MICRF405

User Manual for Development System

315MHz
433MHz
868MHz
915MHz

FW v.2

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1. *Introduction*

This document, "MICRF405 User Manual for Development System" describes the features of the development system for MICRF405. For details on the MICRF405 transmitter (a product in the RadioWire™ product line): Please refer to the appropriate data sheet. For the latest updates on products related to RadioWire™, please visit www.micrel.com.

The MICRF405 can be used in several frequency bands. Several development systems are made:

For the
- 315MHz band,
- 433.92MHz band,
- 868MHz band and
- 915MHz band

Default frequencies are selected to match the MICRF600, MICRF610 and MICRF620 development systems. The MICRF6x0 modules are using a MICRF505 or MICRF506 transceiver chip. They can be used to receive the signals transmitted by the MICRF405 development system (of course, any adequate receiver can be used, but the development systems for these modules match the development system for the MICRF405):
- For the 433.92MHz band, MICRF620 can be used as a receiver
- For the 868MHz band, MICRF610 can be used as a receiver
- For the 915MHz band, MICRF600 can be used as a receiver

The operation and features of the development system are equal for all frequency bands. The main differences are the frequency band, bit rate and number of frequency channels:

Dev System for frequency band	Modulation	On-the-air bit rate (bps)	Manchester coded	Number of frequencies
315MHz	Modulation using 2 sets of dividers	19231	No	1
433.92MHz	Modulation using 2 sets of dividers	19231	No	4
868MHz	Modulation using 2 sets of dividers	15152	No	2
915MHz	Modulation using 2 sets of dividers	19231	No	25

Note that all development systems for MICRF405 have the same firmware[1] version, and all source files are available in a common set of files (a “Project”).

Outline of this document:

Following this introduction, an overview of the board’s inputs/outputs is given. Then a Get-started chapter is included, and the different modes of operation are described. An overview of how to program/update the firmware is also included. Finally, a list of changes for this firmware version is given, as well as a description of the firmware.

Purpose of the Development system:

The development system provides hands-on experience with the MICRF405 transmitter. The user can use the included firmware and hardware, or make a new program and flash it into the micro controller. That is, the user can use the boards both to evaluate the MICRF405, and as an aid in the development of a radio communication system.

A separate PC program is available. Through this program, it is possible to set the programming word for the MICRF405 (both the frequency dividers and the control bits can be set). This program is referred to as “RF TestBench”. Please observe: It is possible to read out the firmware version of the development board via RF TestBench.

Main modes of operation of the Development system:

- **RF Test Modes.** The user can test the RF properties of the transmitter. It is possible to transmit a 1010… pattern, a random pattern or a carrier. In addition, the user can select to bypass the micro controller (MCU) completely (i.e. tristate all IOs of the MCU), and control the RF part via header pins, e.g. by an external micro controller. In addition, transmitting packets using ASK is one of the test modes.

- **Link-Test Mode.** In this mode of operation, the development board is a “Master”. “Messages” (5 printable ascii characters) are transmitted. This mode is useful when testing radio communication in different environments, testing antennas, testing encapsulation etc. MICRF6x0 development systems can be used to receive the messages.

- **Simple Byte Transfer Mode.** In this mode, the user can enter a number of bytes into a development board (using e.g. a PC). The board will then transmit the bytes. A 64-byte deep buffer is implemented. Only 1 frequency is used. MICRF6x0 development systems can be used to receive the transmitted bytes.

[1] “Firmware” (FW) = the program used in the micro controller

Development System Features:

- Pre-programmed frequencies (centre RF frequencies, i.e. middle of “tx0” and “tx1”)
  - 315MHz band: 1 frequency, f0=315.00MHz
  - 433.92MHz band: 4 frequencies, f0=433.43MHz, f1=433.71MHz, f2=434.00MHz, f3=434.29 MHz
  - 868MHz band: 2 frequencies, f0=868.31MHz, f1=868.95MHz
  - 915MHz band: 25 frequencies, f0=904.30MHz, …, f12=915.25MHz, … , f24=926.25MHz
- Default frequencies (used in RF test mode and Simple byte transfer mode):

Dev System for frequency band	TX0 (MHz)	TX1 (MHz)	Centre freq = (TX1+TX0)/2 (MHz)	Single-sided deviation = (TX1-TX0)/2 (kHz)
315MHz	314.909091	315.087719	314.998405	89
433.92MHz	433.333333	433.517241	433.425287	92
868MHz	868.210526	868.400000	868.305263	95
915MHz	915.151515	915.354839	915.253177	102

Note: for the frequencies used in ASK test mode, refer to the section “ASK Test Mode”.

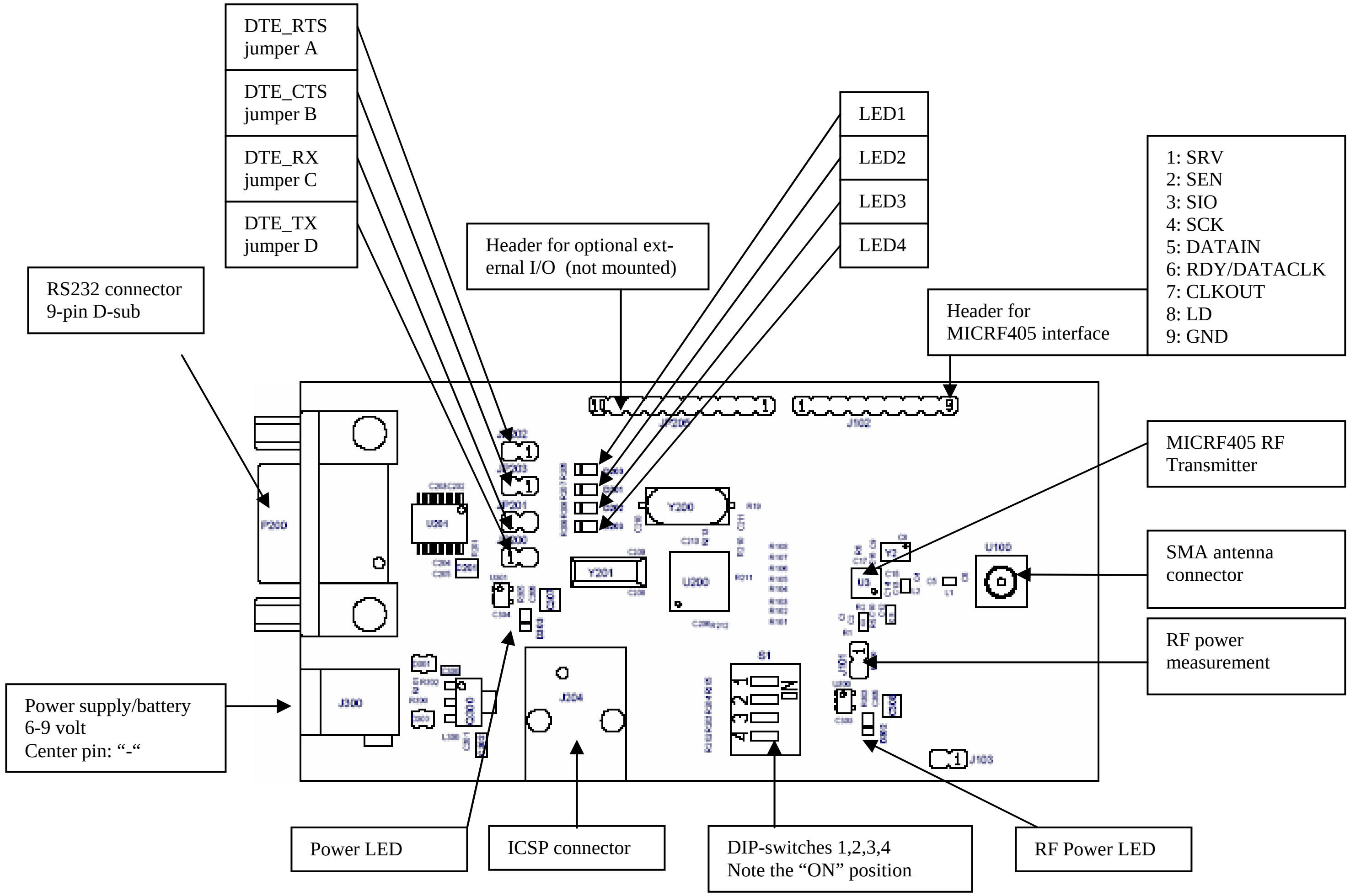
- Automatic hopping
  - In ”Link Test Mode”: Development board jump to a new frequency channel approx 10 times/sec. Channels are used randomly
- Flash-based micro controller (PIC18LF4320) for easy firmware upgrade/testing. Plug directly into ICD2 from Microchip.
- Antenna: External antenna
- User interface: Asynchronous serial interface: RS232-level or logic level I/O pins (9600-8-N-1)
- 4 DIP switches to select mode of operation
- 1 LED to indicate power on
- 1 LED to indicate RF powered
- 4 LEDs to indicate status or control information
- Possible to use 5 external I/O pins (for user FW development)
- Possible to monitor the interface between RF chip and micro controller via header pins
- Possible to measure RF-part power consumption

Power supply:

- 6 - 9 volt DC
- Apply “ - “ to the centre pin (note!)

External antenna connector:
Type: SMA

2. Development Board Inputs/Outputs



2.1.Summary of DIP-Switch Settings

To select mode of operation, bring DIP-switches ON or OFF according to the table below.

The modes of operation (described in detail in the following sections) are:

- “RF Test Modes”: Enter TX mode, TX a carrier, TX 1010… or a random pattern, enter PC-configurable mode or bypass (tristate) micro controller for user-operation of the RF part, enter ASK test mode
- “Link Test Mode”: Use a development board to transmit a fixed packet
- “Simple Byte Transfer Mode”: Construct a packet based on user input (from e.g. a PC) and transmit it

The 4 DIP-switches (labelled 1 2 3 4) are placed in a single component. In addition “ON” is written on the component. In the table below, “1” means “ON”, “0” means “OFF”.

