

Mifare 1k transponders have 1024 bytes of memory organised into sixteen sectors. Each sector contains four blocks, with sixteen bytes of memory in each block. The first block in the first sector of the memory, block 0, is read-only and contains the four-byte UID. The last block of each of the sixteen sectors is known as the Sector Trailer Block, and contains security data for the block. This leaves 47 blocks, or 752 bytes of memory available to the user for data storage.

Mifare 4k transponders have their memory split into two sections:
the lower half is organised in the same way as in the 1k card, into 32 sectors containing four blocks of 16 bytes;
the upper half is organised into eight sectors, each containing 16 blocks of 16 bytes.
Taking account of block 0, which again is read-only, and the Sector Trailer Blocks in each of the forty sectors, this leaves 215 blocks, or 3440 bytes of data storage on each 4k card.

Data storage can be configured in one of two forms:
standard format, where each block stores sixteen bytes of data;
'Value' format, a more secure format used for e-purse applications, incorporating error-checking.

In the Value format, a sixteen byte block stores only four bytes of data, but stores it twice, and also stores the inverted (2's complement) form of the data as well, to reduce the risk of error. The simplest way to find this inverted form is to subtract the data, as a decimal number, from 255. For example, if the data = 200, the inverted from is 255 – 200 = 55.

This still leaves four unused bytes in the block. These are used to store the one-byte block address (1 to 62 for the 1k card, and 1 to 254 for the 4k card.) Again, for security against data corruption, this block address is stored twice, and the inverted (2's complement) form of the address is also stored twice. This Value format is illustrated in the following diagram:

Byte	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Contents	Data				Inverted Data				Data				Address	Inv. Address	Address	Inv. Address

The next diagram represents the situation where the data = 200 and is stored in block 25:

Byte	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Contents	200				55				200				25	230	25	230

11. Using Mifare mode

When using the Value format, three additional commands are available:

- Increment – add a 4-byte value to the value in the memory block;
- Decrement – subtract a 4-byte value from the value in the memory block;
- Transfer – copy the contents of the memory block to another location.

These commands are covered in more detail in exercise 9.

Most of the Mifare mode commands recognised by the RWD-MICODE reader module are similar to their ICODE equivalents.

The main differences are:

- Two of the unused bits in the status byte in ICODE mode have functions assigned in Mifare mode.
- The UID returned by the 'U' command (in the GetRFIDUID macro) has only seven bytes of data in Mifare mode. All seven of these are used in Ultralight transponders, but only the first four are valid for the Classic type – the remaining three bytes being set to 0. All seven bytes must be read!
- Transponder read / write commands do not require the inclusion of the transponder UID since in Mifare mode, the reader module can communicate with just a single transponder. (ICODE transponders require the UID because the reader can handle multiple ICODE transponders, and so the command must make clear which transponder is being addressed.)
- Transponder read / write commands require the use of security keys stored in the reader module when in Mifare mode.
- In Mifare mode, an additional key 'K' command (in the StoreRFIDKey macro) is used to store security keys in the reader module.
- Three additional transponder commands, increment, decrement and transfer, are available to manipulate data stored in a special 'Value' format, available only in Mifare mode.

11.2 Mifare mode status byte

Bit	Value	Significance
7	1	Always
6	1	Internal or antenna fault
5	1	Mifare Ultralight transponder,
	0	Mifare Classic (1K or 4K transponder)
4	1	Mifare 4K transponder,
	0	Mifare 1K transponder
3	1	RS232 error (System controller communications)
2	1	Transponder communications OK
1	1	Transponder UID accepted.
0	1	Reader module memory write error.

Example status values:

Binary	Decimal	Status
10000000	= 128	No tags detected. No errors.
10000110	= 134	Mifare 1K tag detected, UID accepted. No errors.
10010110	= 150	Mifare 4K tag detected, UID accepted. No errors.
11000000	= 192	Internal or antenna fault (check connections).

12. Exercise 5 – Reader module communications in Mifare mode

12.1 Introduction

This aim of this exercise is equivalent to that of exercise 1, in the ICODE section. Its purpose is to confirm the correct selection of Mifare mode.
It uses the Initialise and GetRFIDStatus functions to configure the communication link and read the current value of the reader module status byte.

12.2 Objective

To establish communications between the host controller and the RWD-MICODE reader module by:

- connecting and configuring the system hardware;
- configuring the Flowcode RFID component within a simple Flowcode program;
- writing configuration data to the RFID reader module;
- obtaining and displaying the status information from the RFID reader module

12.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- an LED E-blocks2 (BL0167)
- a Mifare RFID transponder.

12.4 The Flowcode program in detail

The aim of the program is to:

- Initialise the RFID module using the Initialise function;
- read the module's status byte repeatedly, using the GetRFIDStatus function;
- display the status byte value on a bank of LEDs connected to Port B to allow the states of the individual bits to be observed easily. If bits 1 and 2 are both set to 1, a transponder has been detected and communications has been established.

  A reminder:

Bit	Value	Significance
7	1	Always
6	1	Internal or antenna fault
5	1	Mifare Ultralight transponder,
	0	Mifare Classic (1K or 4K transponder)
4	1	Mifare 4K transponder,
	0	Mifare 1K transponder
3	1	RS232 error (System controller communications)
2	1	Transponder communications OK
1	1	Transponder UID accepted.
0	1	Reader module memory write error.

12.4.1 Initialise function

The Initialise function sends the configuration information required to the reader module using the protocol selected in the component properties panel.

The value returned is the reader module status byte generated when the protocol was selected. This can be used to confirm the presence of the RFID reader module and the successful execution of the command.

Expected outcome:

- Bit 7 = 1 Reader present
- Bit 0 = 0 No memory write error

12.4.2 GetRFIDStatus function

The GetRFIDStatus function causes the reader module to return the current value of the reader module status byte.

This can be used to detect the presence of a matching transponder.

Expected outcome when a transponder is accessed:

- Bit 7 = 1 Reader present
- Bit 2 = 1 Transponder communications OK

Bit 1 = 1 Transponder UID accepted.

