

## PMA71xx

SmartLEWIS<sup>TH</sup> MCU  
RF Transmitter FSK/ASK 315/434/868/915 MHz  
Embedded 8051 Microcontroller with 10 ADC  
Embedded 125 kHz ASK LF Receiver

## TDA7210

RF Receiver FSK/ASK 434/868 MHz

## XC822

8-bit Microcontroller

## BCR421

LED Driver

## IFX20001

Low Dropout Voltage Regulator

## RF Remote Controlled LED Lamp

Application Note

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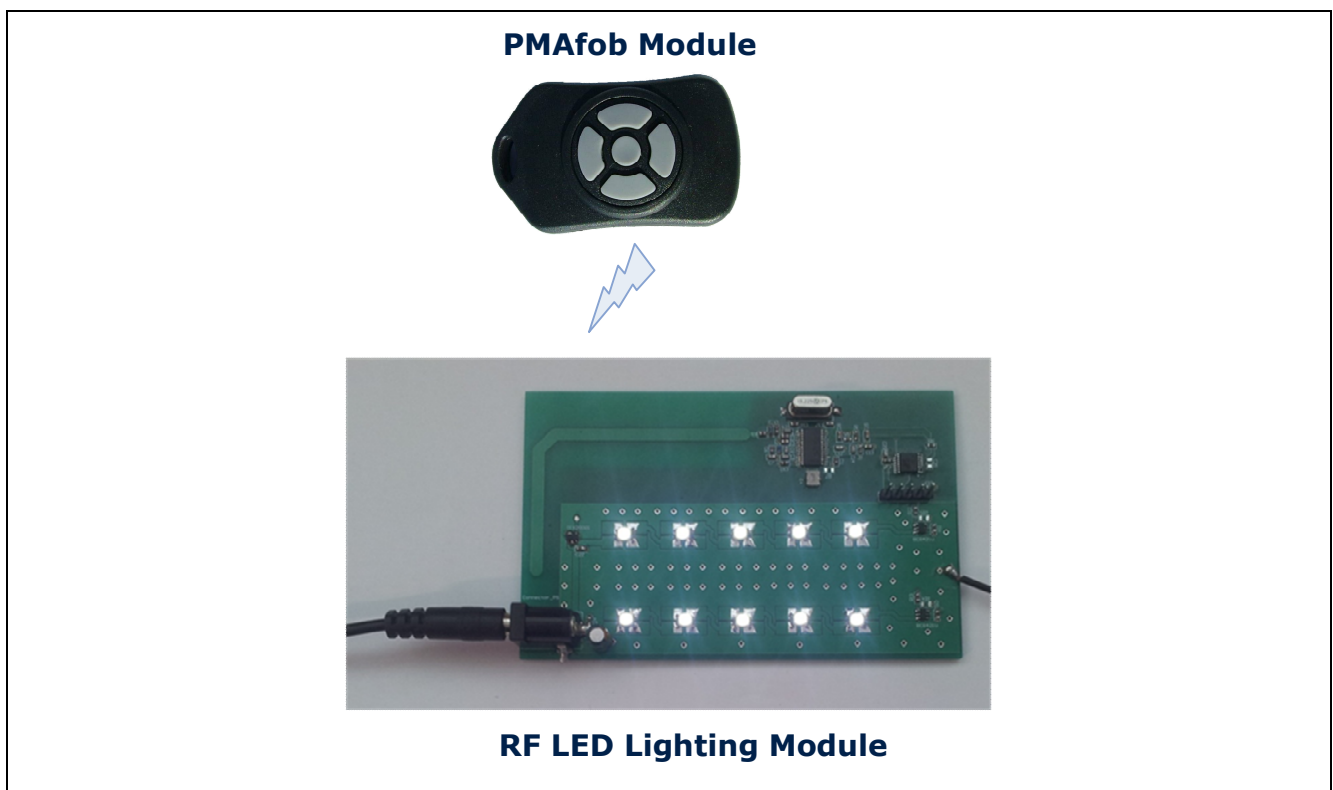
## 1 Introduction

In the RF remote lighting kit, LED lighting is controlled using a remote controller through radio frequency. LED lighting can be switched ON or OFF and dimmed by pressing a button on remote controller. The use of RF remote control makes lighting control more comfortable. Because of dimming feature, total power consumption of lighting can be reduced depending on lighting usage.

RF remote lighting kit consists of one RF remote controller (called PMAfob) and RF LED lighting module or board where PCB-printed antenna, RF receiver module, 8 bit microcontroller and LED lighting with LED driver are located. When the button on PMAfob is pressed for a particular function (eg. Dimming LEDs), the command, Battery voltage, remote control ID are packed into 128 bits information. The Manchester coding is generated based on 128 bits information and is used to modulate RF carrier at 434 MHz.

On RF LED lighting module, the RF signal is received using the PCB printed antenna. The receiver circuitry demodulates the RF signal and passes its output to 8 bit microcontroller for decoding. The reference code or software for decoding Manchester coded signal is available upon request. The microcontroller controls LED driver in order to switch ON or OFF the LEDs or change LED brightness.

Some features of reference kit include button stuck detection, XTEA encryption, battery voltage measurement and power down mode for energy saving. It operates at 434 MHz frequency band and uses ASK modulation. More detail would be described in the next few pages of the application notes.



**Figure 1 RF Remote Controlled LED Lamp Reference Kit**



## 2 RF Remote Controller Hardware

RF Remote Controller hardware consists of passive components, crystal unit and PMA7105 IC as shown in Figure 2. The PMA7105 IC is a low power wireless FSK / ASK transmitter with an embedded microcontroller that offers a single chip solution in frequency bands of 315 / 434 / 868 / 915 MHz. With its highly integrated mixed signal peripherals, PMA7105 IC requires only a matching circuit and crystal unit for operation as remote control

Using PMA7105 IC, features of RF Remote Controller are implemented in its software. PMA7105 peripherals such as GPIO (General Purpose Input Output), voltage sensor and RF transmitter are used for remote control functionality. GPIOs are connected to five external buttons as input user interface. These GPIOs are configured as inputs through GPIO Special Function Register (SFR). Pull-up and pull-down resistors are implemented in PMA7105 IC and are selected through SFR so no external components are required. Voltage sensor is used for measuring external supply voltage to PMA7105 IC. Voltage measurement is done by calling voltage measurement function in ROM library.

The internal RF transmitter consists of power amplifier, PLL synthesizer, Manchester/Bi-phase encoder and ASK/FSK modulator. In software, SFRs are used to configure RF related parameters for RF transmitter. For remote controller, SFRs are set for operating at 434 MHz, ASK modulation, 5 dBm output power level and 1 kbps data rate of Manchester coding. For information on operating PMA7105 device, please refer to PMA71xx datasheet [1].