DIP1	DIP2	DIP3	DIP4	Mode of operation
0	0	0	0	Simple byte transfer mode, type 1
0	0	0	1	Simple byte transfer mode, type 2
0	0	1	0	not used
0	0	1	1	not used
0	1	0	0	RF Test, Tristate all uC I/Os
0	1	0	1	RF Test, Transmit a random pattern
0	1	1	0	RF Test, ASK Test Mode
0	1	1	1	not used
1	0	0	0	Link Test, 5 bytes payload, type 1
1	0	0	1	Link Test, 5 bytes payload, type 2
1	0	1	0	Link Test, 26 bytes payload, type 1
1	0	1	1	Link Test, 26 bytes payload, type 2
1	1	0	0	not used
1	1	0	1	RF Test, Transmit 1010 ...
1	1	1	0	RF Test, Transmit carrier
1	1	1	1	RF Test, PC-mode

"Type 1": (this refers to the format of the packets transmitted)
"Framelength" = length of "Framelength", "Payload" and "CRC".
CRC (2 bytes) is calc'ed by firmware on "Framelength" and "Payload" fields
Compatible with MICRF6x0 Link Test/Simple byte transfer mode

"Type 2": (this refers to the format of the packets transmitted)
"Framelength" = length of "Payload" and "CRC"
CRC (0, 1 or 2 bytes) is calc'ed on-chip (by MICRF405) on "Payload" field

"Packet Engine" data interface used in "Simple byte transfer mode" and "Link Test"
"Bitwise" data interface used in "Transmit 1010 ..." and "Transmit random"

3. Getting Started

Before power-up of the development board:

- Get familiar with the inputs/outputs (refer to "Development Board Inputs/Outputs")
- Select mode of operation via DIP-switches
- If Simple Byte Transfer Mode is selected: Select interface to user data. Insert the 4 jumpers "DTE_RTS", "DTE_CTS", "DTE_RX", "DTE_TX" to select RS232 interface. Remove the jumpers to select "logic level" interface (connect to e.g. another micro controller).

As a first step, it is suggested to set the development board in transmit 1010… mode (DIP1, 2 and 4 ON). Use an oscilloscope, a spectrum analyzer, a MICRF6x0 dev system or your own receiver board to monitor/receive the transmitted signals.

Enter PC-mode (all DIPs ON) and use the PC-program (RF TestBench) to change the frequency, output power and bitrate.

If you are using a development system for the 433.92MHz, 868MHz or 915MHz band, and you have the corresponding MICRF6x0 development system available, you can try the Link Test Mode (only DIP1 ON). On the MICRF6x0 board, make sure DIP1 and DIP4 are ON. This will be the "Slave". Try to increase/decrease the distance between the boards, and observe LED1 on the MICRF6x0 board. LED1 (MICRF6x0 board) will be on as long as the link is OK.

Set the board in Simple Byte Transfer Mode (all DIPs OFF). Connect it to a PC running HyperTerminal. Send characters or text files via the board. Note: No ARQ is used – number of "data packets" getting through depends on link quality. Make sure the cable is 1:1, and that RTS, CTS, TX, RX and GND are used. Make sure the data format is 9600-8-N-1 and hardware handshake is used. Also make sure the jumpers for RS232-use are in place.

4. RF Test Modes

In the RF Test Modes, only 1 frequency is used. If not changed via the PC program[2], the frequency is:

- 315MHz band: 315.00MHz
- 433.92MHz band: 433.43MHz
- 868MHz band: 868.31MHz
- 915MHz band: 915.25MHz

Note: for the frequencies used in ASK test mode, refer to the section "ASK Test Mode".

DIP-switch setting ("1" means "ON", "0" means "OFF"):

Combin. #	DIP1	DIP2	DIP3	DIP4	Text
1	1	1	0	0	Not used in this firmware version
2	1	1	0	1	Transmit 1010 …
3	1	1	1	0	Transmit carrier
4	1	1	1	1	Enable configuration via PC
5	0	1	0	0	Bypass micro controller
6	0	1	0	1	Transmit a random pattern
7	0	1	1	0	ASK Test Mode

Use of LEDs:
LED1, LED2, LED3, LED4: Not used in RF Test Modes.

<u>Combination #1, Not used</u>

<u>Combination #2, Transmit 1010… :</u>

The board will enter transmit mode and transmit a 1010… pattern. Combination #2 can be used to test parameters like deviation and transmit spectrum. Use a MICRF6x0 development board or your own rx-board to receive the signals, or observe the spectrum on a spectrum analyzer.

<u>Combination #3, Transmit carrier:</u>

The board will enter transmit mode and transmit a carrier, that is: no modulation is applied. This can be used to check the frequency spectrum, the output power, and the current consumption. Note that the "TX0" frequency is used for the MICRF405.

[2] Refer to chapter 9 and chapter 4 ("Combination #4").

Combination #4, Enable configuration via PC:

This setting is also referred to as "PC mode".

Refer to the chapter called "PC-Program" (chapter 9) for details on the PC program.

Make sure the 4 jumpers "DTE_RTS", "DTE_CTS", "DTE_RX" and "DTE_TX" are in place.

If the power-LEDs are off: Make sure the board is powered-on without the RS232 cable connected, and then connect the RS232 cable.

Entering "PC mode": Before any command is given from the PC, the RF chip will stay in the mode selected before "PC mode" was selected (transmit/standby etc).

While in "PC mode": When a control word is sent from the PC to the board, the board will store the entered word in EEPROM and program the RF chip with it. The complete control word is written into the MICRF405 in a single operation.

It is possible to transfer a control word from any of the 3 "Transfer" buttons (PC program buttons, refer to the RF TestBench user guide):

- Quick Setup or
- Complete Setup or
- Control Word

When leaving "PC mode": The board will use the default control word already programmed into the FLASH program memory, or it will use the control word entered from the PC program and stored in the EEPROM. Which one to select (the source of the control word) is selected in the PC program (select→Tools →Development Board Commands)[3].

From the PC program, try e.g. to change the output power level (PA setting) and observe the effect on spectrum, power consumption and link range.

Note: If using the PC program to read out the contents of the MICRF405 registers: Make sure to have no external load on the SIO and SCK pins, or else you might get some unwanted results.

[3] The "EEPROM control word" can be used in "RF Test Modes", "Link Test Mode" and "Simple Byte Transfer Mode". If the "EEPROM control word" is used in "Link Test Mode": No frequency jumping is done – only the user-entered control word stored in EEPROM will be used.

Combination #5, Bypass Micro Controller:

Using this combination, it is possible to use an external micro controller to control the RF part. Connect to the interface pins as described in “Development Board Inputs/Outputs”. The interface pins are connected to the “MCU” side of the MCU-RF connection.

All I/O pins of the on-board micro are tristated. None of the MCU’s IOs are set as output at power-on, if this combination is selected. That is: The User has full control, without the MCU interacting at all (not programming the RF chip etc). The DIPs are tested before the IOs are initiated.

Note: When using this mode, first make sure DIPs are set correctly, then apply power to the board.

Combination #6, Transmit a Random Pattern:

The board will enter transmit mode and transmit a random, Manchester-coded pattern (i.e. without a DC component). Combination #6 can be used to test parameters like deviation and transmit spectrum.

Combination #7, ASK Test Mode:

In this test mode, the board will transmit packets with a defined format. ASK modulation is used. The ASK modulation type is OOK (on-off-keying), and the bit rate is 1200bps (1202bps). The board will transmit a new packet every 100msec approx, and enter power-down between transmissions.

For every frequency band, a single frequency is used:

- 915.000MHz,
- 868.308MHz,
- 434.000MHz,
- 315.000MHz

The packets have this format:

- 3 bytes Preamble (1010…)
- 3 bytes Sync (11001100…)
- 1 byte Length (length of payload and CRC fields = 7)
- 5 bytes Payload (5 printable ascii characters)
- 2 bytes CRC (calculated using the Payload field as input)

The purpose of this mode is to demonstrate the ASK feature. If you have an ASK receiver, you can search for packets with this format and e.g. bring a LED ON if you receive a packet. This can be used for range/environment testing.

Suggestions for RF Testing:

1) Set the development board to transmit a carrier. Use a spectrum analyser to observe the frequency spectrum
2) Repeat for transmit 1010…
3) Use a MICRF6x0 dev board or your own board as receiver, and use the MICRF405 board in “transmit 1010…” mode. Use an oscilloscope to observe the tx’ed and rx’ed data (Data I/O). Set tx’ed data as the trigger source.

5. Packet format in "Link Test" and "Simple Byte Transfer" Modes

In "Link Test" and "Simple Byte transfer mode", the development board will construct a "packet" and transmit it. The format of the packets is equal in both modes, and described in the figure below.

Preamble	Sync	Framelength	Payload	CRC

Preamble: 1-4 bytes, always a 1010… pattern. Used as a "training sequence" by the receiver; the receiver can use this pattern to adjust it's sampling clock for the incoming data

Sync: 1-4 bytes. This field is used to identify "Start of frame". It can hold a fixed sync-pattern, an ID or an address.

Framelength: 1 byte. Refer to description of "Packet type 1" and "Packet type 2" below.

Payload: n bytes. This is the "message" or the "useful data".

CRC: 0-2 bytes. Checksum. Refer to description of "Packet type 1" and "Packet type 2" below.

5.1.Packet format, Type 1 and Type 2

Two different format types are implemented. The difference is how the "Framelength" and "CRC" fields are used.

For "Type 1", "Framelength" holds the length of the "Framelength", "Payload" and "CRC" fields, and CRC is calc'ed on the "Framelength" and "Payload" fields. This is compatible with the MICRF6x0 development system.

For "Type 2", "Framelength" holds the length of the "Payload" and "CRC" fields, and CRC is calc'ed on the "Payload" field (this is the MICRF405 "Packet Engine" format).

Framelength, Type 1 (grey fields are included in the length):

Preamble	Sync	Framelength (grey)	Payload (grey)	CRC (grey)

CRC, Type 1 (grey fields are included in CRC calculations):

Preamble	Sync	Framelength (grey)	Payload (grey)	CRC

Framelength, Type 2 (grey fields are included in the length):

Preamble	Sync	Framelength	Payload (grey)	CRC (grey)

CRC, Type 2 (grey fields are included in CRC calculations):

Preamble	Sync	Framelength	Payload (grey)	CRC

Packet format, Type 1

"Framelength" = length of "Framelength", "Payload" and "CRC" fields.
CRC is calc'ed on the "Framelength" and "Payload" fields by the firmware.

The "packet engine" is used, but this format violates the packet-engine format. In the packet-engine, "Framelength" is "not counting itself". To overcome this, an additional dummy-byte is sent, and a 16-bit CRC is calculated by the firmware.

If, from the PC program, the User selects to "Use the control word from EEPROM", several fields are in any case overruled by the firmware when "type 1"is used. These are[4]:

- Sync_en = 1
- Load_en = 1

- MOD_LDc_en = 0
- PA_FEc_en = 1
- PA_LDc_en = 1
- LD_en = 1

- BIT_IO_en = 0
- Manchester_en = 0
- Sel_CRC = 0 (making CRC in MCU)
- SyncID_Len = 2 (txing 3 sync bytes)
- Pream_Len = 2 (txing 3 preamble bytes)

- SyncIDi (i=2,1,0) = 0xCC (11001100...)