12.5 What to do

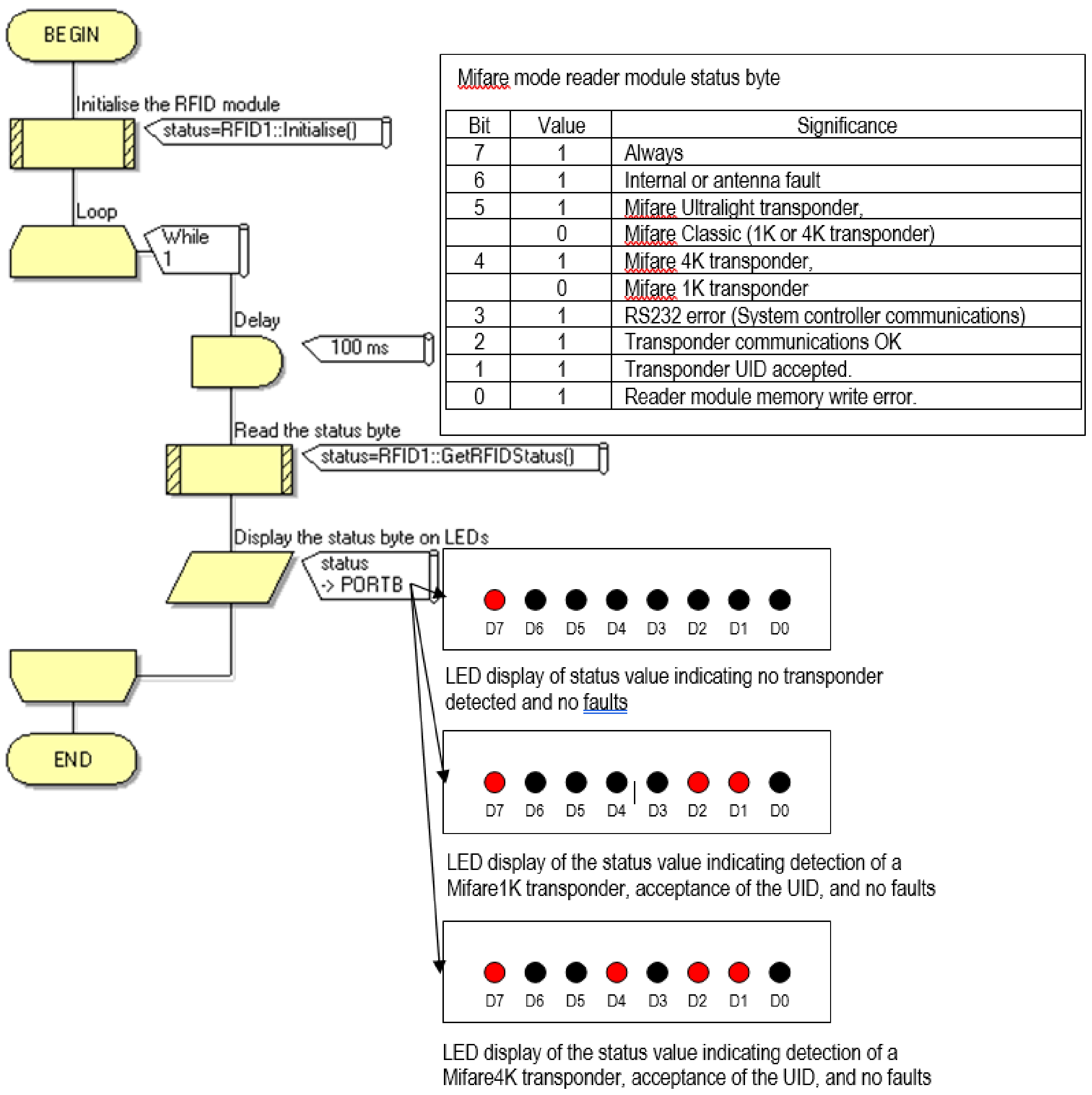
1. Write the Flowcode program using the following steps as a guide:

- load the RFID component into a new Flowcode flowchart;
- use the RFID component properties to select the Mifare protocol;
- insert a Component Macro, and select the RFID(0) component and the 'Initialise' macro to Initialise the RFID reader module;
- create a program loop that continuously cycles every 100ms (approximately) and uses the RFID component 'GetRFIDStatus' to read the status of the RFID reader module;
- write the returned status value to the LEDs on Port B so that the individual bits can be observed.

  (Alternatively, the program written in exercise 1 can be modified by changing the RFID component properties to the Mifare protocol.)

2. Compile the program and transfer it to the PIC chip.
3. Run and test the program by observing the LEDs to see if the status byte is displayed both when a Mifare card is present, and when no card is present.

The resulting Flowcode program is shown in the next diagram.


BEGIN
Initialise the RFID module
status=RFID1::Initialise()
Loop
While
1
Delay
100 ms
Read the status byte
status=RFID1::GetRFIDStatus()
Display the status byte on LEDs
status
-> PORTB
END
D7 D6 D5 D4 D3 D2 D1 D0

Mifare mode reader module status byte

Bit	Value	Significance
7	1	Always
6	1	Internal or antenna fault
5	1	Mifare Ultralight transponder,
	0	Mifare Classic (1K or 4K transponder)
4	1	Mifare 4K transponder,
	0	Mifare 1K transponder
3	1	RS232 error (System controller communications)
2	1	Transponder communications OK
1	1	Transponder UID accepted.
0	1	Reader module memory write error.

LED display of status value indicating no transponder detected and no faults

LED display of the status value indicating detection of a Mifare1K transponder, acceptance of the UID, and no faults

LED display of the status value indicating detection of a Mifare4K transponder, acceptance of the UID, and no faults

12.6 Further work

Introduce an ICODE tag to the reader and confirm that it cannot be detected in Mifare mode.

13.1 Introduction

The value of the reader module status byte returned when a Mifare Classic transponder is detected depends on the size of the transponder data memory available.

Mifare 1K = 134 (Bit 4 of the status byte = 0)
Mifare 4K = 150 (Bit 4 of the status byte = 1)

If either of these values is returned in the status byte, a transponder is available and the UID can be read. The UID is not required to be included in any of the data read / write commands because Mifare mode cannot handle more than one transponder at a time.

13.2 Objective

The objective for this exercise is to write a Flowcode program that will display, on the LCD, the 8-byte UID of any Mifare transponder in communication with the RFID reader module.

13.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- an LED E-blocks2 (BL0167)
- an LCD E-blocks2 (BL0169)

a Mifare RFID transponder (several if possible – make a note of the UIDs).

13.4 The Flowcode program in detail

The program will:

- access the reader module's status byte using the Initialise function;
- check that a transponder has been detected, and that there are no errors;
- display each byte of the transponder 4-byte UID, in turn, on the LCD display, using the GetRFIDUID function and the ReadRFIDUID function, whenever a transponder has been detected;

loop back and re-read the status byte repeatedly.

13.4.1 **GetRFIDUID function**

This function causes the reader module to return seven bytes of UID data from a transponder. If no transponders are present, or there is a fault, the status byte will indicate this, and so no data will be returned.
The seven UID bytes are required for compatibility with Ultralight transponders. Classic transponders only use four bytes so the reader module sets the remaining three bytes to 0.

Data transferred between host controller and reader module by this function:

Send	'U'	ASCII character (decimal value = 85).
Receive	<status>	The value returned is the reader module status byte. This will indicate when a transponder is accessed successfully.

When the status value indicates that no transponder is available, or there is an error, the command terminates here.

When a transponder is detected and there are no faults, the UID data is returned.