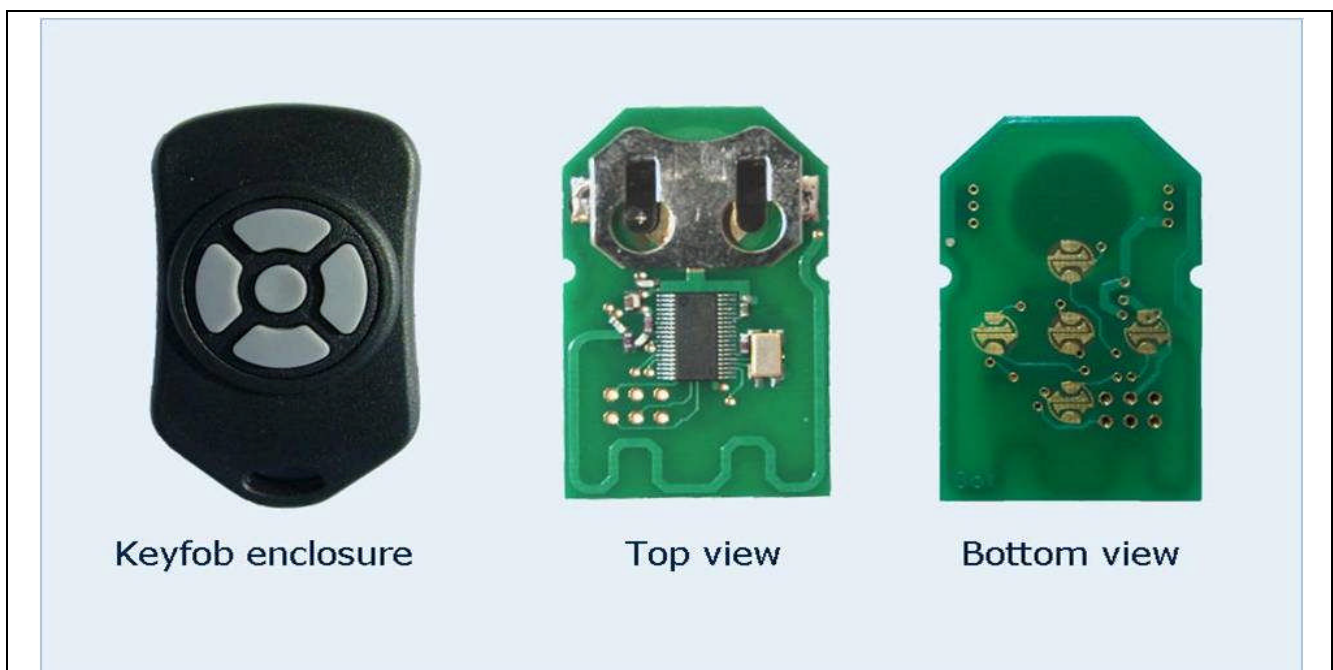


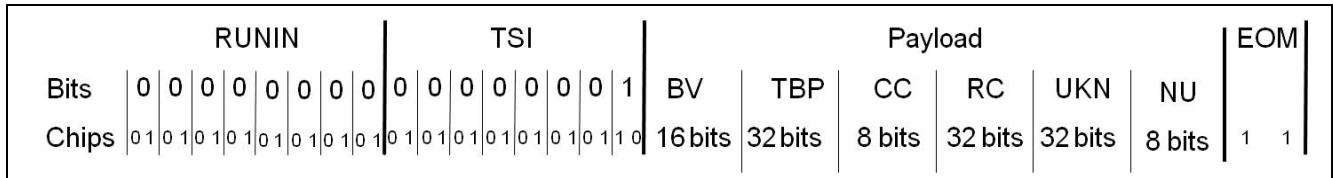
Figure 2 PMAfob Hardware

## 3 RF Protocol Frame

Before information or data is transmitted to RF LED Lighting module, the data is arranged in protocol frame as shown in Figure 3. The protocol starts with hexadecimal digits, 0xFFFF. These bits are used to synchronize internal data clock with received bits on the receiver. The oscillator signal of receiver requires one milli second for stabilizing and then receiver starts to receive RF signal. The bits are used as header for indicating start of payload bits.

Payload bits contain the information or data of RF remote controller. It contains two bytes of battery voltage, four bytes of press counter, one byte of command code, one byte of counter and four bytes of unique key number.

Each remote controller can be identified with its unique key number which is located in PMA7105 ROM memory. The received command code tells microcontroller to adjust LED lighting intensity or to switch on / off LED lighting. To protect transmitted data from unwanted access, the data can be encrypted using security algorithm (eg. AES 128 or XTEA).



**Figure 3 Protocol Frame**

RUNIN	: Run in sequence (synchronization)
TSI	: Telegram Start Identifier
BV	: Battery Voltage
TBP	: Total Button Presses
CC	: Command Code
RC	: Rolling Code
UKN	: Unique Key Number
NU	: No Use
EOM	: End of Message

## 4 RF Remote Controller Software

This section describes software implementation for some features of RF remote controller as found in PMAfob Software Example application note [2]. The SW example supports the following features :

- Five buttons (Handling of five external wake-ups)
- Button stuck detection
- Debounce buttons
- XTEA encryption
- Battery voltage measurement
- Energy saving by using Power Down Mode

The PMA51xx starts program execution within the startup file. After RAM initialization the wake-up flag in SFR (Special Function Register) DSR.1 [WUP] is checked to decide whether the PMA51xx starts up from a reset or because of a wake-up event.

If PMA51xx starts up from reset PP1-PP4 and PP6 (WU0-WU4) are configured as external wake-up pins. Therefore the port direction must be set to input and the internal pull-up resistors must be activated (assumed that a pressed button generates a LOW on the pin). Also PP8 is set to input and its internal pull-up resistor is activated. This is used for analysing the port sampling array. Finally, the Interval Timer is set to the longest possible wakeup interval of about 524 s and the PMA51xx is set into Power Down Mode to save energy and waits for a wakeup event.

If PMA51xx starts up from Power Down Mode with a wake-up event, the wake-up source is checked. Seven wakeup sources are handled by the PMAfob Software Example. These are the Watchdog Timer, the external wake-ups WU0-WU4 and the Interval Timer. The Watchdog Timer wake-up has the highest priority. If a Watchdog Timer wake-up occurs, a software reset is triggered to ensure that all SFRs have a predefined state.

If no Watchdog Timer wake-up preceded, the external wake-ups are checked. When an external wake-up has been detected, the appropriate wake-up source is disabled (masked), a wake-up ID is stored in the xdata and the Interval Timer is set to 50 ms.

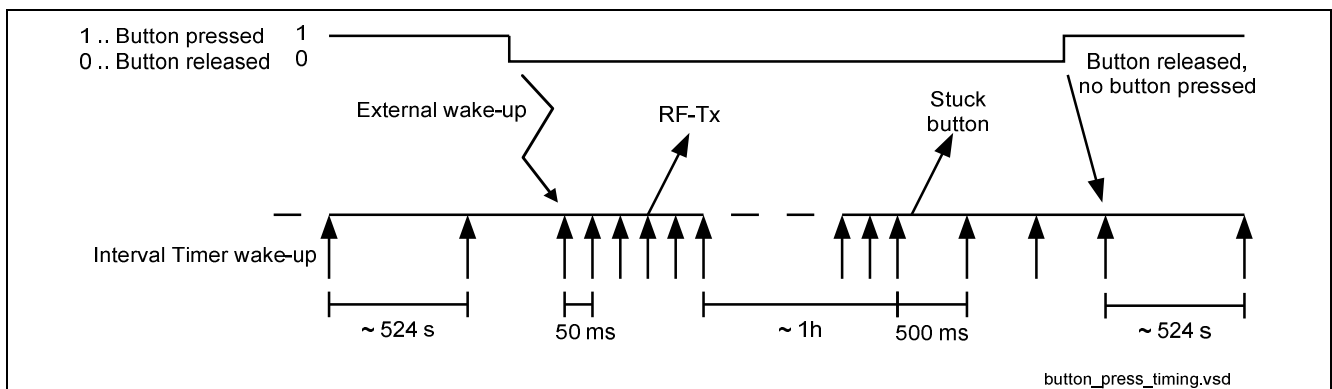


In the Interval Timer wake-up routine the pins PP1-PP4 and PP6 are checked to detect whether a button is still pressed. If the external wake-up ID previously stored in the xdata is equal to the currently pressed button a counter is increased. If this counter reaches a predefined value, the button is recognized to be pressed. Then a new rolling code is calculated, the battery voltage is measured, the appropriate command is inserted into the RF-Frame, the RF-Frame is encrypted with AES or XTEA and transmitted. When the new rolling code is written to the EEPROM the ports are sampled for any action. If a button press was detected during writing to the EEPROM, a new rolling code is calculated and the appropriate RF-Frame is sent. For every button which is detected to be unpressed in the Interval Timer wake-up routine the corresponding wake-up is (re-) enabled. If no button is pressed, the Interval Timer is set to the longest possible wake-up interval of about 524 s. A Key Stuck is detected by the Interval Timer wake-up routine when a button is pressed for at least 1h and no other button is pressed in between.

Figure 2 shows the timing of a button press and how the Interval Timer wake-up interval is varied. While no button is pressed the Interval Timer wakes up the PMA51xx with the longest possible interval of about 524 s to save energy. If a button is pressed an external wake-up is detected and the Interval Timer is set to 50 ms. The Interval Timer wake-up service routine checks if the button is still pressed every 50 ms and sets the PMA51xx into Power Down Mode between each measurement. This method is used to debounce the buttons.