Note that this format is compatible with the format used in the MICRF6x0 development system.

In addition, it shows that the User is not restricted to the "packet engine format" when using the packet engine.

[4] Refer to the MICRF405 data sheet for a detailed description of these fields.

Packet format, Type 2

"Framelength" = length of "Payload" and "CRC" fields.
CRC is calc'ed on the "Payload" field (by the MICRF405).

The "packet engine" is used, and the packet-engine format is strictly followed.

Default field-values[5] in the packet engine are given below. This can be changed by the User (with some exceptions, see below).

- Sync_en = 1
- Load_en = 1

- MOD_LDc_en = 0
- PA_FEc_en = 1
- PA_LDc_en = 1
- LD_en = 1

- BIT_IO_en = 0
- Manchester_en = 0
- Sel_CRC = 3 (making 2 bytes CRC on-chip)
- SyncID_Len = 2 (txing 3 sync bytes)
- Pream_Len = 2 (txing 3 preamble bytes)

- SyncIDi (i=3,2,1,0) = 0xCC (11001100...)

The user can change:

- the number of preamble bytes
- the number of sync bytes
- the values of the sync bytes
- number of CRC bytes

If, from the PC program, the User selects to "Use the control word from EEPROM", several fields are in any case overruled by the firmware when "type 2"is used. These are:

- Sync_en = 1
- Load_en = 1
- BIT_IO_en = 0

[5] Refer to the MICRF405 data sheet for a detailed description of these fields.

6. Link Test Mode

Refer to chapter 5 for a description of “Type 1” and “Type 2” format.

DIP-switch setting (“1” means “ON”, “0” means “OFF”):

Combin. #	DIP1	DIP2	DIP3	DIP4	Text
1	1	0	0	0	5 bytes payload, Type 1 format, compatible with MICRF6x0
2	1	0	0	1	5 bytes payload, Type 2 format, not compatible with MICRF6x0
3	1	0	1	0	26 bytes payload, Type 1 format, compatible with MICRF6x0
4	1	0	1	1	26 bytes payload, Type 2 format, not compatible with MICRF6x0

Use of LEDs:
LED2, LED3, LED4: Not used in Link Test Mode
LED1: On while tx’ing a packet

In this mode of operation, the MICRF405 board is a “Master”. The “packet engine” in the MICRF405 chip is used.

If not overruled from the PC-program, all pre-programmed frequencies are used (refer to *“RF Test Modes”*, *“Enable configuration via PC”*. Automatic hopping between the frequencies is implemented.

If < 25 frequencies are pre-programmed: The frequency table still holds 25 entries. That is, several “frequency indexes” points to the same frequency (refer to “Introduction”.)

In this mode of operation, a “Message” is sent from the board. The message is build of 5 (or 26) printable ascii characters:

- First, a character ‘a’… ‘y’, indicating the frequency index for the frequency used (not the frequency number, but the index in a look-up table)
- 2 characters = “BC” (or 21 characters)
- ‘m’ (the message is sent from a master)
- Finally, carriage return (0x0D) is tx’ed as the last byte of the message (=the payload)

The following procedure is implemented for “Link Test”:

LOOP

  Enter transmit mode on frequency *n*

  Transmit “Message” and CRC checksum

  Enter power-down mode

  Wait for timer period (approx 100msec)

  Use “next frequency” (from a randomly ordered list) and repeat

END_LOOP

7. Interface in Simple Byte Transfer Mode

In “Simple Byte Transfer Mode”: Interface to the board in the following way.

Select interface:

- Insert the 4 jumpers (A, B, C, D) to select RS232 interface
- Remove the 4 jumpers (A, B, C, D) to select logic levels. Connect jumper pins directly to e.g. a micro controller

The board is treated as a DCE (data communications equipment).

The connected user is treated as a DTE (data terminal equipment).

That is, a DCE-DTE cable should be used. This cable should be 1:1, that is: Connect pin ***i*** on the DCE side to pin ***i*** on the DTE side. The following pins are used (referred to a 9-pin connector, names related to DTE):

Pin #	Name (DTE side)	Direction	
(both DTE and DCE)		DTE	DCE

CTS is an input to the DTE. It is used to control data flow from DTE to DCE. DCE brings CTS active to signal “DCE ready for bytes from DTE”. DCE brings CTS inactive to signal “DCE not ready for bytes from DTE”. Before DTE outputs bytes to DCE, the CTS line is tested. If CTS is active, DTE knows that DCE is ready to receive bytes, and DTE transfer the bytes on the TXD line.

Maximum number of bytes to transmit in one “data frame” is 64 bytes. The board will tell user to “stop enter bytes” by setting CTS inactive when the “bytes-from-user buffer” holds 64 bytes. Note: the board can buffer 2 additional bytes. Other bytes will be lost.

The bytes can be entered with random delay between them. As soon as a byte is entered, the board enters transmit mode and sends the presently entered bytes, while still buffering new bytes from user (note that the board does not wait until buffer is full or until user stops entering bytes).

8. Simple Byte Transfer Mode

Refer to chapter 5 for a description of “Type 1” and “Type 2” format.

DIP-switch setting (“1” means “ON”, “0” means “OFF”):

Combin. #	DIP1	DIP2	DIP3	DIP4	Text
1	0	0	0	0	Type 1 format, compatible with MICRF6x0
2	0	0	0	1	Type 2 format, not compatible with MICRF6x0

Note: There is no “Master” or “Slave” in this mode of operation.

Use of LEDs:
LED1, LED2, LED4: Not used in Simple Byte Transfer Mode
LED3: On while tx’ing a packet

Combination #1:
Refer to interface description in “Interface in Simple Byte Transfer Mode”.

- There is no difference between “master” and “slave” in this mode.
- Error detection is implemented (through CRC check)
- Only 1 frequency is used (no frequency hopping)
- Duplicate control or ARQ (packets being acknowledged or re-transmitted) are not implemented in this mode

Data flow from user (“User A”) to development board (“Board A”), then via RF:
1) If Board A is ready to get bytes (CTS is active): User A enters bytes into Board A
2) Bytes are buffered in Board A. When 1 or more bytes are entered, Board A constructs a frame (it adds preamble, sync, length and CRC to the presently entered bytes). Board A then transmits the frame. If >= 64 bytes in buffer, then user is told to stop entering bytes (CTS goes inactive).

Combination #2:
Refer to “Combination #1” above. The main difference is the packet format (refer to chapter 5).

In addition to the different packet format, the following should be noted:
When the packet engine is used and CRC is generated on-chip, then the payload must be >1 byte. Because of this, a frame is transmitted when >1 byte is entered. Observe the consequence: The last entered user-byte may not be transmitted until user enters another byte.

<u>Example, how to use Simple Byte Transfer Mode:</u>

User A (connected to board A) wants to transfer 6 bytes (= “Hello!”). User B (connected to a receive board) receives the bytes.

User A:

- Test if CTS at board A is active. If CTS is active, the board is ready to accept bytes from the user.
- Transfer “Hello!” into the board, using 9600-8-N-1. Transfer lsb of every byte first (after the start-bit).

Board A:

- Read bytes from User A
- Format a packet to transmit 1, 2, 3, 4, 5 or 6 bytes of “Hello!”
- Enter transmit mode
- Transmit the packet
- If more bytes entered by user: Format a new packet and transmit it

Receiver board

- Receive a packet
- Un-pack the bytes from the packet
- Test that the number of bytes is a legal number of bytes (1-64)
- Test that CRC is OK
- Test if RTS is active. If RTS is active, the user is ready to accept bytes from the board.
- Transfer the bytes to User B. Transfer lsb of every byte first.

User B:

Read bytes from board

Note:
Since no addressing is used, other users (let’s say User C, User D and User E) will receive the 6 bytes as well. If the boards are used in a network, the message has to include some address information (and the user’s protocol has to handle it).

9. PC program "RF TestBench"

The PC program is referred to as "RF TestBench".

RF TestBench can be used with or without the development board. It can be used to calculate fields in the control word to enter into MICRF405. Examples: Find settings for a specific bit rate, or get the frequency dividers for a number of frequencies.

"RF TestBench" should be self-explaining, refer to the user guide for the PC program as well.

Installation and running are straightforward, simply double-click "setup.exe" and follow the on-screen instructions.

If using RF TestBench together with a development board:

Make sure the DIP-switches are set like this: (All ON)

Combin. #	**DIP1**	**DIP2**	**DIP3**	**DIP4**	**Text**
1	1	1	1	1	

Using RF TestBench:

- Connect the development board to a PC via a cable:
    - 1:1 RS232 cable
    - Make sure RTS, CTS, TX, RX and GND are included in the cable (pins 2, 3, 5, 7, 8)
    - Note: Power-on the board before connecting the cable to the board if the power-LEDs do not get on

- Power on the board
- Start RF TestBench by double-clicking "RF TestBench"
- Read the text in the welcome-window
- From the main window, select "Dev Board Connection" (COM1 or COM2)
- From the main window, select "RF Device". Select MICRF405. Then select the appropriate frequency band.
- From the main window, use the "Quick Setup" or "Complete Setup" or "Control Word" sections:
    - Use "Quick Setup" if you want the program to calculate parameters based on basic parameters like xtal frequency, RF frequency and bit rate. Enter values and press the "Calc!" button in the Quick Setup section.
    - Use "Complete Setup" to enter the control word fields manually. Press the "Calc!" button in the Complete Section to see resulting frequencies etc.
    - Use the "Control Word" section to change the control word on a register-basis.

- To transfer a control word to the development board: Enter/change the fields and press "Transfer!" (in the appropriate section). The entered values are stored in the micro's EEPROM.

- Observe the "Information" field. If "Success!" is not displayed, please check connections/power and try again.

In the following, some suggestions are made for the user to get familiar with "RF TestBench".

- Experiment with e.g. power levels. Suggestion: Change power level, press "Transfer!" and then give a "Transmit 1010…" command (refer to next paragraph). Observe the result on a spectrum analyser, or use a receiver-board and observe change in range (distance between transmitter and receiver).

- The "Transmit 1010…" command is found here: →Tools →Commands to Dev Board …

- It is possible to use the firmware pre-programmed settings (stored in the FLASH program memory) or the settings stored in EEPROM for the other modes of operation as well (that is: not only in "PC-mode")[6]. Select "FLASH" or "EEPROM" via a command in RF TestBench (→Tools →Commands to Dev Board …). If EEPROM settings are used in Link Test Mode, no frequency hopping will be done – only the frequency and control bits stored in EEPROM will be used.