Receive	<UID0>	
Receive	<UID1>	
Receive	<UID2>	
Receive	<UID3>	
Receive	<UID4>	0 for Mifare Classic transponders
Receive	<UID5>	0 for Mifare Classic transponders
Receive	<UID6>	0 for Mifare Classic transponders

Example:

Before and after a Mifare 1K transponder is detected:

Send	'U'	
Receive	128	Status value indicates no transponder available.
Send	'U'	
Receive	134	Mifare 1K transponder is now available.
Receive	<UID0>	
Receive	<UID1>	
Receive	<UID2>	
Receive	<UID3>	
Receive	0	
Receive	0	
Receive	0	

13.4.2 ReadRFIDUID function

When the GetRFIDUID function is executed successfully, the seven-byte UID of the transponder is stored in a memory buffer created by the RFID component.

The ReadRFIDUID function reads only one of these bytes. The user specifies which byte to retrieve by adding a parameter with a value from 0 to 3.

13.5 What to do

1. Either write the Flowcode program using the following steps as a guide or modify the program from exercise 2, by ignoring the sections in italics:

- *load the RFID component into a new Flowcode flowchart;*
- use the RFID component properties to select the Mifare protocol;
- *configure the LCD display, using the Start macro;*
- *Initialise the RFID module by inserting a Component Macro, selecting the RFID(0) component and selecting the 'Initialise' macro to Initialise the RFID reader module;*
- *create a program loop that continuously cycles every 100ms (approximately) and uses the RFID macro GetRFIDUID to keep looking for a transponder, and copying its UID;*
- *test the value of the returned status byte to determine if a transponder has been detected and valid UID data is available*

- then use the ReadRFIDUID macro to read each of the four UID bytes in turn, and display them on the LCD;
- *If a transponder cannot be accessed, clear the LCD display and loop back to repeat the process.*

2. Compile the program and transfer it to the PIC chip.
3. Run and test the program by observing the LEDs to see if the status byte is displayed when a RFID card is present.
4. Then examine the LCD to check that the four-byte UID is displayed when a card is present.
5. Check that the LCD screen is cleared when the card is removed.

13.6 Further work

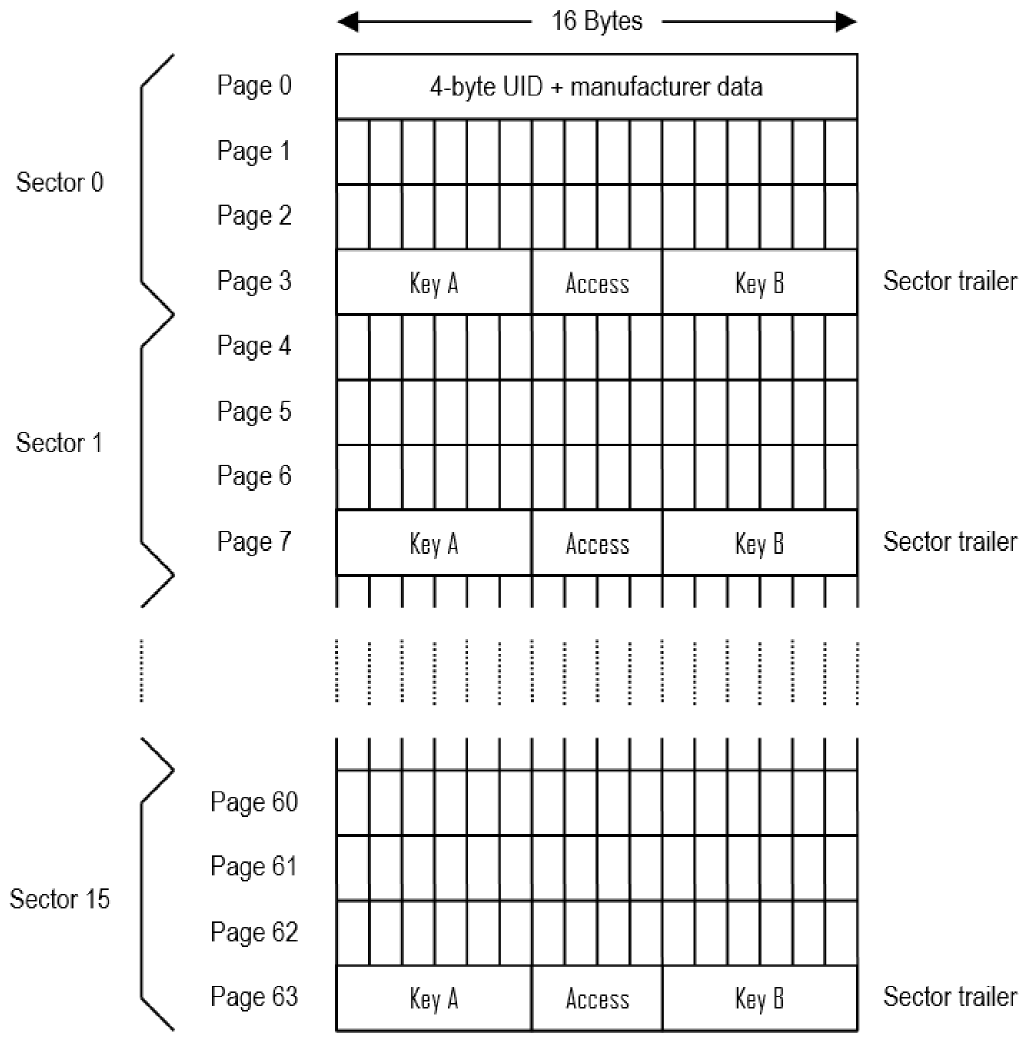
- Obtain the UID from a series of Mifare cards. Make a note of these for future use.

14.1 Introduction

Mifare 1k transponders have 1024 bytes of memory organised into sixteen sectors. Each sector contains four blocks, with sixteen bytes of memory in each block.

Mifare 4k transponders have 4096 bytes of memory organised into forty sectors, thirty-two of which contain four blocks, with the remaining eight having sixteen sectors.

In both cases, the last block of each sector is known as the Sector Trailer Block, and contains security data, in the form of security keys and access bits, for the block.



MIFARE1K memory

The structure of the Sector Trailer Block is emphasised in the next diagram.

Byte	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Contents	Key A						Access bits				Key B					

14.1.1 Security features

Mifare transponders contain security features that control access to sectors of memory by means of two security keys and accompanying access rules.

The keys, known as Key A and Key B, are each six bytes in length. The access rules define which key must be used to perform read / write commands on each block of memory. The options controlled by the access bits are:

- access to a block is read / write;
- access to a block is read only;
- access to a block is write only;
- data is stored in standard data or Value format;
- use Key A and / or Key B for access.

Every transponder command must be accompanied by the correct key.
Access can require the following conditions:

- the use of Key A only;
- the use of Key B only;
- the use of either of Key A or Key B.

    or access can be denied regardless of which key is used.

In the final case, the selected command cannot be executed on that block of memory. These access conditions are set separately for each of the commands – Read, Write, Increment, Decrement and Transfer. A data block can be made 'read-only' by preventing the use of the Write command.