If a button is pressed for at least 150 ms (three button checks in the Interval Timer wake-up service routine resulted in a pressed button) a Button Press is identified and an RF-Transmission is started. The debounce time of 150 ms can be easily changed by modifying the value of `BUTTON_PRESS_DUR` defined in file `defines.h` and or changing the Interval Timer settings. As long as the button is pressed the Interval Timer wakes up every 50 ms to check the button. This is done for at most 1 h.

If a button is pressed for about 1 h, and no other button is pressed in between, the button is detected to be stuck and the Interval Timer is set to 500 ms to save energy. If the button is released, and no other button is pressed, the Interval Timer is set to about 524 s again.



**Figure 4** Interval Timer Timing

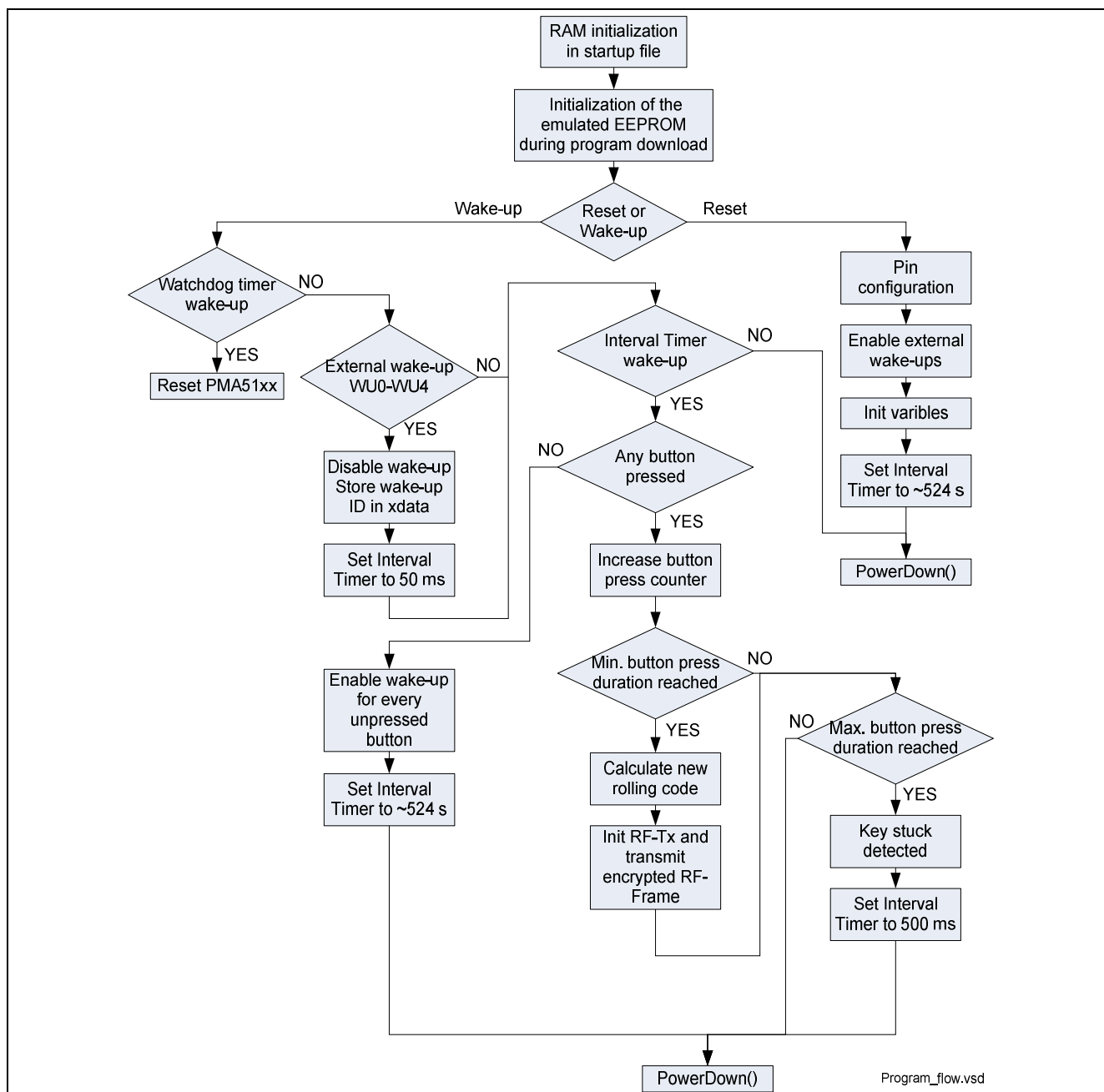


Figure 5 Program Flowchart of PMAfob Software

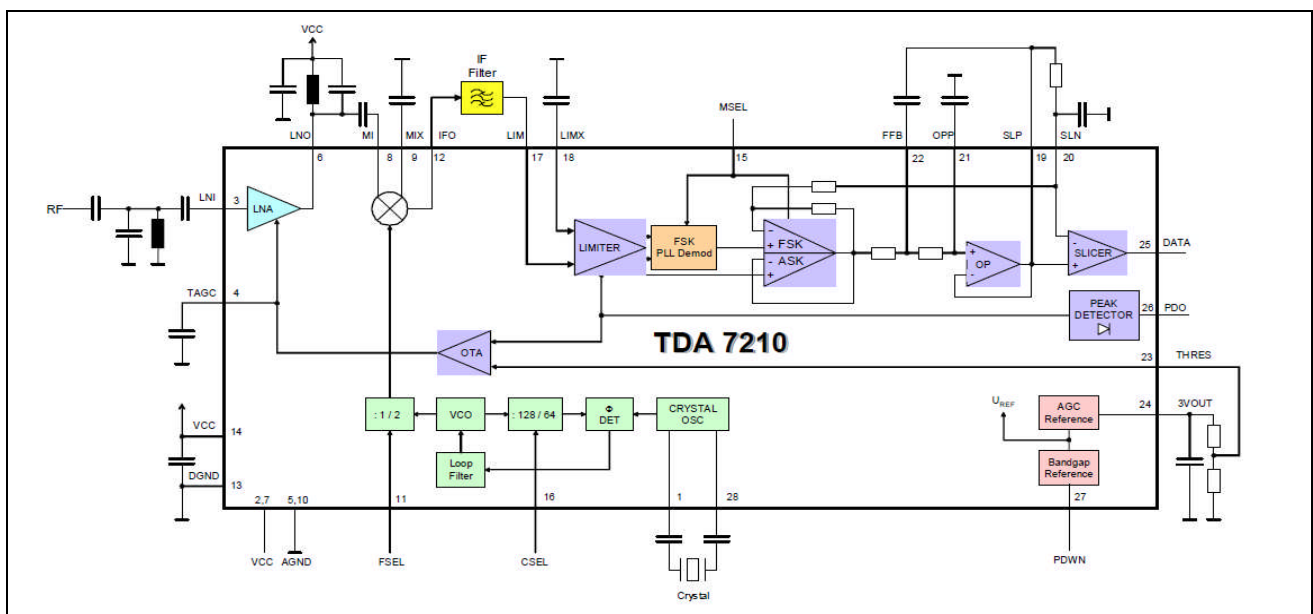
## 5 RF LED Lighting Module

RF LED Lighting module receives the RF signal from RF remote controller. Based on received command, the LED would be switched on or off or dimmed on RF LED lighting module. RF LED lighting module consists of RF TDA7210 receiver circuitry with PCB antenna, XC822 microcontroller, BCR421 LED driver, LEDs and IFX20001 voltage regulator. The followings describe each sub-section in more detail.

### a. TDA7210 Receiver Circuit

RF receiver IC, TDA7210 from Infineon is a “one-chip” receiver for short range remote control applications. As shown in Figure 7, the basic structure of a superheterodyne Receiver is built of a low-noise amplifier (LNA) and mixer at front-end as shown in Figure 6. A PLL controlled local oscillator is used at mixer LO input. IF-stage (10.7MHz typical) incorporates an IF-amplifier, demodulator and data regenerator.

RF receiver circuit consists of only few external components as shown in Figure 7. PCB antenna is matched to LNA input by a wideband LC network. Between LNA output and mixer, an additional tank circuit is used. The designs of PCB antenna, matching network affect the sensitivity level of receiver which determines communication distance. For more detailed information on operation of RF receiver, please refer to TDA7210 datasheet [3].