- If "EEPROM settings" is selected, the board can be disconnected from the PC, and the different modes of operation can be run- and now the settings stored in EEPROM are used. To use the pre-programmed settings again: Enter "PC-Mode" (DIP-setting described above) and give command from RF TestBench: Instruct the board to use the FLASH memory as the source (where to get the control word from).

- Other possibilities are (→Tools →Development Board Commands):
- Read out the firmware version number (the firmware stored in flash program memory of the micro controller)
- Restart micro controller (MCU) program (like a power-on reset). Note: This does not reset the MICRF405 transmitter chip
- Reset EEPROM control word - settings to "default" (= pre-programmed settings from firmware)
- Read out the present EEPROM control word
- Read out the present MICRF405 register values

[6] In PC-mode, the settings entered by the User (and stored in EEPROM) are always used.

10. Firmware change/upgrade

The development boards are equipped with a socket for ICSP (in-circuit serial programming).

Through ICSP, it is possible to download new firmware into the micro controller.

The download feature is made for use with MPLAB ICD2 from Microchip. Connect the development board directly to the ICD2 using the cable from the ICD2 kit.

Via ICD2, it's possible to step through and debug firmware code as well. That is: Make your own program, download it, debug it and run it!

MPLAB IDE (integrated development environment) is available for free from Microchip's homepage. (C-compiler must be bought[7], but you do not need it for firmware upgrading, that is, if you have a new .hex file to download).

How to upgrade firmware ("xxx.hex", xxx=firmware name) (skip reading this if you are familiar with ICD2):

- Connect ICD2 to your PC and to power (please refer to ICD2 user manual)
- Connect ICD2 and development board via the "standard ICD2 cable"
- Start MPLAB IDE [8] (menu selections below refer to the MPLAB IDE program)
- Select Configure → Select Device… → "PIC18F4320" → OK
- File → Import… → "xxx.hex" → Open
- Programmer → Select Programmer → MPLAB ICD2
- Programmer → Settings → Power Tab : Make sure "Power target circuit from MPLAB ICD2" is checked
- Programmer → Settings → Program Tab: Make sure "Allow ICD 2 to select memories and ranges" is checked → OK
- Identify and press the "Reset and connect to ICD" button in the main menu field.
- If the "Target not found" warning pops up, repeat steps above.
- Identify and press the "Program target device" button in the main menu field
- Wait for programming to finish (refer to the "Output" window) and remove the development board from ICD2.
- Optional: Confirm firmware version via RF TestBench

[7] A demo version is available for free.
[8] Assumes correct drivers for MPLAB ICD2 are installed (when connected to the USB port for the first time, your PC should detect the new device and guide you through the installation, note: 2 drivers will be installed).

11. Changes in this Firmware Version

V2 2006 03 03 PKB

Included ASK modulation test mode
By default, MOD_LDc is not used for the packet engine
The SEN line is kept high a minimum time (> 1 fc-period)
RFPRG_Wait_Lock() procedure updated
RFPRG_Enter_Tx() procedure updated
ClkOut_en default value = 0
In Init_Main: Always reset USART-registers (user input will be ignored in RF test modes and Link test)
When tx1010... or a random pattern (uing bit-banging): Change DATAIN asap after a raising edge of DATACLK (MICRF405 samples DATAIN at raising edge of DATACLK, and then it’s OK to change it)
Make sure that the INT0IF flag is cleared when starting to tx1010... or a random pattern
Testing RTS active ("low") before giving data out to user
Changed/updated comments

V1 2006 02 06 PKB

Initial release

12. MICRF405 Development System: Firmware Description

The development board has a micro controller unit (MCU) on-board. The MCU is a PIC18LF4320 from Microchip, which is in-circuit re-programmable (this process is referred to as "flashing the MCU").

The program flashed into the MCU is described below. This program is also referred to as "firmware" (FW).

Note: All FW is free of charge. The intention of the FW is to provide examples/suggestions to the user. No guarantee is implied as to the suitableness of the firmware in a given application. All code must be tested in the application at hand.

12.1. Project

The source, header and link files are put together in a *project*. The C programming language is used (with some exceptions, refer to file descriptions below).

The FW can be made to operate in the 315, 433, 868 or 915 MHz bands. The frequency band is selected in a header file via a #define" statement ("p18def.h"). The necessary files for all frequency-bands are included in the project. In "pa8def.h", include 1 and only 1 of the following defines:

```
#define MICRF405_315
#define MICRF405_433
#define MICRF405_868
#define MICRF405_915
```

12.2. Tools

"What do you want to do?" The tools you need depend on your answer to this question. Below, some suggestions are given.

If you want to

- Open up the source files to get hints/ideas to your own program:
  - Any text editor can be used

- Control the development-board MICRF405 chip by your own, external MCU:
  - Make sure the DIP switches are set to "Tristate on-board MCU mode" and connect to the development board header pins, then power-on the development board.

- Flash the on-board MCU with a new .hex file:
  - Install MPLAB IDE (free of charge from microchip.com)
  - Get and install a MPLAB ICD 2 (in-circuit debugger/programmer). This is a "box" between the PC running MPLAB IDE and the development board.

    - Other “flash utilities” exist as well

- Make your own program, based on the assembly language:
    - MPLAB IDE: This includes an “assembler”
    - MPLAB ICD2: Use this to flash the MCU

- Make your own program, based on the C language:
    - MPLAB IDE and ICD2 (as above)
    - C-compiler. A “demo-version” of “MPLAB C18 compiler” can be downloaded for free from microchip.com.

Notes on Tools:
You may get errors/warnings/messages if you try to compile the included FW. This may happen if a new version of the MPLAB and/or the C-compiler is introduced. It is suggested to always use the latest versions, but these may be different from the versions used when the FW was released. To correct errors, and to test if warnings/messages require special attention: Please refer to the documentation from Microchip.

12.3. File Structure

All the project files (firmware) are typically collected in a .zip file. After un-zipping the files, you will see “a lot” of files. Several types are used. These are:

.asm	Source files based on assembly language
.c	Source files based on the C-language
.h	Header files, includes definitions, prototype declarations and variables
.hex	Main output file, can be flashed into the MCU
.lkr	Linker file
.mcp	Project file
.mcw	Workspace file, contains 1 (and only 1) project

Other types, generated when compiling the project:
.cod, .coff, .err, .lst, .map, mcs, .o (these are not described in this document).

In MPLAB IDE, go to Project -> Open … and select the .mcp file.

In addition to the type of file, you should notice the naming convention used. Every file name is started (or made of) a 3-5 character abbreviation corresponding to the type of procedures in the file. For example, the “gen.c” file is a collection of general procedures and “gen.h” is the corresponding definitions, prototype declarations and variables. This character abbreviation is also used in the procedures and variables. Example: If you want to take a look at the “GEN_Init_Ports()” procedure, you should open the gen.c file.

12.4. #defines in Source Files

In all source files, some definitions are made before the code is started.

In all .c – files, the following definition is included:

- #define C_FILE

In all .asm – files, the following definition is included:

- #define ASM_FILE

The “C_FILE” or “ASM_FILE” definition is used to include the correct header file (standard Microchip definitions of registers and bits).

In addition, a #define is included to identify the file name. Example: In “gen.c”, the following is included:

- #define GEN_FILE

This definition is tested in the header-files. If the definition is made, then procedure prototypes and variables are declared in the header file. If not def’ed, then procedures and variables are included as an “extern” type.

Example: “gen.h” can be #included in all source files; procedures/variables will be declared only 1 time (when included in the “gen.c” file).

12.5. Source File Description

Below, the source files and header files are described.

Refer to the flowcharts of the main procedures as well.

The source files typically include several header files. The “include-tree” for main.c is given in the figure below.

In particular, the following header files are included in several source file:

- p18def.h
  - Here, the frequency band is #def’ed
  - Other, general def’s are made as well

- p18xxxx.h
  - Here, the correct header file (standard definitions of registers and flags) is included. The “c” header file or the “asm” header file for the selected micro controller is included. Note: p18f4320.h (for .c files) and p18f4320.inc (for .asm files) are files made by Microchip, they are typically located where you have installed MPLAB.

- c_subst.h

- Here, some practical macro definitions are made, like the type definition “uint8” for “unsigned char”

- io_xxx.h
    - Here, the correct IO definitions are included. If you make your own program with other IOs, simply replace the #included file in io_xxx.h (only done at this single place, not in every file that uses the IOs).

```
- main.c
  ├── p18def.h
  ├── - p18xxxx.h
  │     ├── p18F4320.h
  │     └── p18F4320.inc
  │
  ├── c_subst.h
  ├── rfpck.h
  ├── - rfprg_xxx.h
  │     ├── p18def.h
  │     ├── rfprg_405_315.h
  │     ├── rfprg_405_433.h
  │     ├── rfprg_405_868.h
  │     └── rfprg_405_915.h
  │
  ├── gen.h
  ├── - io_xxx.h
  │     └── io_dev405.h
  │
  ├── usart.h
  ├── eep.h
  ├── crc.h
  └── cmn_defs.h
```

<u>Overview of source files:</u>

- 405asm.asm
- config.asm
- crc.c
- eep.c
- eepinit.asm
- gen.c
- main.c
- rfpck.c
- rfprg.c
- usart.c

Name:
    405asm.asm
Short description:
    Procedures for tx'ing 1010 and a random pattern using "bit-banging"
Header file:
    -
Typical procedures:
    Toggle_Data_Out
    Random_Data_Out
Notes:
    This is an .asm file. Assembly code is selected to maximize efficiency; tx'ing bit-by-bit up to 200kbps, while at the same time testing DIP switches and user input from USART. At 200kbps, the number of instruction cycles/bit is "small" (13)[9]. At bit rates < 20kbps, a .c file can easily be made, but the procedures are designed for max bitrates (note that the dev boards, without hw changes, are made for bitrates up to 20kbps only).

Name:
    config.asm
Short description:
    Setting up micro controller configuration bits.
Header file:
    -
Typical procedures:
    None
Notes:
    This is, and should be, an .asm file

[9] For the selected MCU with the selected xtal.

Name:
crc.c
Short description:
CRC (cyclic redundancy check) calculations
Header file:
"crc.h"
Typical procedures:
CRC_Byte(void)
Notes:
CRC calculations can be made by the “packet engine” in MICRF405 as well. However, if the user does not want to follow the frame structure of the packet engine, but still wants to use CRC, the user must make the CRC in firmware.