Mifare 1k cards and blocks in the lower half of 4k cards can have different access conditions set for each block. For the upper half of 4k cards, conditions are set for groups of five blocks. The access control bits themselves can also be protected, by preventing any write commands to their own block. The effect of this is permanent and must be carefully planned. (It will not form part of these exercises!)

The RWD-MICODE reader module contains a memory array that allows up to 32 6-byte keys to be stored. Each transponder read/write command must include the array index for the key being used, and a flag to indicate whether the key is to be used as Key A or Key B.

The requested operation will be allowed only if:

- the key being addressed in the reader module matches the equivalent key in the transponder for the sector being addressed.
- the access bits allow the requested operation to be performed using the supplied key.

The next exercise uses the StoreRFIDKey function to create a new key value. The ReadRFIDBlock function and the ReadRFIDBuffer functions are used to transfer data from the transponder memory to the reader module memory buffer, and from there, transfer it to the LCD display.

14.2 Objective

To design and test a Flowcode program that will demonstrate the use of security keys to access data from a Mifare transponder. When the correct key is used, data will be read from block 5 of the transponder's memory, and displayed on the LCD.

14.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- an LED E-blocks2 (BL0167)
- an LCD E-blocks2 (BL0169)

a Mifare RFID transponder.

14.4 The Flowcode program in detail

The program will:

- run the RFID reader module in Mifare mode;
- write new security key values to the reader module key storage array, using the StoreRFIDKey function;
- attempt to read data continuously from block 5 of a Mifare transponder, using the ReadRFIDBlock function and display the returned status byte on the LEDs, using the ReadRFIDBuffer command;
- display the status byte values under the following conditions:
    - no card present;
    - card present, but using the incorrect key value;
    - card present, and using the correct key value;
- display the current key location on the LCD when a read command is completed successfully.

14.4.1 Default Keys

Mifare transponders are supplied by the manufacturers with default (transport) setting for all the keys and access bits. These settings allow full access, (read and write access) to the memory using key A for each operation.

Incorrect reprogramming of a sector trailer block can cause the sector to become permanently unusable, so this exercise will demonstrate the basic security features by changing the corresponding settings in the reader module, rather than in the transponder card itself.

The transport key settings depend on the manufacturer of the Mifare transponde.
The most common values are:

Key A	160, 161, 162, 163, 164, 165 (0xA0, 0xA1, 0xA2, 0xA3, 0xA4, 0xA5 in hexadecimal)
Key B	176, 177, 178, 179, 180, 181 (0xB0, 0xB1, 0xB2, 0xB3, 0xB4, 0xB5 in hexadecimal)

or

Key A	255, 255, 255, 255, 255, 255 (0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF in hexadecimal)
Key B	255, 255, 255, 255, 255, 255 (0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF in hexadecimal)

14.4.2 StoreRFIDKey function

The RWD-MICODE reader module contains a memory array that allows up to thirty-two 6-byte keys to be stored. Keys can be stored in the reader module using the StoreRFIDKey function, which sends the ‘K’ command to the reader module.

Data transferred between host controller and reader module by this function:

Send	'K'	ASCII character (decimal value = 75)
Send	<index>	Location in the key storage array (0 to 31)
Send	<data0>	Key byte 0
Send	<data1>	Key byte 1
Send	<data2>	Key byte 2
Send	<data3>	Key byte 3
Send	<data4>	Key byte 4
Send	<data5>	Key byte 5
Receive	<status>	

For example:

Store the key 176, 177, 178, 179, 180, 181 to location 3 in the key storage array

Send	'K'	
Send	3	<index>
Send	176	<data0>
Send	177	<data1>
Send	178	<data2>
Send	179	<data3>
Send	180	<data4>
Send	181	<data5>
Receive	<status>	

14.4.3 ReadRFIDBlock function

The ReadRFIDBlock command causes the reader module to copy the four bytes of data from a specified transponder memory block into the memory buffer of the reader module. If no transponders are detected, the supplied UID is incorrect, or there is a fault, the status byte will indicate this and no data will be returned.

Data transferred between host controller and reader module by this function:

Send	'R'	ASCII character (decimal value = 82).
Send	<block address>	
Send	<key index>	(0 to 31 for KeyA, add 128 if the KeyB is to be used.)
Receive	<status>	

If the status value indicates that no transponder is available, or there is an error, the command terminates here.

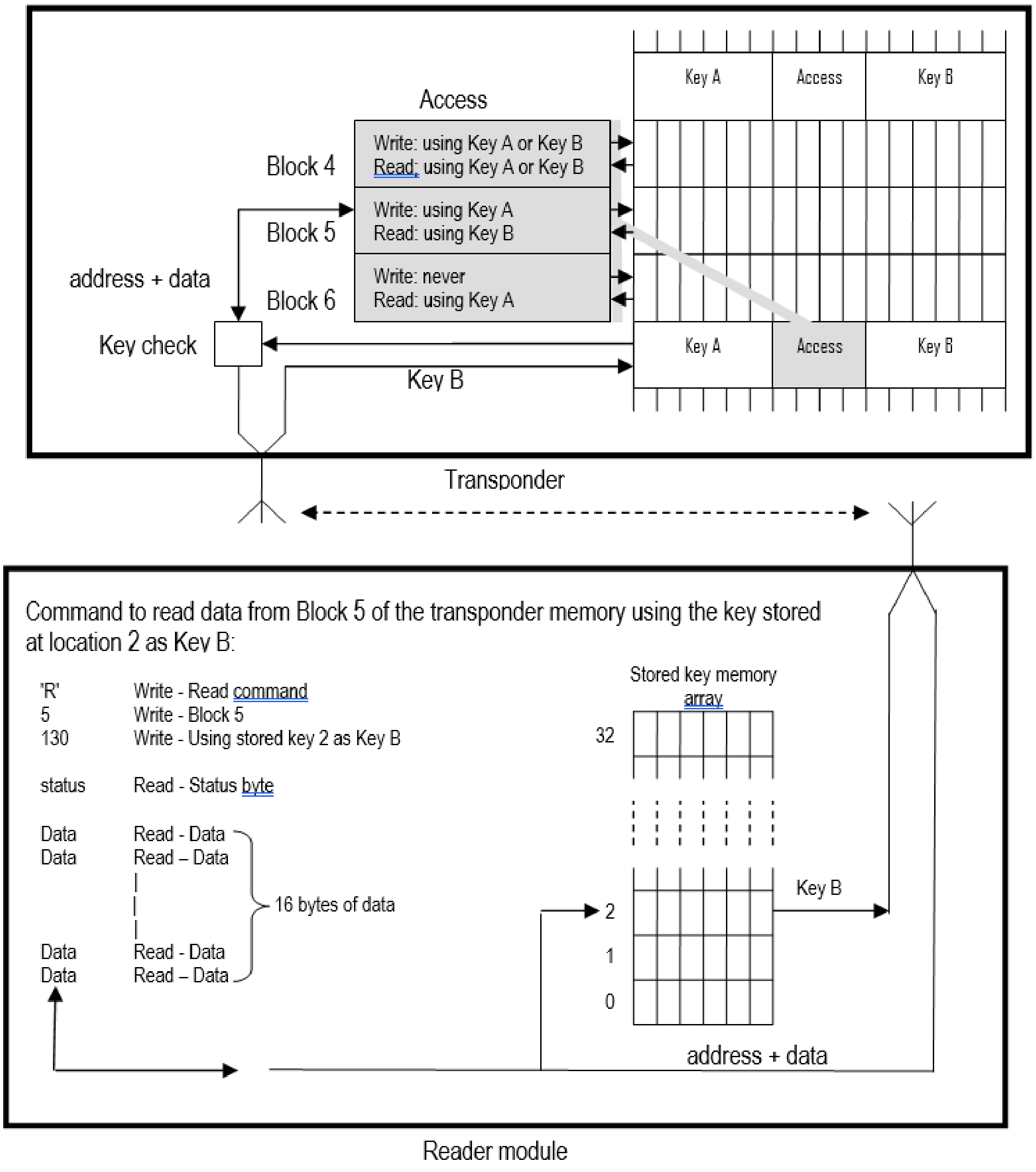
When a transponder is available and there are no faults, the memory block data is copied to the reader module buffer.

```
Receive      <data>
Receive      <data>  ⎫
                |    ⎬  Receive 16 bytes of
                |    ⎪
Receive      <data>  ⎭
Receive      <data>
```