**Figure 6 Block Diagram of Front-End Matching**

TDA7210 output signal is available at Data pin or pin 25 of receiver IC. The output signal is measured using oscilloscope as shown in Figure 7 and Figure 8. The received output signal is Manchester coded signal, which has 50% duty cycle and period of 1 milli second. Each Manchester bit is represented with a mark (high) and a space (low) in chip. Manchester bit ‘1’ consists of a mark and a space while bit ‘0’ consists of a space and a mark.

When RF lighting module is not receiving its wanted RF signal, noise would appear at Data pin. The noise appear in front and end of received signal as shown in Figure 7. The received output signal (Rx output) is verified with the transmitted signal (Tx output). XC822 microcontroller processes the received output signal further and its detailed information is described in the next section, XC822 Microcontroller.

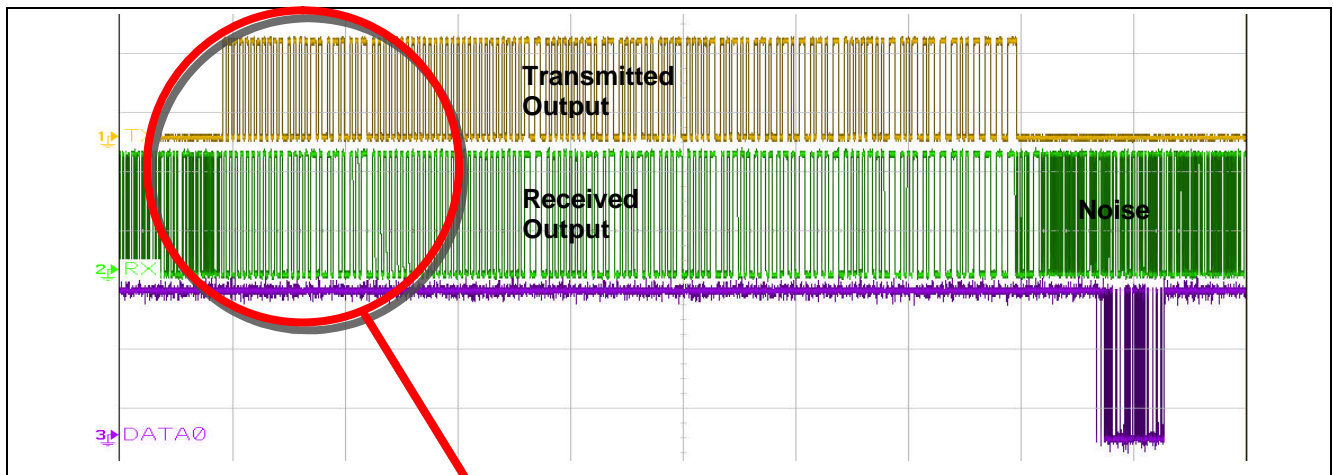


Figure 7 Output Waveforms at Transmitter, Receiver and XC866

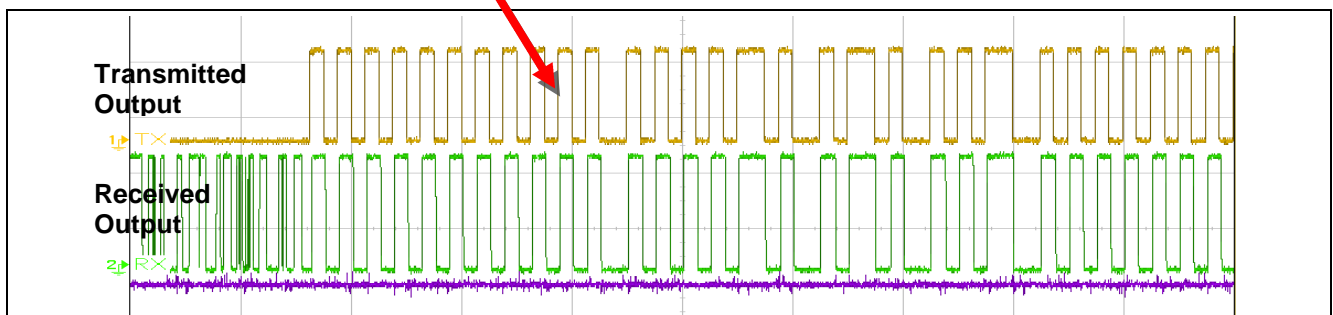


Figure 8 Detailed Output Waveforms at Transmitter, Receiver

### b. XC822 Microcontroller

XC822MT-2FRI is an entry level 8051-compatible 8-bit microcontroller with 4KB on-chip Flash memory and 16 pins. It can easily decode the transmitted messages, calculate the desired LED brightness levels and modulate the LEDs with high frequency PWM signals to avoid flicker.

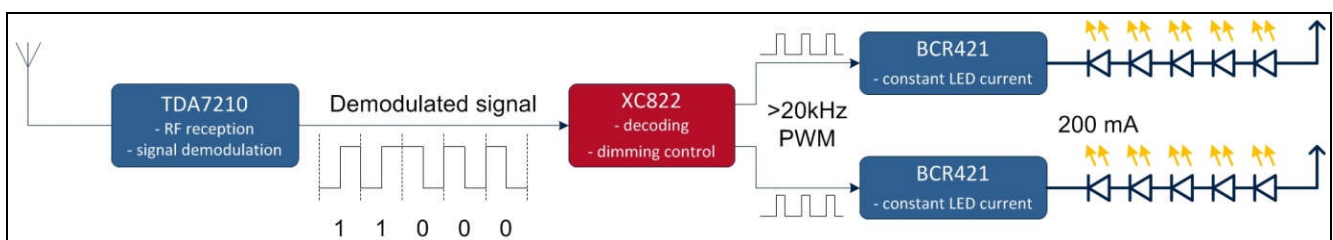
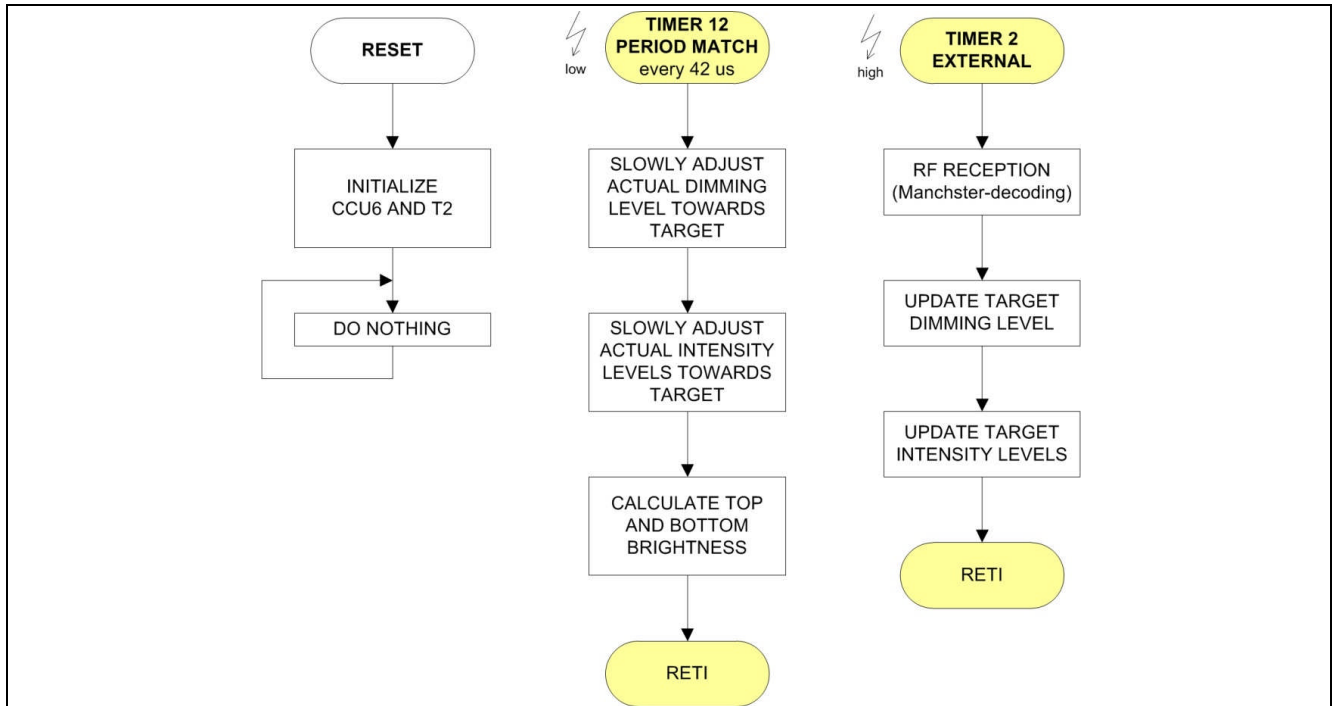