Name:
eep.c
Short description:
EEPROM procedures
Header file:
"eep.h"
Typical procedures:
uint8 EEP_Read_EEprom(uint8 ee_address)
void EEP_Write_EEprom(uint8 ee_address, uint8 ee_data)
Notes:

Name:
eepinit.asm
Short description:
Init some parameters stored in EEPROM
Header file:
-
Typical procedures:
None
Notes:
This is, and should be, an .asm file. When the program is compiled and then flashed into the MCU, some EEPROM values are set to their default values.

Name:
    gen.c
Short description:
    General procedures for use in all types of applications
Header file:
    "gen.h"
Typical procedures:
    GEN_Enable_Int(void)
    GEN_Init_Ports(void)
Notes:

Name:
    main.c
Short description:
    Main program, including initial set-up and interrupt vectors
Header file:
    -
Typical procedures:
    Main(void)
Notes:
    Includes all files to make the main program work

Name:
    rfpck.c
Short description:
    RF-chip procedures for tx'ing "packets" with a defined format
Header file:
    "rfpck.h”
Typical procedures:
    RFPCK_Tx_Packet(void)
Notes:

Name:
    rfprg.c
Short description:
    RF-chip procedures for programming RF chip
Header file:
    "rfprg.h”
Typical procedures:
    RFPRG_Enter_Tx(void)
Notes:

Name:

usart.c

Short description:

USART interface procedures, including handshaking

Header file:

"usart.h"

Typical procedures:

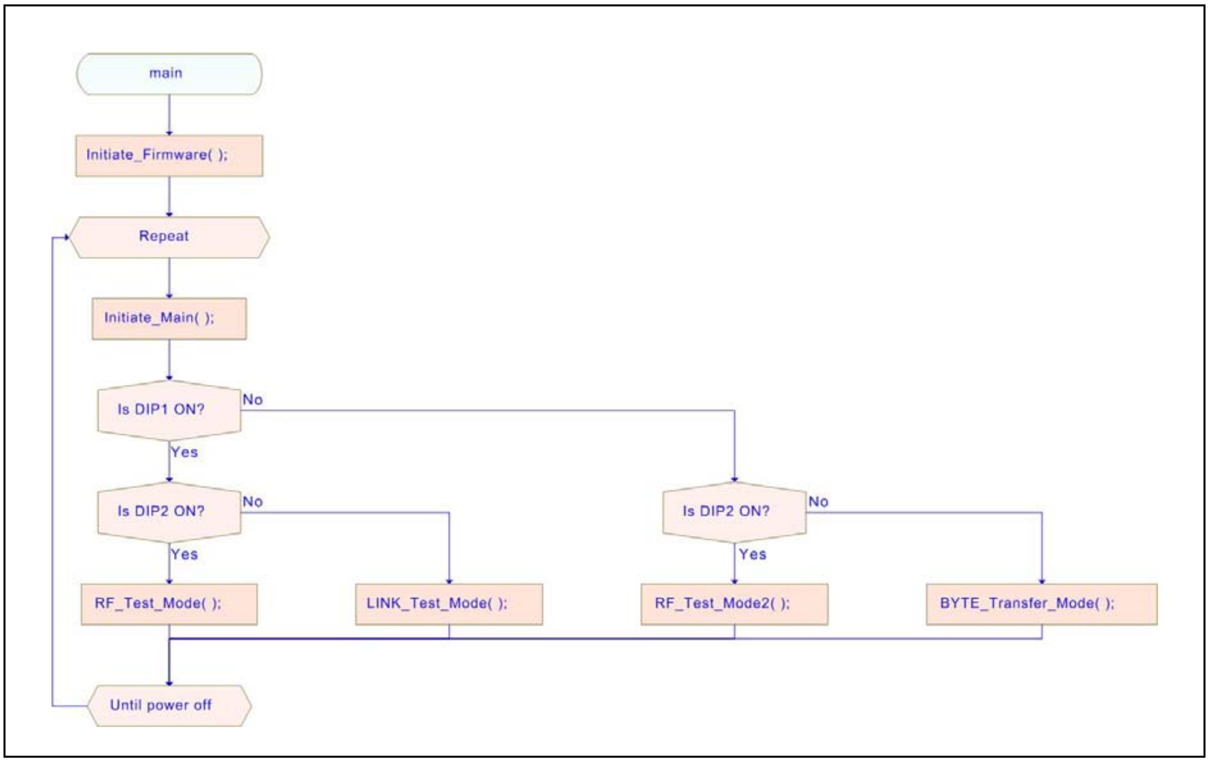
USART_Output_Byte(uint8 usart_byte)
USART_Init(void)
USART_Enable_Input_From_DTE(void)

Notes:

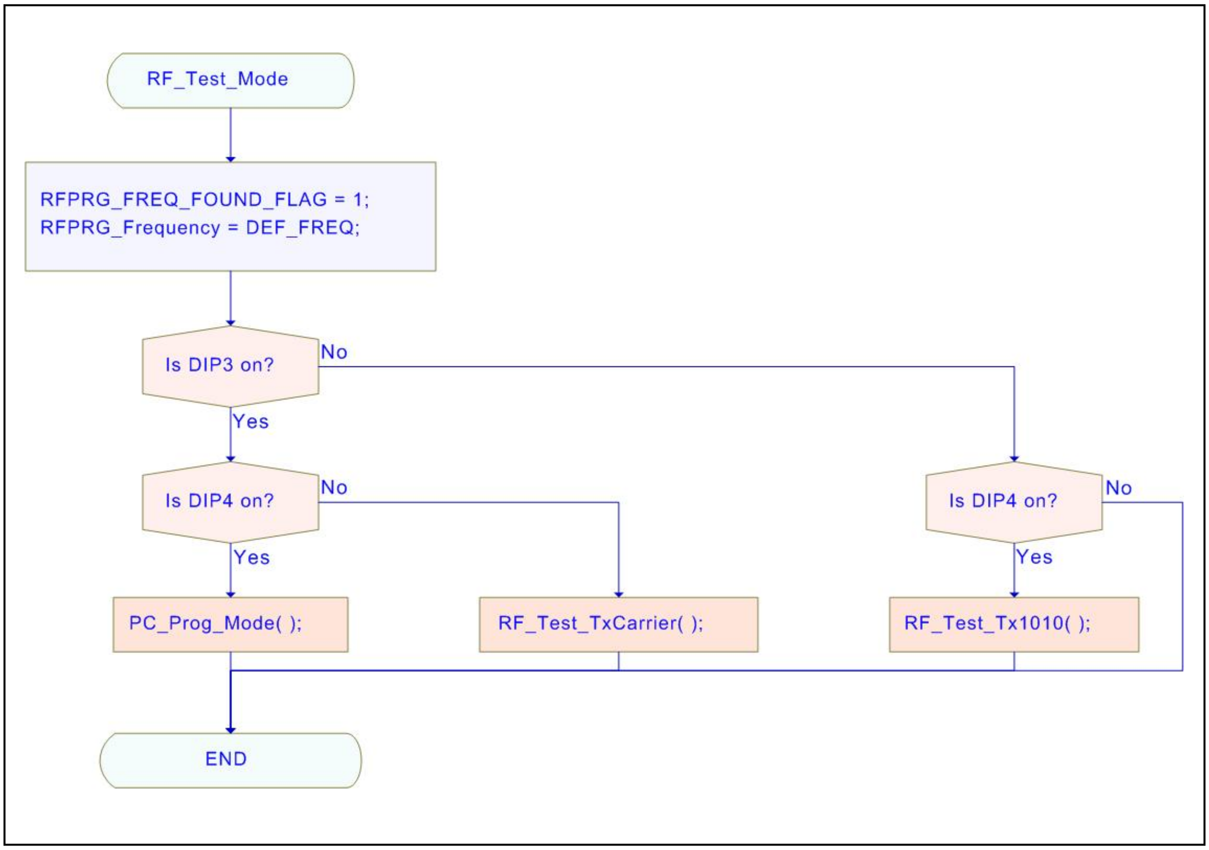
"USART" = Universal synchronous asynchronous receiver transmitter", an on-board micro-controller module made for serial communication via e.g. RS232

12.6. Flow Charts

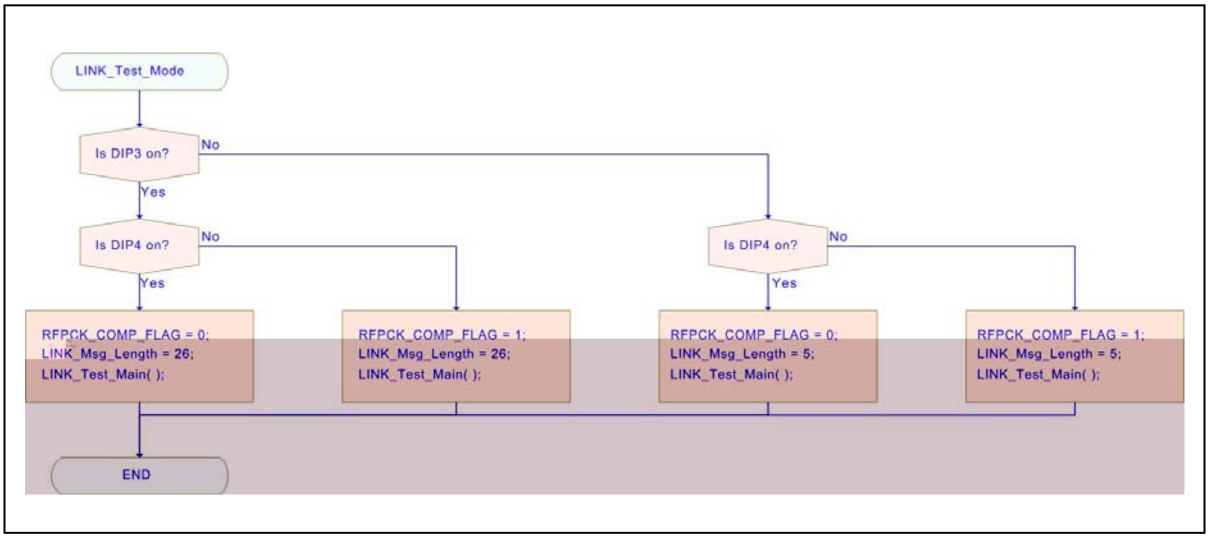
Below, flow charts for selected procedures are given. These should give the reader an overview; still, the interested reader is encouraged to look at the source code as well.