For example:

Read the sixteen bytes of data from block 5 of a Mifare transponder, using the key stored at array index 2 as Key A

Send	'R'	ASCII character (decimal value = 82).
Send	5	<block address>
Send	2	<key index>
Receive	<status>	Stop here if the status value indicates a fault.
Receive	<data0>	
Receive	<data1>	Receive 16 bytes of data
	|	
	|	
Receive	<data14>	
Receive	<data15>	



14.5 What to do

Either write the Flowcode program using the following steps as a guide or modify the program from exercise 3, by ignoring the sections in italics:

1. Write the Flowcode program using the following steps as a guide:

- configure the reader for Mifare mode;;
- *Initialise the LCD display;*
- *Initialise the RFID module using the 'Initialise' macro;*
- insert two Component Macros, for the RFID(0) module, each using a StoreRFIDKey macro, the first to write the key 0xff, 0xff, 0xff, 0xff, 0xff, 0xff to key storage array location 0, and the second to write key 0xa0, 0xa1, 0xa2, 0xa3, 0xa4, 0xa5 to key storage array location 2;
- *use the 'GetRFIDUID' macro to attempt to read the UID of a transponder continuously, at 100ms intervals;*
- *use the value of the returned status byte to determine if a transponder has been detected and valid UID data is available;*

print “No card detected” until a transponder is detected.

When a transponder is detected:

- *use the ReadRFIDBlock macro to read the data from block 5 of the transponder memory, using 5 as the address byte and 0 as the Key_type byte in the parameters;*
- *use the value of the returned status byte to determine if the read command has been executed correctly;*

if the command has not been executed correctly, print “Read error” on the LCD, and loop back to the beginning of the program.

When the ReadRFIDBlock command has been executed successfully:

- *use the ReadRFIDBuffer macro to read each of the four data bytes copied from the transponder memory block, and display them on the LCD;*

then return to the main program loop.

2. Compile the program and transfer it to the PIC chip.
3. Run and test the program by observing the LEDs to see if the status byte is displayed when a Mifare RFID card is present. Examine the LCD to check that the data is displayed when a card is present.

14.6 Further work

- Modify the program to read data from other blocks on the transponder card.
- Find out what happens if you use an incorrect 6-byte key to access the card.

15 Exercise 8 - Write data to a Mifare transponder

15.1 Introduction

So far, the Mifare mode exercises have looked at the issues involved in detecting, identify and read data from an Mifare transponder by the RFID reader module. The next step is to modify that program to write blocks of data to the transponder's memory. This will allow information to be stored in memory of a transponder and to be changed when necessary.

As for the ICODE transponder in exercise 4, the process required to write a block of data to a transponder is the reverse of the read process. After detecting and identifying a transponder, the 4 bytes of data must be written to a memory buffer in the reader module, created by the Flowcode RFID component. Then the contents of buffer can be written to the transponder, along with the transponder's UID - obtained during the identification process.

The Flowcode function, WriteRFIDBuffer copies data, one byte at a time, into a memory buffer. Then the function WriteRFIDBlock, is used to copy the contents of the buffer to a particular location in the transponder’s memory.

15.2 Objective

To write a Flowcode program that will modify the previous program by adding the ability to write data from the keypad to a Mifare transponder.

15.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- a Keypad E-blocks2 (BL0138)
- an LCD E-blocks2 (BL0169)
- a Mifare RFID transponder (several if possible – make a note of the UIDs).

15.4 The Flowcode program in detail

The program overview is exactly the same as in exercise 4, for the ICODE transponder. It will:

- detect the presence of a Mifare transponder;
- read the transponders UID;
- read data from block 5 of the transponder’s memory;
- display the 4 bytes of data on the LCD;
- check to see when a key on the keypad is pressed;
- write the ASCII value of the key pressed to the transponder memory, using the WriteRFIDBuffer and WriteRFIDBlock functions;
- check that the new data has been transferred successfully.

15.4.1 WriteRFIDBuffer function

The data to be sent to the transponder memory block is first written to a memory buffer in the reader module, created by the RFID component using the WriteRFIDBuffer function. The function needs to know which of the four bytes of the buffer to write to, and so an address (0 to 3) must be provided in the Parameters box of the macro properties.

All 4 bytes should be written individually before the 'WriteRFIDBlock' function is executed, otherwise some random data may be sent.
15.4.2 WriteRFIDBlock function

The WriteRFIDBlock function causes the reader module to write four bytes of data from the buffer created by the Flowcode RFID component, to a specified memory block in a transponder.

If no transponder is detected, the supplied UID is incorrect, or there is a fault, the status byte will reflect this and the data will not be transmitted to the transponder.

Data transferred between the host controller and the reader module by this function:

```
Send       'W'              ASCII character (decimal value = 87).
Send       <block address>        0 to 27

Send       <UID0>   ⎫
                    ⎬  Send all four bytes of data.
             |      ⎪
Send       <UID7>   ⎭

Send       <data0>  ⎫
                    ⎬  Send all eight bytes of the UID.
             |      ⎪
Send       <data3>  ⎭
Receive    <status>
```

15.5 What to do

Either write the Flowcode program using the following steps as a guide or modify the program from exercise 4, by ignoring the sections in italics.
1. Write the Flowcode program using the following steps as a guide:

- configure the reader for Mifare mode;
- *Initialise the LCD display;*
- insert two Component Macros, for the RFID(0) module, each using a StoreRFIDKey macro, the first to write the key 0xff, 0xff, 0xff, 0xff, 0xff, 0xff to key storage array location 0, and the second to write key 0xa0, 0xa1, 0xa2, 0xa3, 0xa4, 0xa5 to key storage array location 2;
- *use the 'GetRFIDUID' macro to attempt to read the UID of a transponder continuously, at 100ms intervals;*
- *use the value of the returned status byte to determine if a transponder has been detected and valid UID data is available;*
print “No card detected” until a transponder is detected.