Figure 9 Receiver Module block diagram

The demodulated signal is received by a single microcontroller pin as a Manchester-encoded bit stream. This signal is directly connected to the T2EX input of the XC822 microcontroller on the receiver board. T2EX is the external input of the Timer 2 (T2) module of XC822. T2 is a flexible 16-bit timer with some additional capabilities. Since this module is capable of detecting rising or falling edges on T2EX, the microcontroller can detect the rising and falling edges of the demodulated (and inverted) signal and measure the time passed between the edges. The distance between edges can be 1000  $\mu$ s (2 chips) or 500  $\mu$ s (1 chip). The microcontroller measures these distances with a nominal resolution of 42 ns. If the measured distance is not 1 or 2 chips, the received edge is deemed noise and the microcontroller will wait for a new packet. A tolerance of about 15% is allowed to be robust against ambient noise and to accommodate internal oscillator imperfections. Detecting the edges and knowing the distance between them is enough to decode a Manchester-encoded signal. Every falling edge is followed by a rising edge and every rising edge is followed by a falling edge.

Whenever an edge is detected, T2 generates a capture event interrupt where the received signal is evaluated. If no edge is detected, T2 overflows and re-initializes every 2.73 ms.

Once the RC-5 packet is received, the microcontroller determines whether it contains new button information and acts on it.



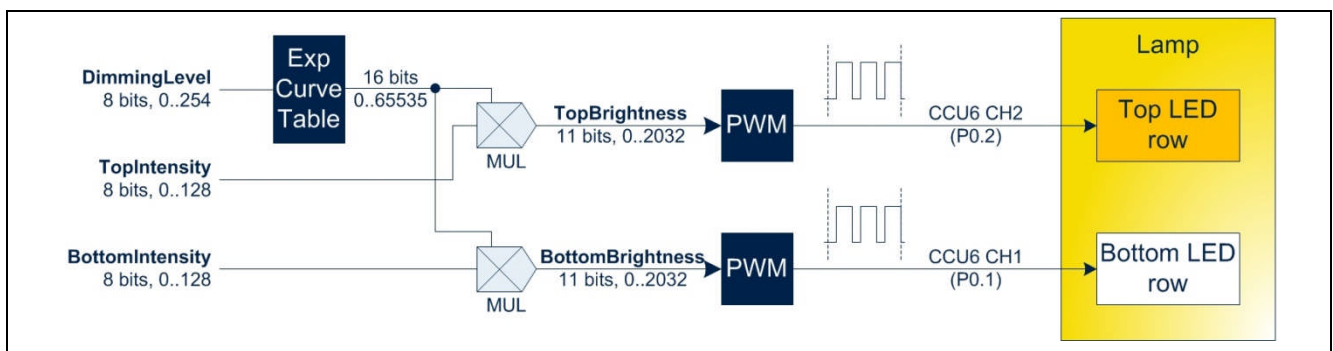
**Figure 10 Overview of the main functions and interrupts of the Receiver Module**

Modules used:

- Timer 2 (T2) takes care of receiving and decoding the transmitted bit stream and it generates a Timer 2 External interrupt every time there is a change in the incoming signal level
- The Capture/Compare Unit 6 (CCU6) modulates the LEDs to control the brightness and provides a time base for exponential dimming and brightness level calculations

The two rows of LEDs form an LED lamp. Their overall (combined) brightness is controlled by a dimming level value. This value changes exponentially to compensate for the logarithmic nature of human vision and make changes in brightness appear natural. The rows can be separately controlled by the intensity values. The intensity values are multiplied by the common dimming level to create the respective brightness levels for the LED rows. This is useful if the two rows have LEDs with different color (e.g. one row of warm white and one row of cool white LEDs to make the color temperature of the lamp tunable). By changing the two intensity values relative to each other the lamp color can be adjusted without affecting how bright the lamp looks.

The brightness of the lamp changes when the dimming level is updated. This does not affect the lamp color.



**Figure 11 LED Lamp dimming level and color control block diagram**

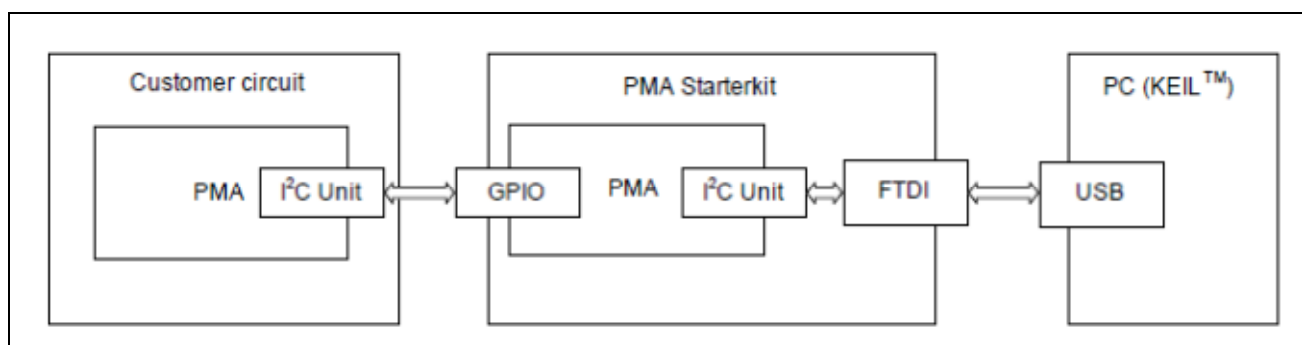
In the current demo, the LEDs are of the same color and the intensity values can only be 0% or 100% (row enabled/disabled).

## 6 Programming Access

### a. PMA7105 for RF Remote Controller

Infineon PMA RF USB Stick can be used as a Flash Programming Interface for RF Remote Controller. The Flash Programming uses I2C interface. Figure 12 shows how the PMA starterkit is used as programmer for a RF Remote controller. For the communication between the PMA on the Starterkit and KEIL driver on the PC, an FTDI chip is used. The PMA on the Starterkit interacts with the FTDI via the I2C unit. RF Remote Controller is programmed by the PMA on the Starterkit. Therefore the PMA on the Starterkit uses a software implementation of the I2C and the GPIO PP2, PP3, PP4 and PP5.

KEIL compiler is used for compiling and downloading software to PMA7105 device. On Project menu, select Option for Target. Option for Target window would appear as shown in Figure 14. Select Utilities tab on Option for Target window. Under Use Target Driver for Flash Programming, choose Infineon PMA Starter Kit Driver. Next click the button, Settings and the window, Flash Download Settings appears as shown in Figure 15. For programming RF Remote Controller using PMA RF USB kit, select the option, Use GPIO Connector. For more detailed information on programming an external PMA7105, please refer to PMA Starter Kit application note [4]



**Figure 12 Usage of PMA Starterkit as Programmer**

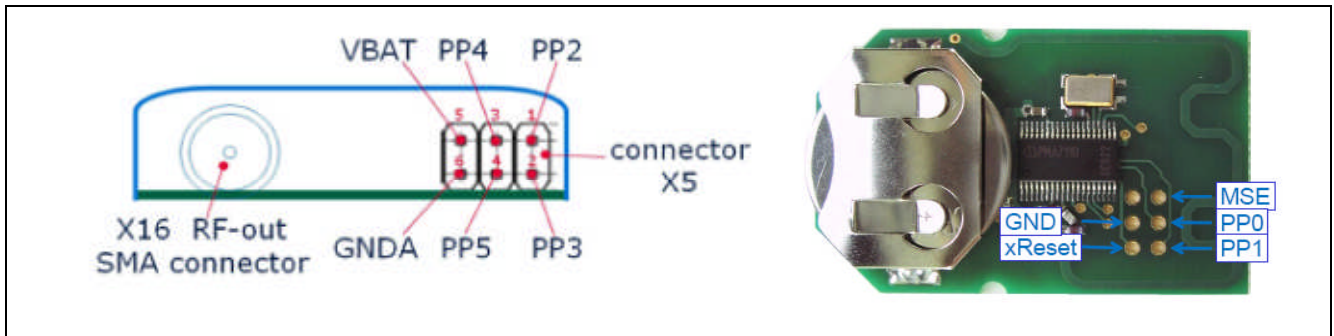
For the purpose of programming RF Remote Controller, the GPIO signals available on connector X5 of the PMA RF USB Stick have to be connected to the pins on the PMA-IC as shown.