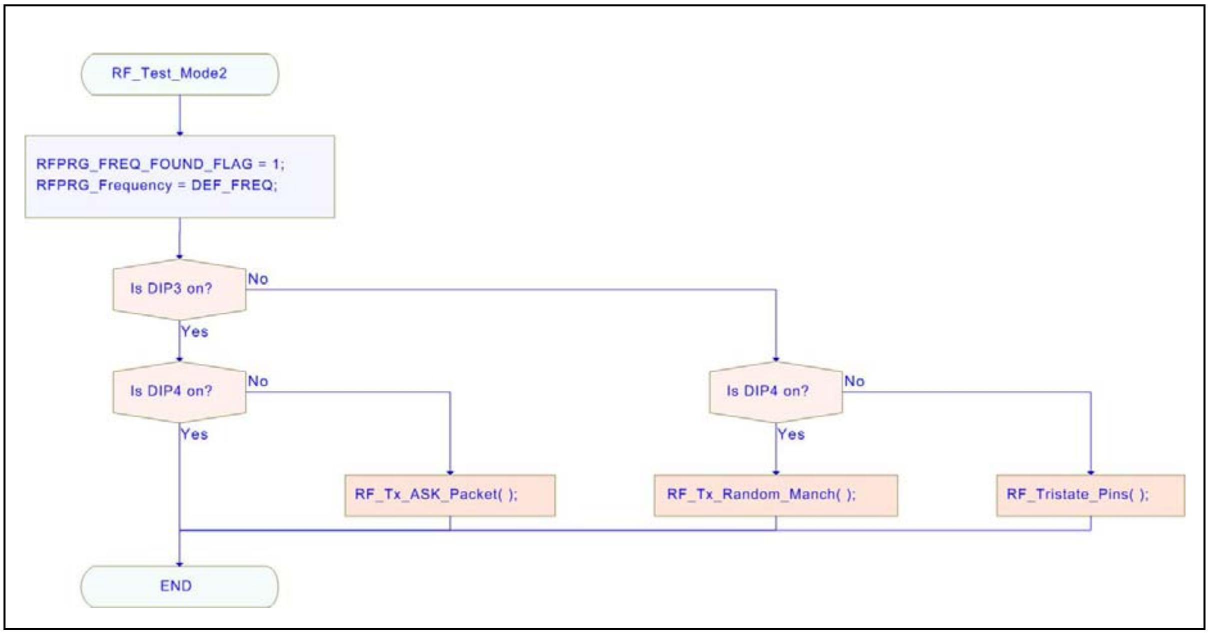
Flow Chart 1: Main program



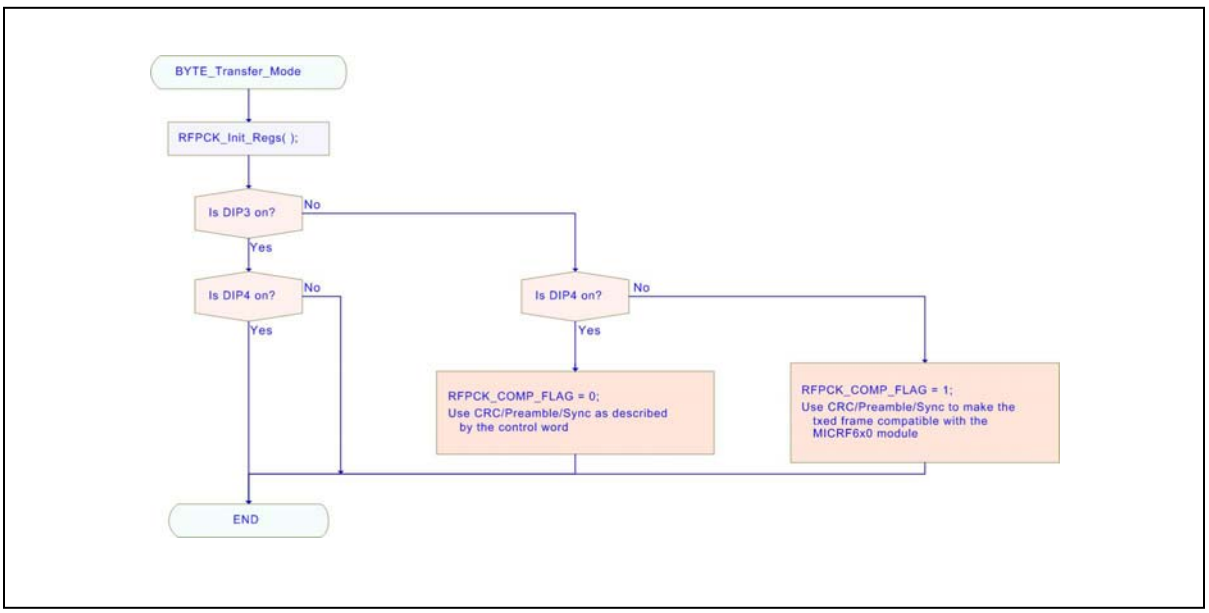
Flow Chart 2: RF_Test_Mode



Flow Chart 3: LINK_Test_Mode



Flow Chart 4: RF_Test_Mode2



Flow Chart 5: BYTE_Transfer_Mode

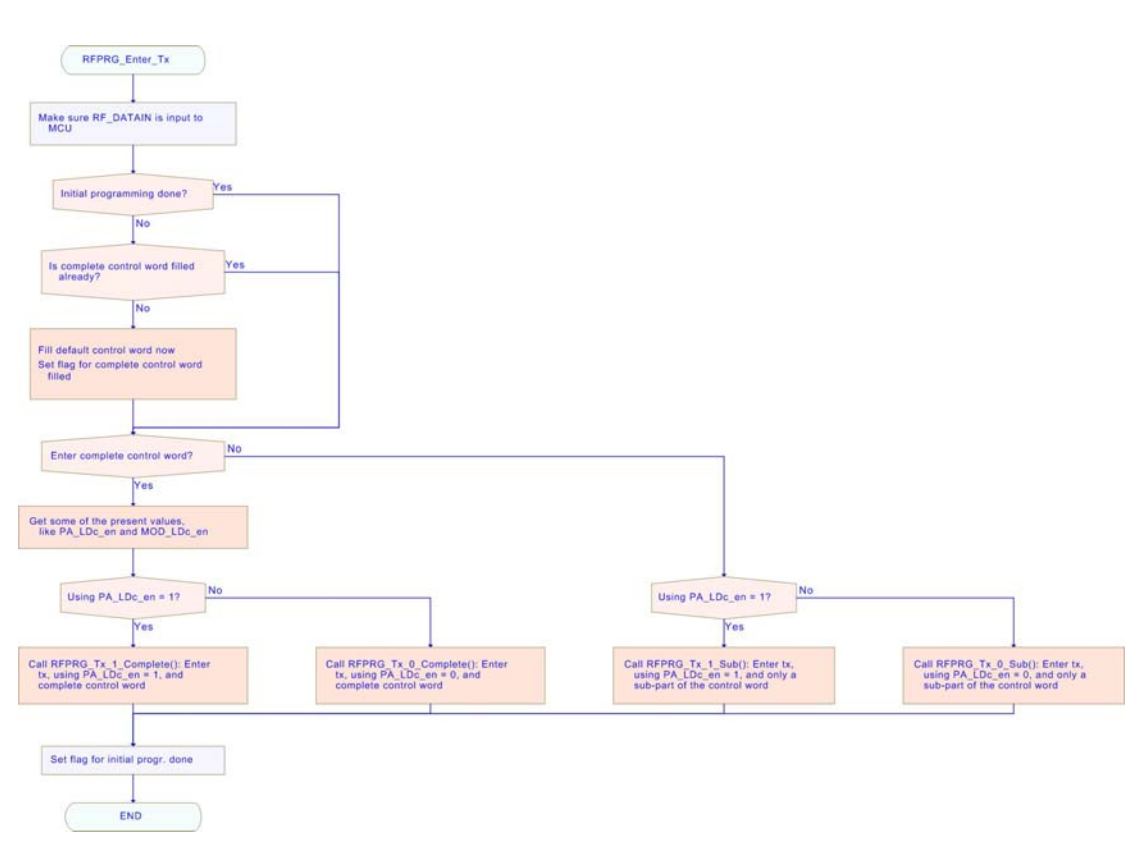
Enter_Tx procedure:

Below, the Enter_Tx procedure and some selected sub-procedures are shown.

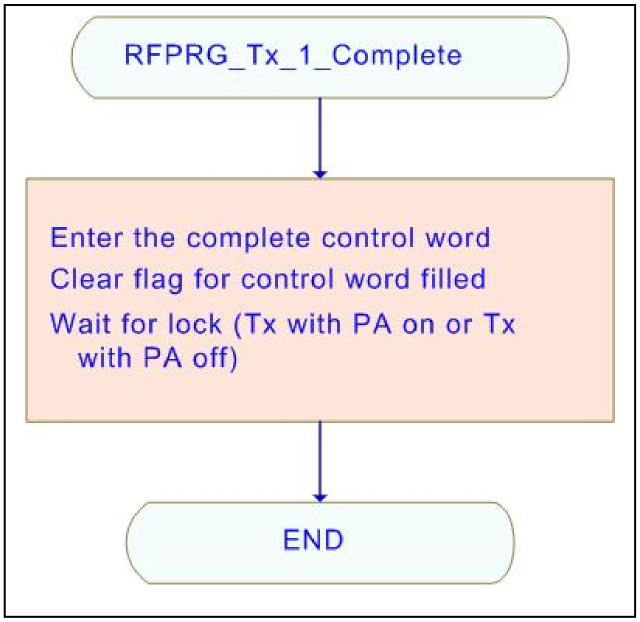
Note: These are made for the 915MHz band, which is slightly different from the other bands: The VCO_Freq setting is constant over-the-band for all frequency bands except for the 915. Therefore, when entering “a few bytes only”: In addition to the A, N, M dividers, the register holding VCO_Freq is entered as well.