When a transponder is detected:

- *use the ReadRFIDBlock macro to read the data from block 5 of the transponder memory, using 5 as the address byte and 0 as the Key_type byte in the parameters;*
- *use the value of the returned status byte to determine if the read command has been executed correctly;*
if the command has not been executed correctly, print "Read error" on the LCD, and loop back to the beginning of the program.

When the ReadRFIDBlock command has been executed successfully:

use the ReadRFIDBuffer macro to read each of the four data bytes copied from the transponder memory block, and display them on the LCD;

Check to see if any key on the keypad has been pressed:

- *insert a Component Macro;*
- *open its properties and select the KeyPad(0) component;*
- *select the GetNumber macro;*
- *add a decisions box to check when a key has been pressed – i.e. the 'keyval' variable, returned by the GetNumber macro, is not 255;*
if no key has been pressed loop back to the beginning of the program.

When a key has been pressed:

- *insert a Component Macro;*
- *open its properties and select the RFID(0) component;*
- *select the WriteRFIDBuffer macro, and add address '0' and data 'keyval' to the Parameters box;*
- *in the same way, insert three more Component Macros with addresses '1', '2' and '3' respectively, and with data '0' for all three;*
- *insert another Component Macro for the RFID(0) component;*
- *select the WriteRFIDBuffer macro, and add address'5' and Key_Type '0' to the Properties box, to write the contents of the buffer to block 5 of the transponder memory;*
then return to the main program loop.

2. Compile the program and transfer it to the PIC chip.
3. Run and test the program by:

- observing the LEDs to see if the status byte is displayed when a RFID card is present
- examining the LCD to check that data is displayed when a card is present;
pressing a key on the keypad and observing that the value of the key is transferred to the transponder memory and then picked up and displayed on the LCD.

4. Do not delete this program as it can be modified for use in exercise 9!

15.6 Further work

- If more than one Mifare transponder is available, introduce each one, in turn, into the reader field to prove that the system is reading and writing the data from each individual tag.
- Find out what happens if you use an incorrect 6-byte key to access the card.

16. Exercise 9 – Using Value format

16.1 Introduction

Mifare classic transponders can use 16-byte memory blocks to store 4-byte (32-bit) numeric value using a special 'Value' format that allow three extra commands to be used on them.

In the Value format, a sixteen byte block stores only four bytes of data, but stores it twice, and also stores the inverted (2’s complement) form of the data as well, to reduce the risk of error. The simplest way to find this inverted form is to subtract the data, as a decimal number, from 255. For example, if the data = 200, the inverted from is 255 – 200 = 55.

This still leaves four unused bytes in the block. These are used to store the one-byte block address (1 to 62 for the 1k card, and 1 to 254 for the 4k card.) Again, for security against data corruption, this block address is stored twice, and the inverted (2’s complement) form of the address is also stored twice. This Value format is illustrated in the following diagram:

Byte	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Contents	Data				Inverted Data				Data				Address	Inv. Address	Address	Inv. Address

The next diagram represents the situation where the data = 200 and is stored in block 25:

Byte	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Contents	200				55				200				25	230	25	230

16.1.1 The FormatRFIDValue function

The FormatRFIDValue function is used to set up the 16 bytes in a memory block in Value format.

In normal use, the data in each individual byte of a block has no direct relationship to the other bytes. When a block is used in Value format, only the first four bytes are used directly. It stores a 32-bit number in other words. The remaining twelve bytes contain copies of that number, or its inverse, are used as a simple checksum and must be related to the first 4 bytes as described above.

In Value format, the RFID transponder is capable of performing simple 32-bit arithmetic operations using the three additional commands (increment, decrement, and transfer). Random data can be written to the memory block at any time, but if it breaks the Value format structure, the additional commands will not work.

16.1.2 The IncrementRFIDValue function

The Mifare Increment command takes the 4-byte value stored in the source block, adds the supplied 4-byte number to it, and stores the result in the destination block.

All the other bytes in the block are adjusted to maintain the Value format bytes.

The sequence is:

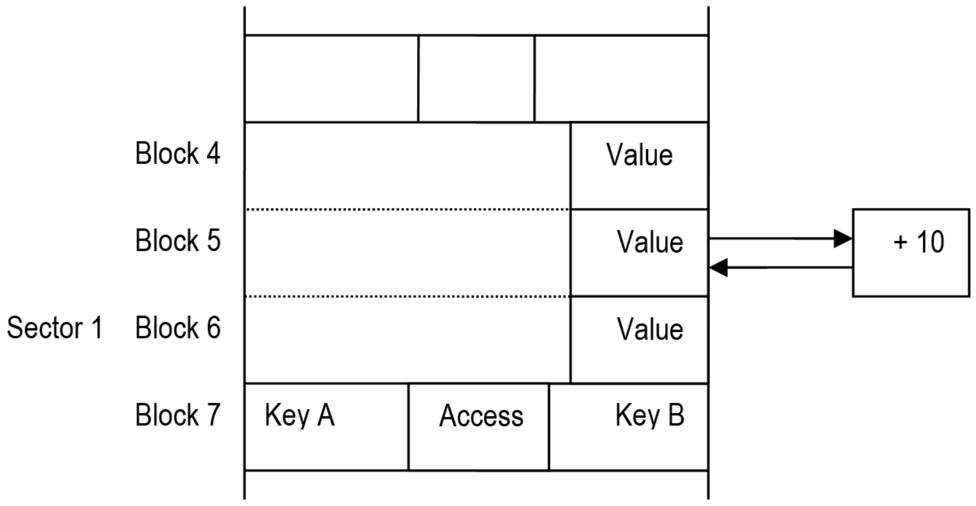
Send	'I'	ASCII character (decimal value = 73).
Send	<source block address>	0 to 255
Send	<key>	
Send	<destination block address>	0 to 255
Send	<number byte 0>	
Send	< number byte1>	
Send	< number byte 2>	
Send	< number byte 3>	
Receive	<status>	

For example:

Add 10 to the value currently stored in transponder memory block 5, using the key stored at location 1 as Key A. Store the result to the same memory block.

Send	75	
Send	5	<source block address>
Send	1	<key location = Key A>
Send	5	<destination block address (same as source)>
Send	10	< number byte0>
Send	0	< number byte1>
Send	0	< number byte2>
Send	0	< number byte3>
Receive	<status>	

This process is illustrated in the following diagram:



The IncrementRFIDValue always adds the number 1, i.e. increments the value, specified in the source block address.

16.1.3 The DecrementRFIDValue function

The Mifare Decrement command takes the 4-byte value stored in the source block, subtracts the supplied 4-byte number from it, and stores the result in the destination block.