**Table 1 Signal Connection for Programming PMA**

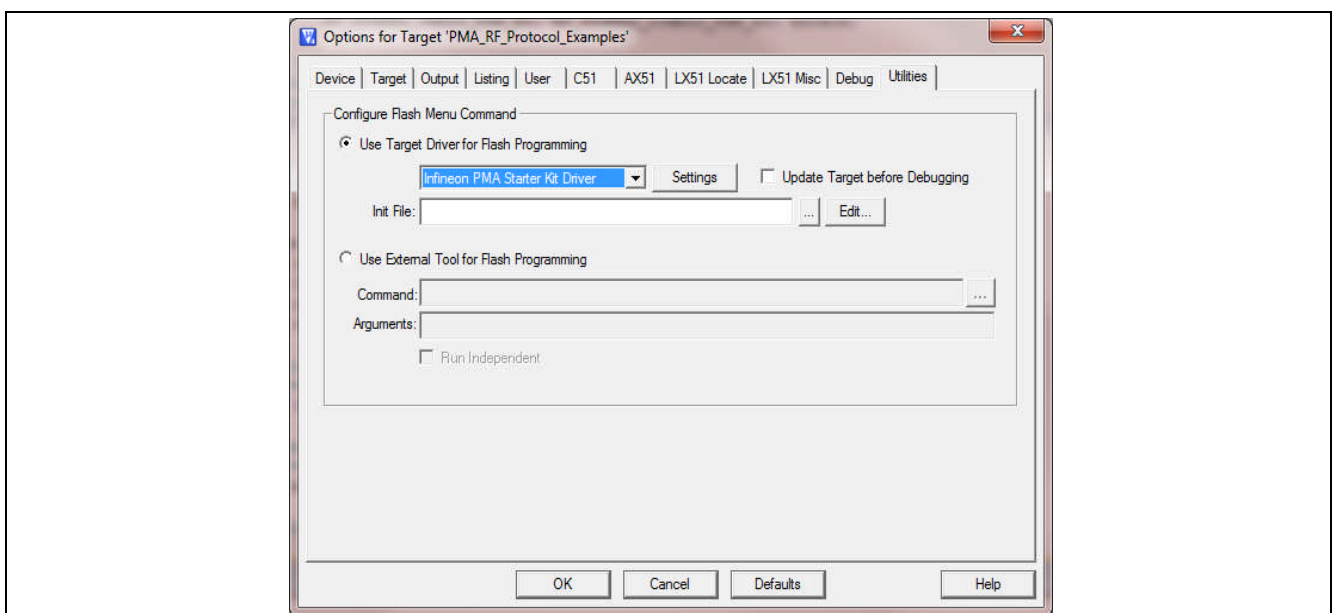
PMA RF USB Stick (connector X5)		PMA IC to be Programmed		Signal Function
Pin #	Signal Name	IC pin #	Signal Name	
1	PP2		PP0	I2C Clock
2	PP3		PP1	I2C data
3	PP4		xReset	Reset
4	PP5		MSE	Mode select enable
5	VBAT	NOT CONNECTED	N.A	
6	GNDA		GND	

The power supply of the external PMA device must be provided from an external source. It is not recommended to supply the external IC using the VBAT output provided on pin 5 of connector X5 of the PMA RF USB stick.

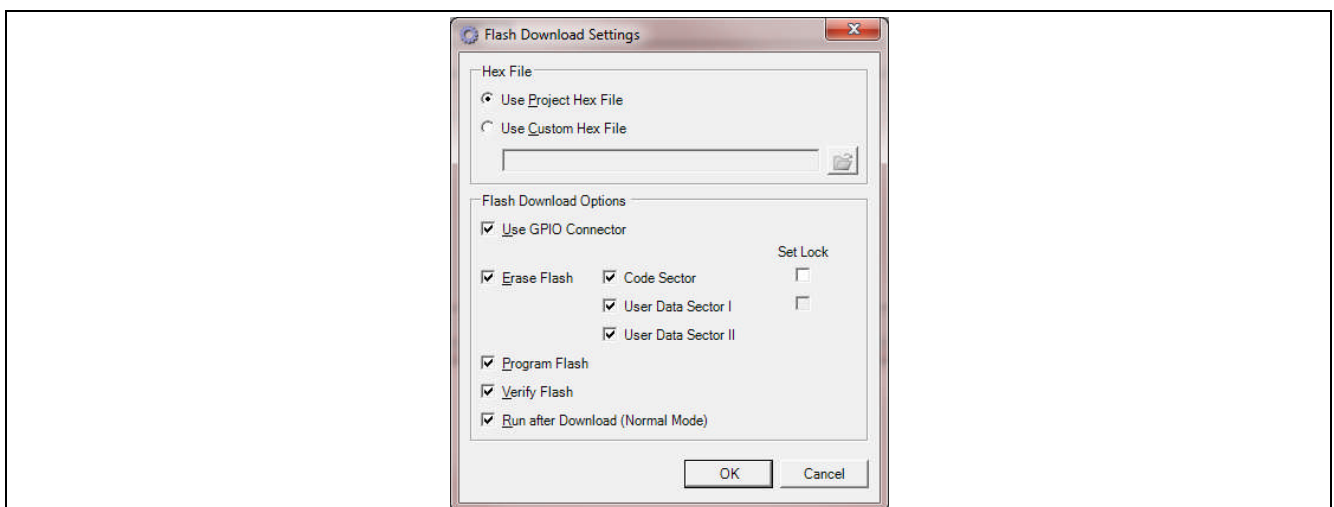




**Figure 13 Connector X5 of PMA RF USB Stick and Connection of RF Remote Controller**



**Figure 14 KEIL Setting for Flash Programming 1**

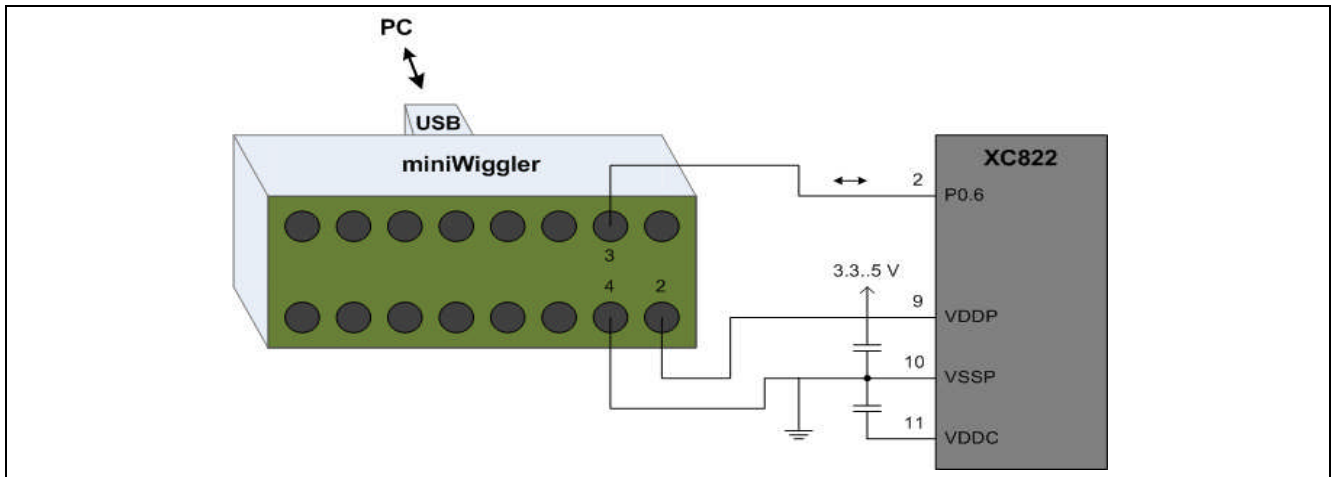


**Figure 15 KEIL Setting for Flash Programming 2**

### b. XC822 on the Receiver Module

The DAP miniwiggler provides programming access to the on-board XC822 via Header 5. The access is over SPD via pin P0.6 of the microcontroller. The BMI (Boot Mode Index) of the microcontroller is preset to User

Mode (Diagnostic). The software project has been developed in DAVE™ and KEIL, and can be downloaded to the microcontroller using KEIL uVision 4 (the settings are preconfigured).