Observe the following cases:

- Use PA_LDc_en = 1 and enter a complete control word
- Use PA_LDc_en = 1 and enter “a few bytes only”
- Use PA_LDc_en = 0 and enter a complete control word
- Use PA_LDc_en = 0 and enter “a few bytes only”



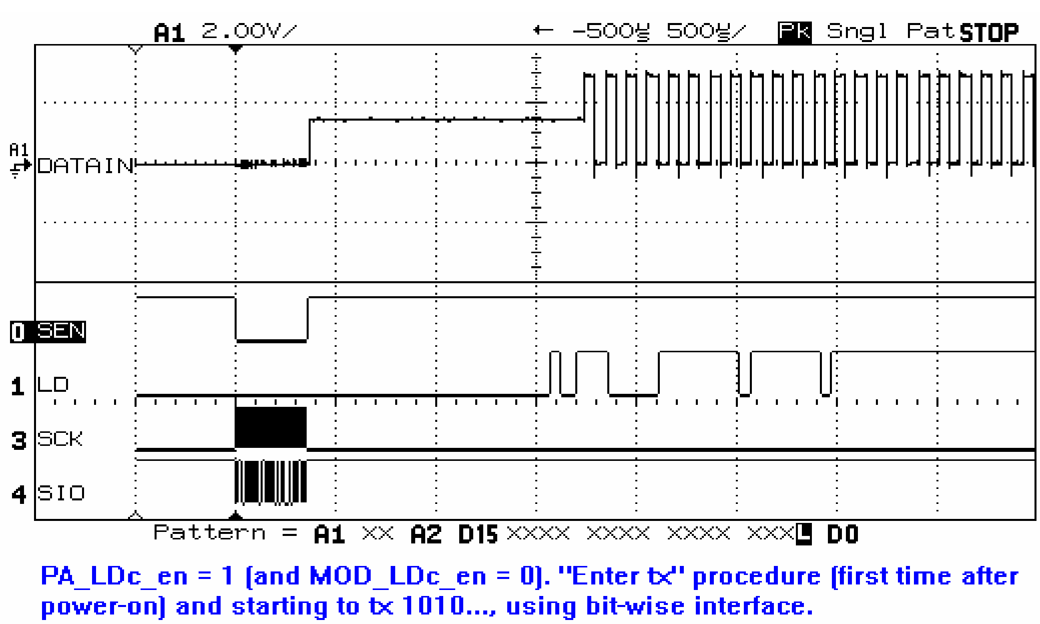
Flow Chart 6: RFPRG_Enter_Tx



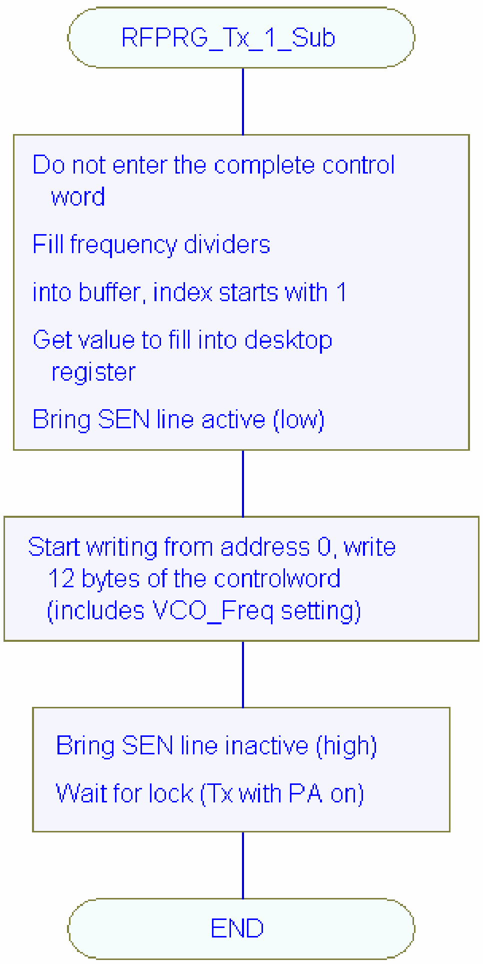
Flow Chart 7: RFPRG_Tx_1_Complete

A screen capture is shown below. Observe:

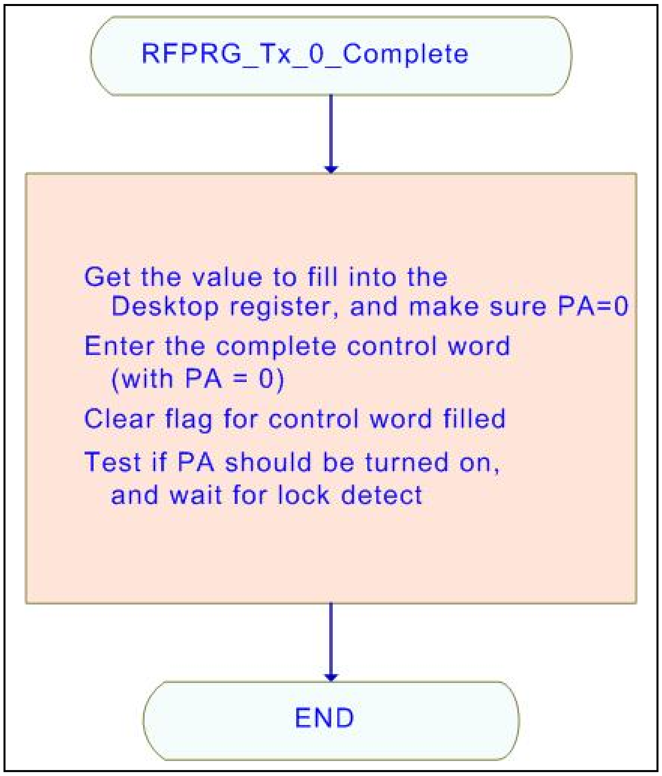
- Only 1 "programming sequence" (SEN going low then high)
- The RF chip turns on PA when LD goes high
- Modulation starts when LD goes high after PA is turned on, DATAIN is kept in tristate until modulation starts



Screen Capture 1: For RFPRG_Tx_1_Complete



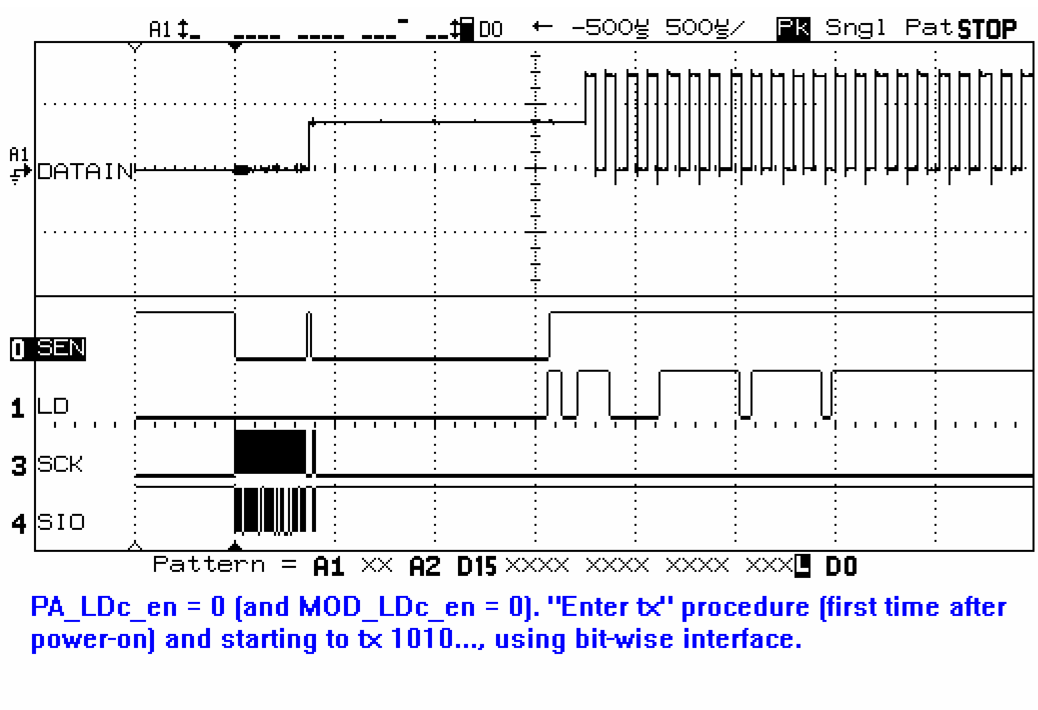
Flow Chart 8: RFPRG_Tx_1_Sub



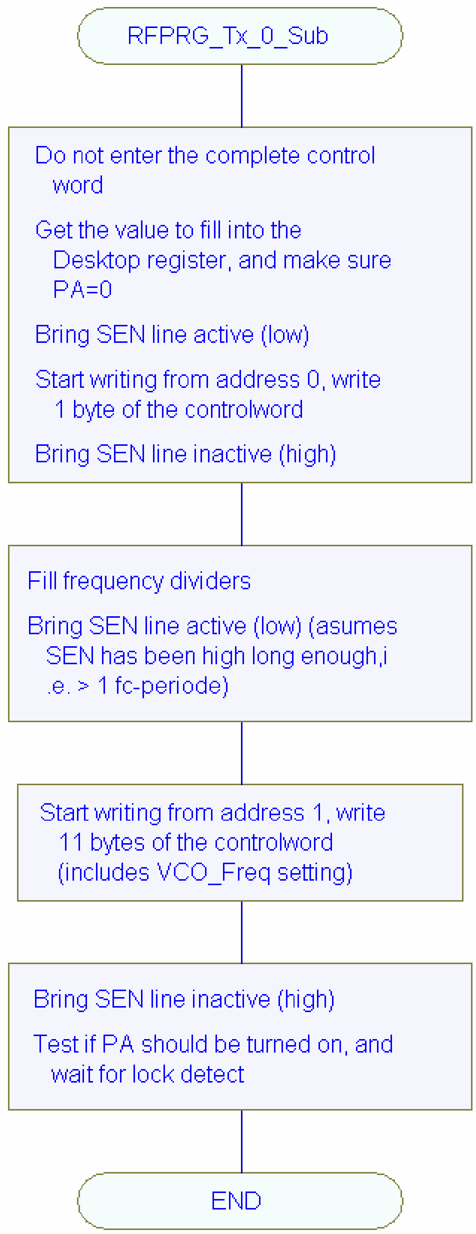
A screen capture is shown below. Observe:

- 2 “programming sequences” (SEN going low then high); first enter tx with PA off, then enter tx with PA on
- MCU turns on PA when LD goes high (then SEN is brought high)
- Modulation starts when LD goes high after PA is turned on, DATAIN is kept in tristate until modulation starts