All the other bytes in the block are adjusted to maintain the Value format bytes.

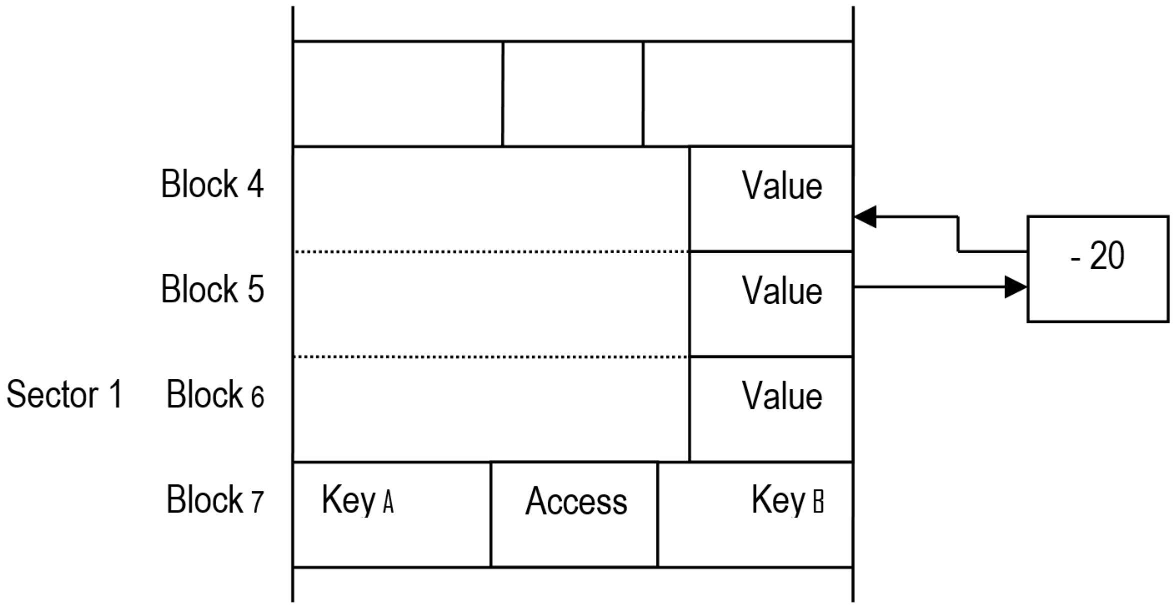
The sequence is:

Send	'D'	ASCII character (decimal value = 68).
Send	<source block address>	0 to 255
Send	<key>	
Send	<destination block address>	0 to 255
Send	< number byte 0>	
Send	< number byte1>	
Send	< number byte 2>	
Send	< number byte 3>	
Receive	<status>	

For example:

Copy the value currently stored in transponder memory block 5 to transponder memory block 4 (in the same sector), subtracting 20 from the copied value as it is written. Use the data key at storage location 1 as Key B.

Send	'D'	
Send	5	<source block address>
Send	129	<key location (Key B = 1 + 128)>
Send	4	<destination block address>
Send	20	< number byte0>
Send	0	< number byte1>
Send	0	< number byte2>
Send	0	< number byte3>
Receive	<status>	



The DecrementRFIDValue always subtracts the number 1, i.e. decrements the value, specified in the source block address.

16.1.4 The TransferRFIDValue function

The Mifare Transfer command takes the 4-byte value stored in the source block and copies it to the destination block.

All the other bytes in the block are adjusted to maintain the Value format bytes.

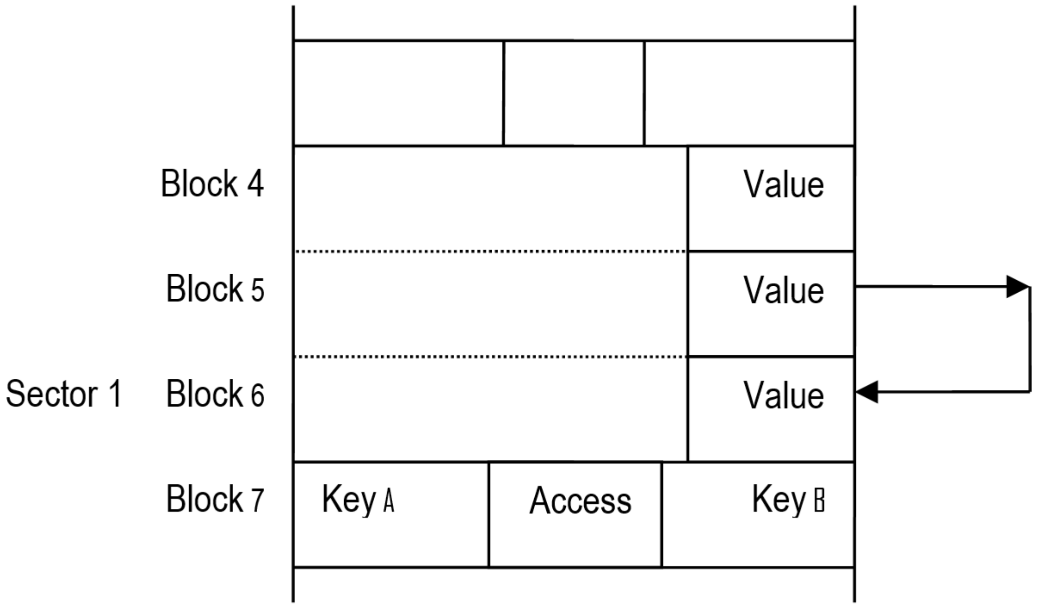
The sequence is:

```
Send        'T'        ASCII character (decimal value = 84).
Send     <source block address>          0 to 255
Send        <key>
Send     <destination block address>  0 to 255

Receive  <status>
```

For example:

Copy the value currently stored in transponder memory block 5 to transponder memory block 6 (in the same sector), without modifying the value. Use the data key at storage location 3 as Key A.

```
Send     'T'
Send     5          <source blockaddress>
Send     3          <key location>
Send     6          <destination block address>

Receive  <status>
```



16.2 Objective

To write a Flowcode program that will demonstrate the Value format for data, and the use of the IncrementRFIDValue and DecrementRFIDValue functions.

16. Exercise 9 – Using Value format

16.3 Requirements

This exercise requires the following items (see section 5.2 configuration information):

- a microcontroller, either the PIC based BL0011 or Arduino Uno BL0055
- a copy of Flowcode, version 8 or later, running on the PC
- an RFID E-blocks2 (BL0197) with an RWD-MICODE reader module
- a Keypad E-blocks2 (BL0138)
- an LCD E-blocks2 (BL0169)

a Mifare RFID transponder (several if possible – make a note of the UIDs).