**Figure 16** XC822 programming access block diagram

## 7 Layout Guidelines for RF Receiver IC, TDA7210

As RF signal is concerned, Infineon would recommend some guidelines for PCB layout. RF LED Lighting module is made using two layer PCB board. The top layer is in red and bottom layer in blue as shown in Figure 17. Components connected to the ground use ground via holes for connection to ground on bottom layer. So a solid ground plane is created only on bottom layer. Crystal unit (Y1) and IF filter (Y2) should have a ground plane underneath them. The RF matching components (C1, C2, C3 and L1) are placed near to one another and TDA7210 receiver IC using short tracks.

Separating RF signal between the input and output of internal Low Noise Amplifier (LNA) is important. This is done by placing some distance between RF matching components and these components (C6, C8 and L2). An external DC biasing is provided to the internal LNA through pin LNO or pin 6 of TDA7210 receiver IC. This same DC biasing should be connected as close as possible to pin VCC2 or pin 7 of TDA7210. As shown in Figure 17, the DC biasing at pin 7 is connected to one end of inductor L2 and the other end of L2 is connected to pin 6.

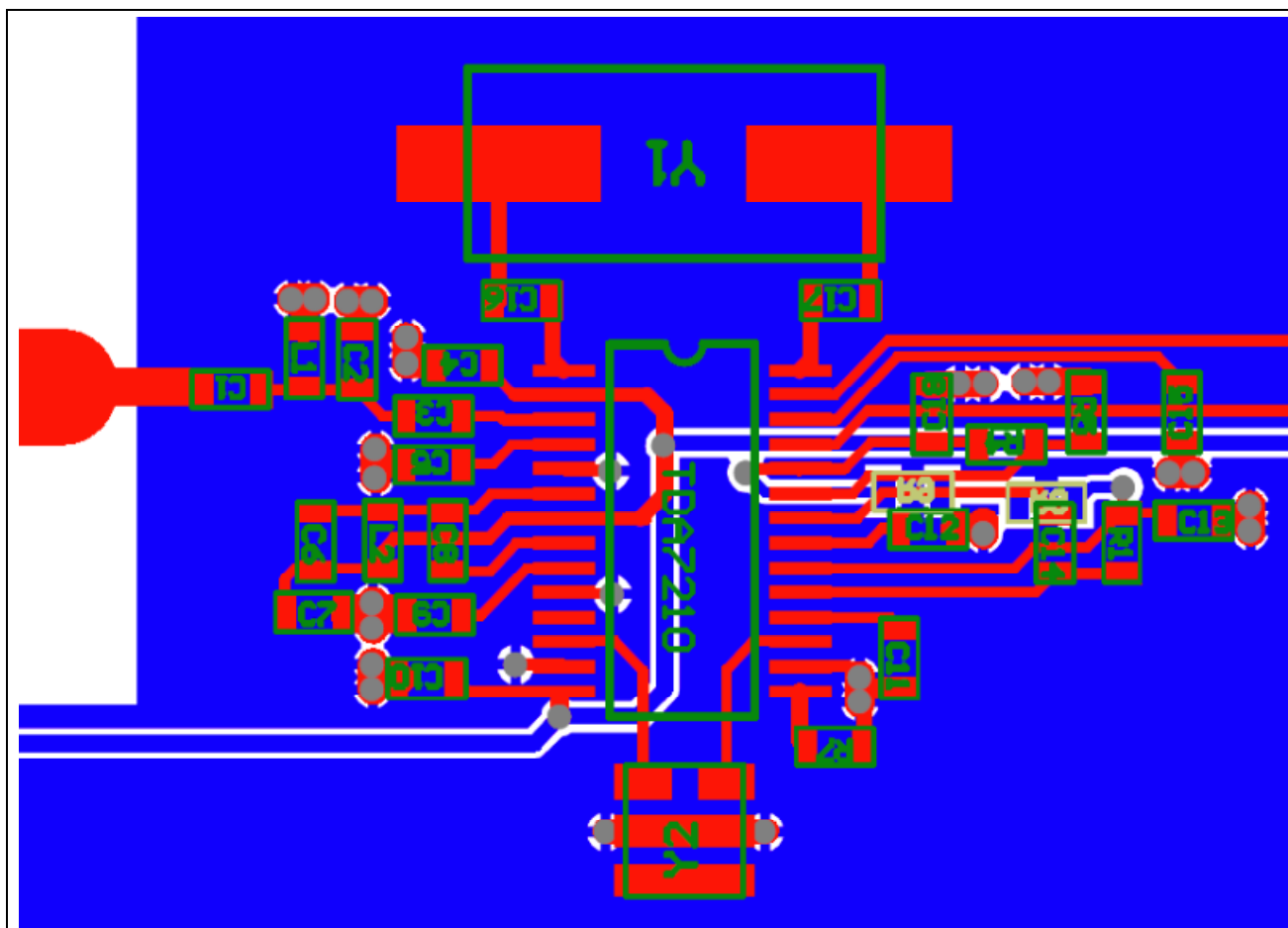


Figure 17 TDA7210 Receiver Layout

## 8 Schematics and Layout

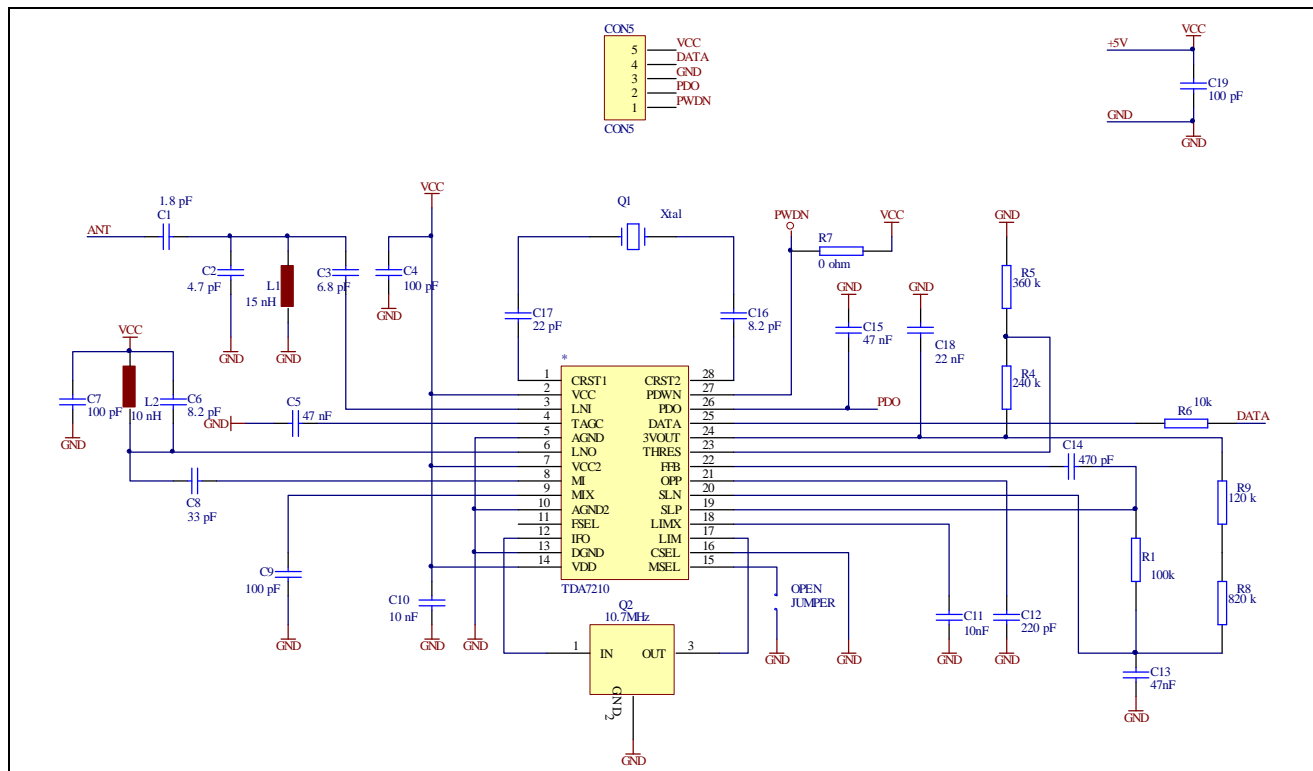


Figure 18 TDA7210 Receiver Schematics

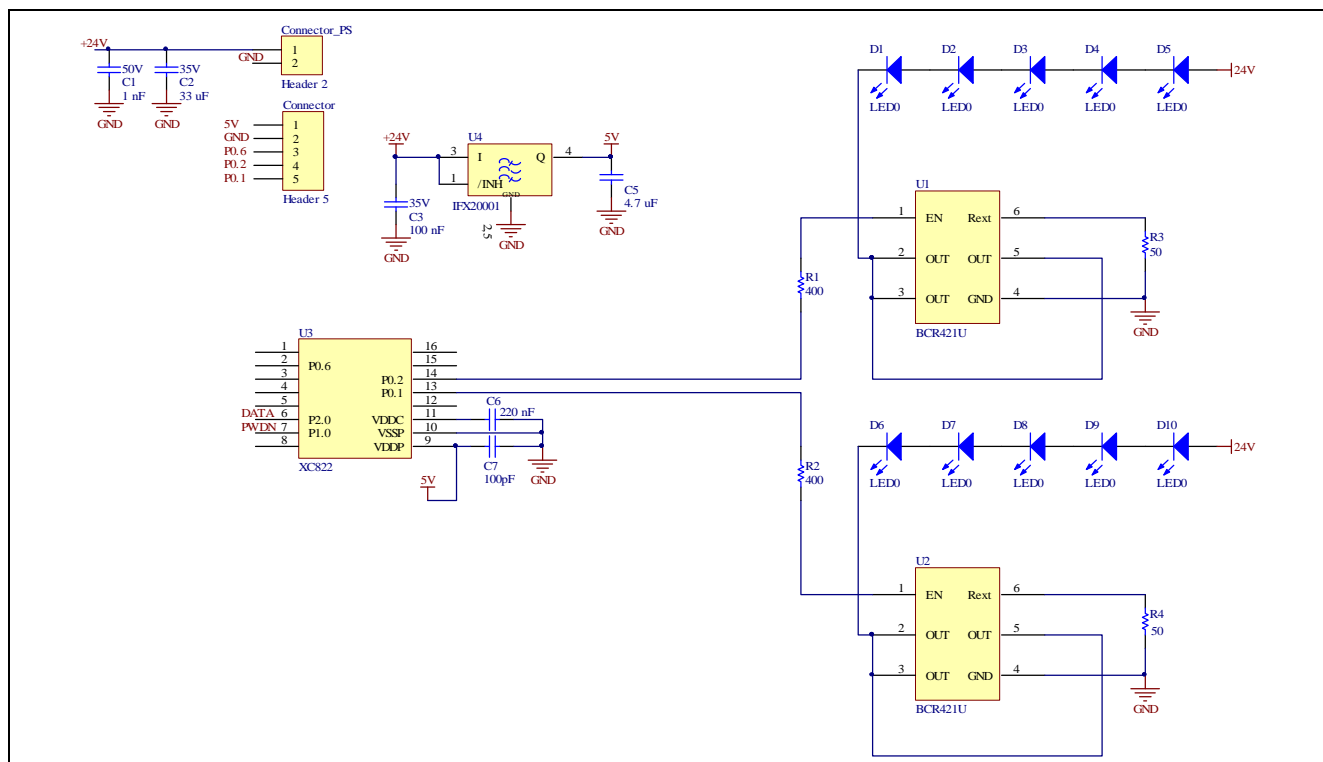
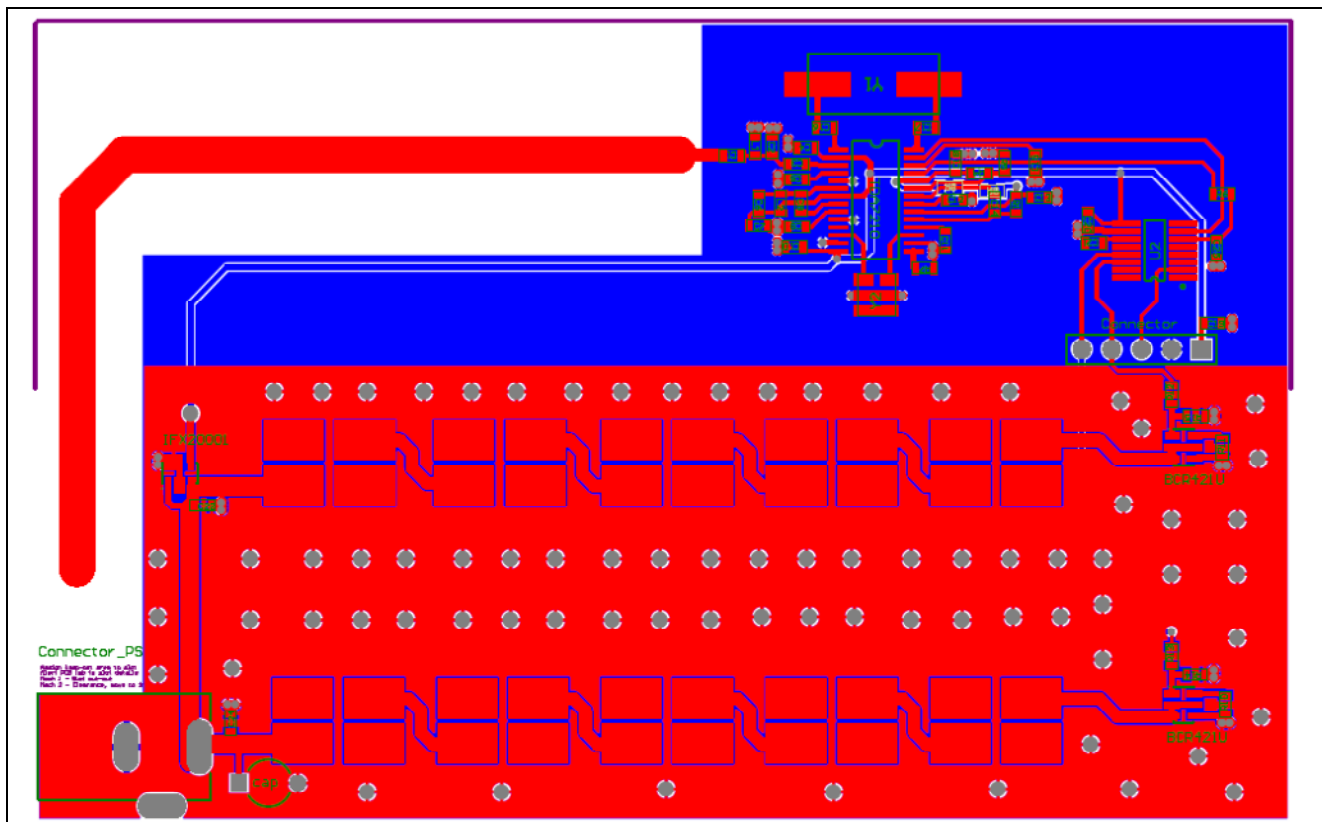


Figure 19 Microcontroller and LED Driver Schematics



**Figure 20** RF LED Lighting Layout

## 9 References

- [1] PMA71xx datasheet version 2.1
- [2] PMAfob Software Example Application Note
- [3] TDA7210 datasheet
- [4] PMA Starter Kit



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