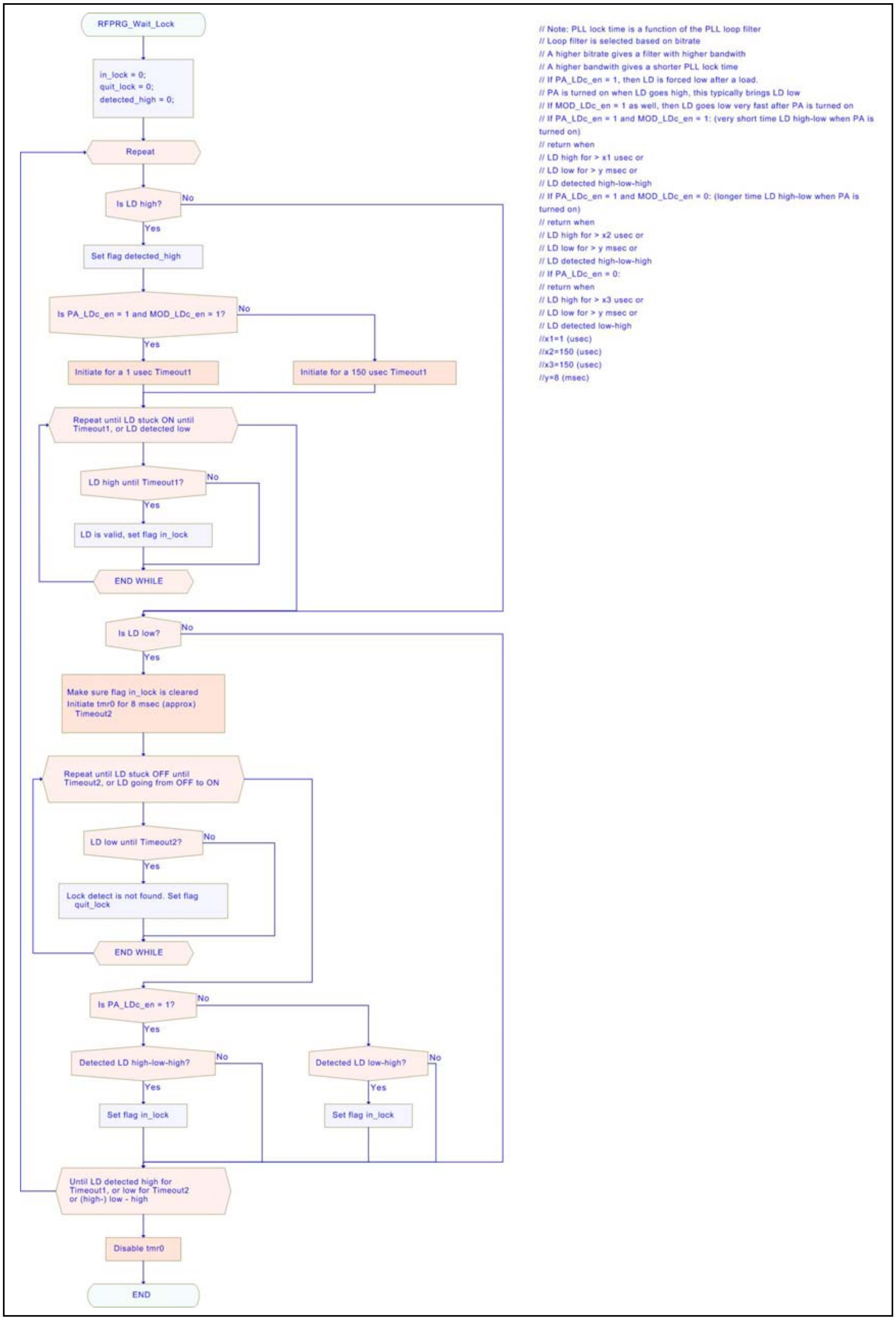
Flow Chart 9: RFPRG_Tx_0_Complete



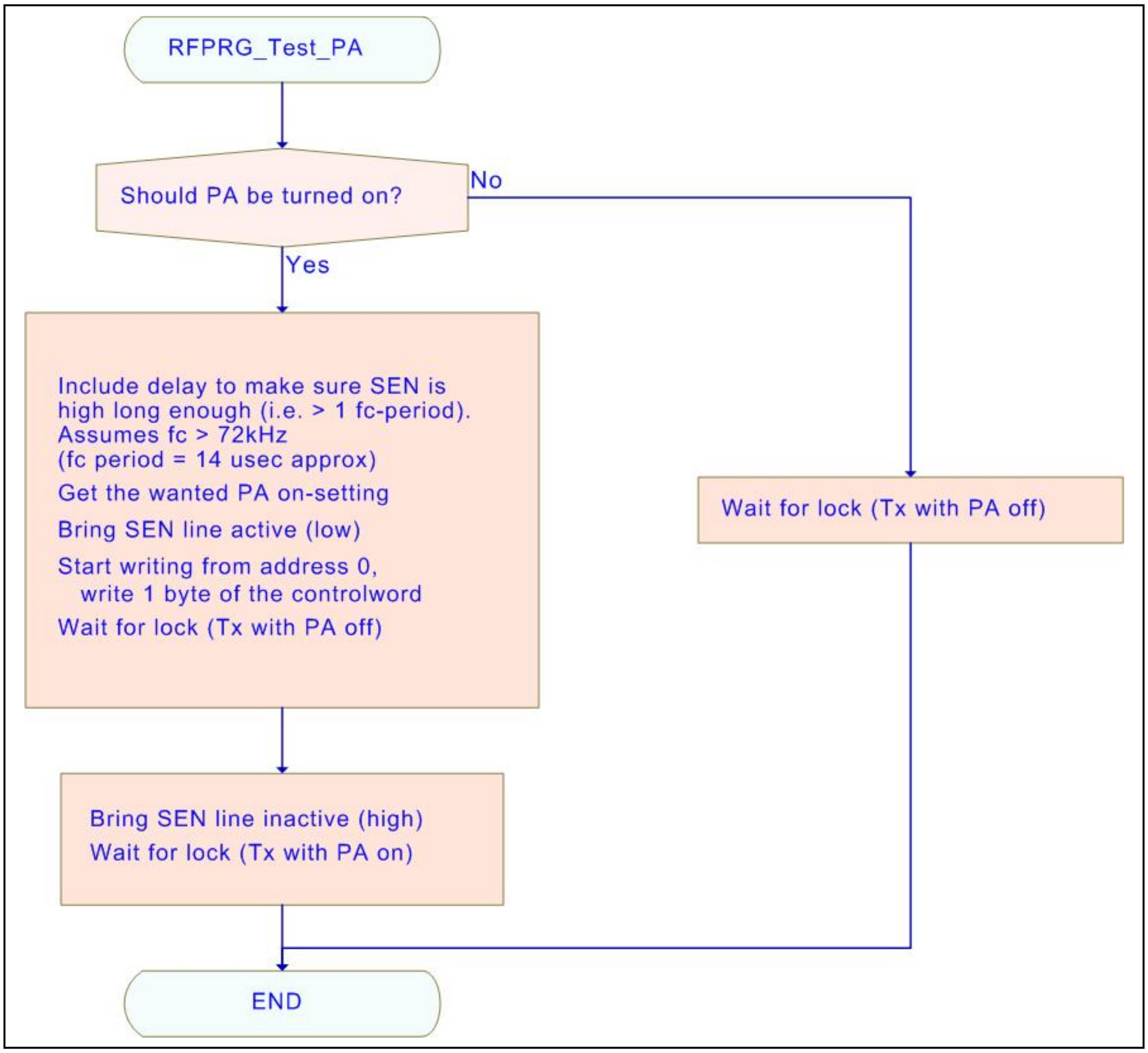
Screen Capture 2: For RFPRG_Tx_0_Complete



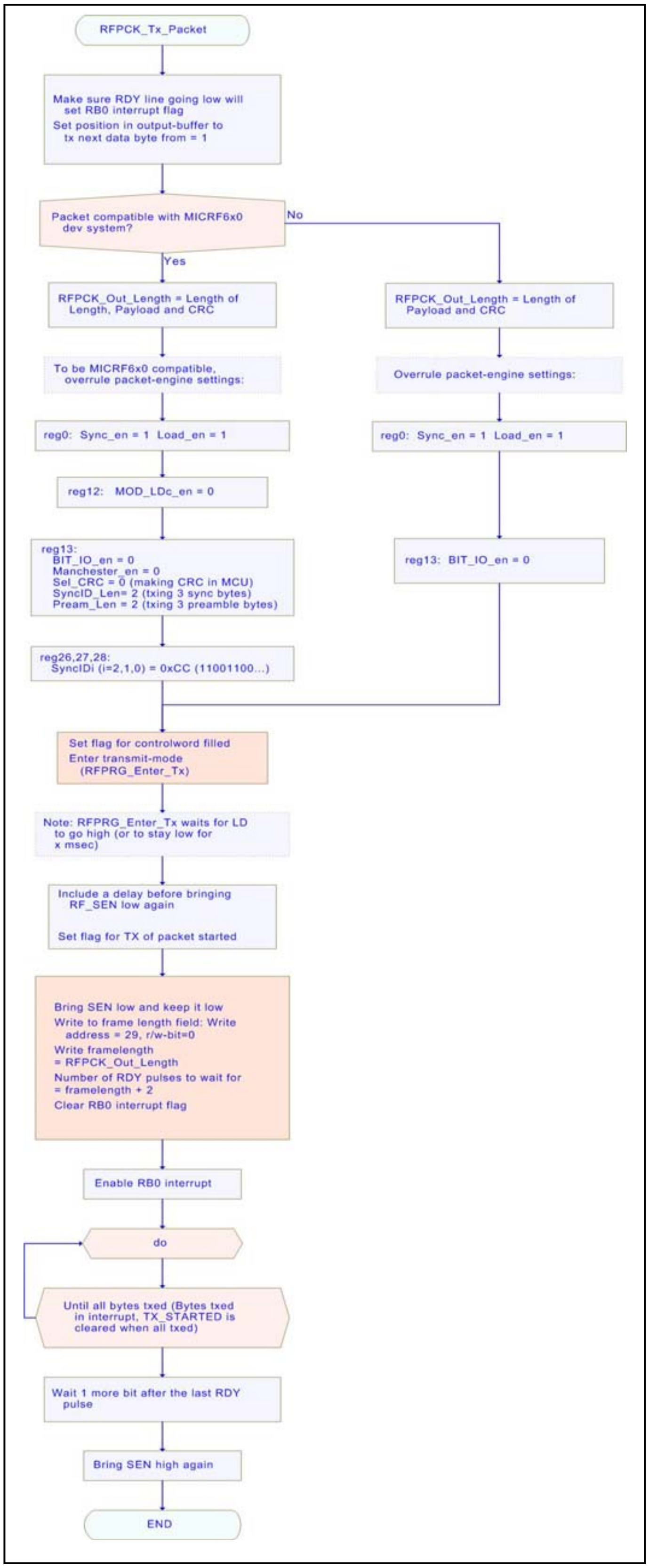
Flow Chart 10: RFPRG_Tx_0_Sub



Flow Chart 11: RFPRG_Wait_Lock



Flow Chart 12: RFPRG_Test_PA



Flow Chart 13: RFPCK_Tx_Packet