16.4 The Flowcode program in detail

The program overview builds on exercise 8.
Like that program, it will:

- detect the presence of a Mifare transponder;
- read the transponders UID;
- read data from block 5 of the transponder's memory;
- display the 4 bytes of data on the LCD;
- check to see when a key on the keypad is pressed;
- write the value of the key pressed to the transponder memory, using the WriteRFIDBuffer and WriteRFIDBlock functions;

check that the new data has been transferred successfully.

However, in addition, it will:

- check to see if the Ü or # keys have been pressed;
- if the Ü key is pressed, the value stored in the transponder memory will be incremented;

if the # key is pressed, the value stored will be decremented.

16.5 What to do

Modify the program from exercise 8, by:

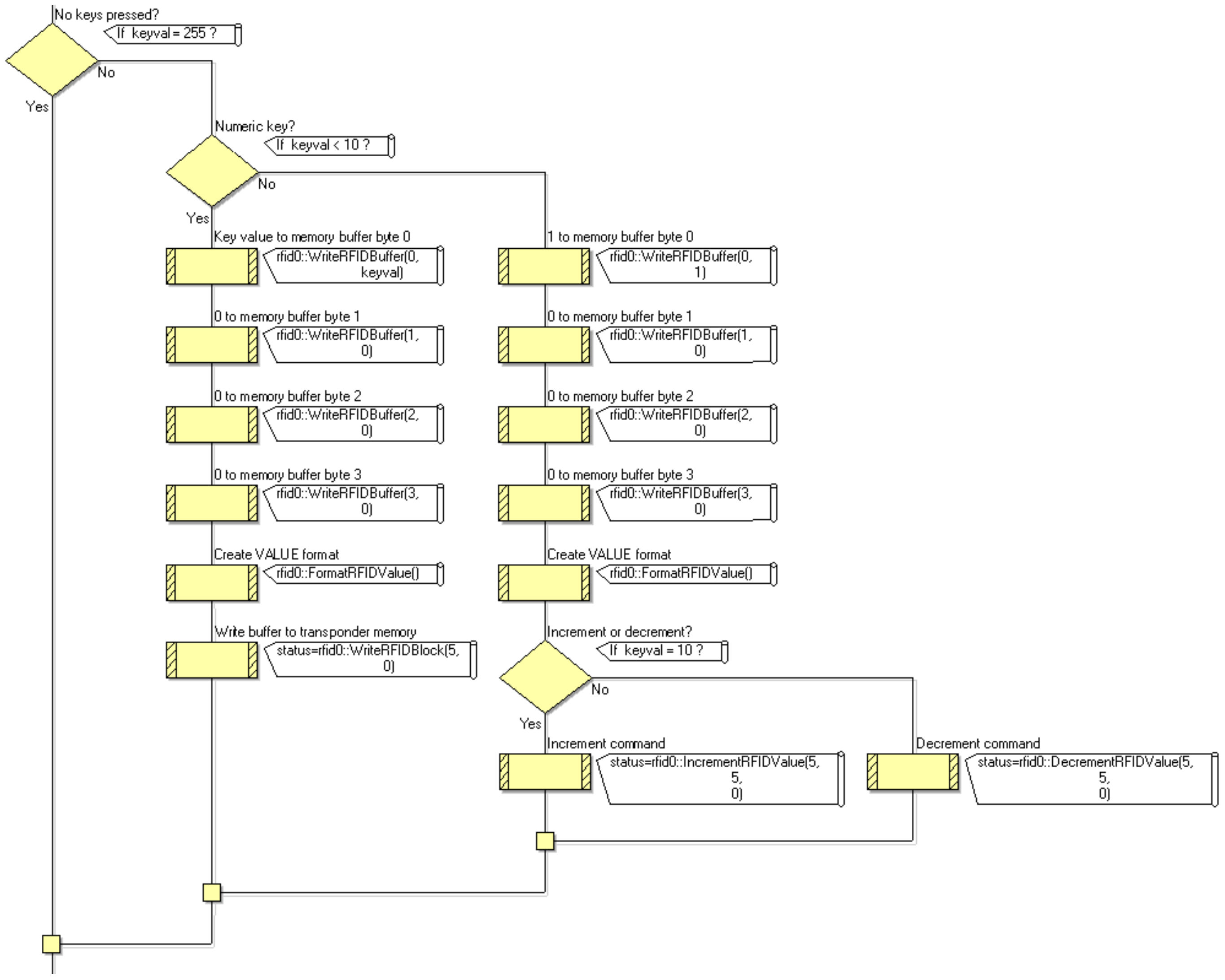
- inserting a Component Macro calling the FormatRFIDValue macro, just before the WriteR-FIDBlock macro which transfers the value of the key pressed to the transponder memory;

inserting another Decision box to test whether the value of the key pressed is less than 10;

  - if it is, then proceed as in the last exercise, and write that value to the transponder memory (but using Value format, as indicated in the previous bullet point);
  - if it is not (i.e. the Ü or # key has been pressed,) then write the number 0001 into the RFID reader memory buffer, and insert a Component Macro calling the FormatRFIDValue macro, to convert to Value format. Then add another Decision box to distinguish between the Ü key and the # key, (the value will be 10 for the Ü key.) If the Ü key has been pressed, then increment the value stored in the transponder card, using the IncrementRFIDValue macro. If the # key is pressed, decrement the value using the DecrementRFIDValue macro.

- Then, whatever the result, loop back to the main loop so that the result is displayed.

The following diagram illustrates these changes:


No keys pressed?
If keyval = 255 ?
No
Yes
Numeric key?
If keyval < 10 ?
No
Yes
Key value to memory buffer byte 0
rfid0::WriteRFIDBuffer(0, keyval)
0 to memory buffer byte 1
rfid0::WriteRFIDBuffer(1, 0)
0 to memory buffer byte 2
rfid0::WriteRFIDBuffer(2, 0)
0 to memory buffer byte 3
rfid0::WriteRFIDBuffer(3, 0)
Create VALUE format
rfid0::FormatRFIDValue()
Write buffer to transponder memory
status=rfid0::WriteRFIDBlock(5, 0)
1 to memory buffer byte 0
rfid0::WriteRFIDBuffer(0, 1)
0 to memory buffer byte 1
rfid0::WriteRFIDBuffer(1, 0)
0 to memory buffer byte 2
rfid0::WriteRFIDBuffer(2, 0)
0 to memory buffer byte 3
rfid0::WriteRFIDBuffer(3, 0)
Create VALUE format
rfid0::FormatRFIDValue()
Increment or decrement?
If keyval = 10 ?
No
Yes
Increment command
status=rfid0::IncrementRFIDValue(5, 5, 0)
Decrement command
status=rfid0::DecrementRFIDValue(5, 5, 0)

Since the data is stored in Value format, only the first four bytes are significant. The display shows the first eight of the sixteen bytes stored in the block. Four of these are the data, and the next four are the inverse of the data.

For example, the display could look like:

5	**0**	**0**	**0**
250	255	255	255

To prove that the four data bytes are operating as a single 32-bit word, try to decrement the data value below zero. What would you expect to happen, and why?

Congratulations – you have just completed the course!