# AN1393

# Using the PIC12LF1840T48A Microcontroller with Integrated Sub-GHz Transmitter

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## INTRODUCTION

The PIC12LF1840T48A is a Microchip microcontroller that has an on-board transmitter. The transmitter is suitable for operation in the 418, 434 and 868 MHz license-free ISM bands. The modulation is On/Off Keying (OOK) or Frequency-Shift Keying (FSK). This document describes the complete implementation of a radio transmitter using the PIC12LF1840T48A.

## KEY REQUIREMENTS

The RF transmitter integrated into the PIC12LF1840T48A has two main functioning modes.

One operation mode, called Preset mode, allows the user to choose from two predefined modes of operation. The setting is done by either pulling the CTRL line low or high. One connection to the DATA line is required to send modulation data to the transmitter.

**TABLE 1: AVAILABLE PREDEFINED CONFIGURATIONS**

| | |
|---|---|
| CTRL = 1 | 433 MHz<br>OOK modulation<br>10 dB output power |
| CTRL = 0 | 868.3 MHz<br>FSK modulation<br>Fdev = 20 kHz<br>10 dB output power |

If one of the pre-defined configurations (see Figure 1) is used, then there is no need to use an extra I/O pin to control the CTRL line of the transmitter. This pin must be either pulled high (using a resistor > 20 KOhm, but less than 1 MOhm), or pulled low.

Another operation mode is called Advanced mode. This mode is useful when the user needs a custom configuration that cannot be satisfied using one the two preset modes. This custom configuration can include custom settings, such as different transmitting frequency, RF output power, transmit power-off timer, fine tuning of the transmitting center frequency, different modulation format, and frequency deviation (if FSK mode is used).

If the Advanced mode is used, the user must implement the two-wire interface required to write data to the Configuration register. Please refer to Table 1 for the full description of the Configuration register.

In this case, an extra I/O pin is needed to control the CTRL pin, acting as a clock line. The DATA line of the transmitter must be connected to an I/O pin of the microcontroller section. This is used to carry both data transmitter over-the-air, and Configuration data (when used in conjunction with the CTRL line). The current reference design has the DATA line connected to the CCP1 line of the microcontroller. This is because the KEELOQ® security IC encoder implementation takes advantage of the internal ECCP peripheral to send KEELOQ security IC data packets.

## CONFIGURATION REGISTER WRITE

The transmitter can be software-configured to use different transmitting frequencies, different modulation and different frequency deviations (in FSK mode). All these settings are done by using a serial interface (using the CTRL line as clock line, and DATA as data line). A total of 16 are clocked, consisting of a Start bit (logic zero), a read/write bit, and the 12-bit Configuration register (see Figure 1).

## CONFIGURATION REGISTER READ

It is also possible to read back the information stored into the Configuration register. Reading operation is done in a similar way to writing data. The read/write bit is logic '1' in this case. Please note that, when reading back data from the Configuration register, a total of 64 clock cycles are required (see Figure 2). Reading only the 13-bit Configuration bits is not allowed. Please notice that the DATA line from the transmitter section becomes an output pin after the 8$^{th}$ falling edge of the CTRL line. Care must be taken to change the microcontroller port connected to the DATA line from output to input. After reading all the data, the port must be put back into Output mode. Reading back information from the Configuration register is not required. This can be helpful during the software development phase. This feature is not used in normal operation mode.

**TABLE 2: CONFIGURATION REGISTER**

| Bit | Name | State | Setting | Default | | Notes |
|---|---|---|---|---|---|---|
| | | | | CTRL = 0 | CTRL = 1 | |
| D12 | Tx Mode | 0 | Automatic Wake-up | 0 | 0 | When set to '1', the transmitter will continuously transmit. When set to '0', the transmitter will go to Sleep mode after a 2 ms inactivity on the data line. |
| | | 1 | Forced Transmit | | | |
| D(11:9) | Frequency | 000 | 418.00 MHz | 100 | 010 | RF Operating center frequency. |
| | | 001 | 433.42 MHz | | | |
| | | 010 | 433.92 MHz | | | |
| | | 011 | 864.00 MHz | | | |
| | | 100 | 868.30 MHz | | | |
| | | 101 | 868.65 MHz | | | |
| | | 110 | 868.95 MHz | | | |
| | | 111 | 869.85 MHz | | | |
| D8 | Modulation | 0 | FSK | 0 | 1 | Modulation format. |
| | | 1 | OOK | | | |
| D(7:5) | Freq. Deviation | 000 | 10 kHz | 010 | 010 | FSK Frequency deviation (not used in OOK mode). |
| | | 001 | 12.5 kHz | | | |
| | | 010 | 20 kHz | | | |
| | | 011 | 25 kHz | | | |
| | | 100 | 40 kHz | | | |
| | | 101 | 50 kHz | | | |
| | | 110 | 80 kHz | | | |
| | | 111 | 100 kHz | | | |
| D4 | RF Power | 0 | 0 dBm | 1 | 1 | Programmed RF output power. |
| | | 1 | 1 dBm | | | |
| D3 | TX Timer | 0 | 2 ms | 0 | 1 | Transmit power-off timer. |
| | | 1 | 20 ms | | | |
| D(2:0) | Fine Tuning | 011 | fc + 6 * PLL Step | 000 | 000 | Fine tuning from programmed center frequency. |
| | | 010 | fc + 4 * PLL Step | | | |
| | | 001 | fc + 2 * PLL Step | | | |
| | | 000 | fc + 0 * PLL Step | | | |
| | | 111 | fc - 2 * PLL Step | | | |
| | | 110 | fc - 4 * PLL Step | | | |
| | | 101 | fc - 6 * PLL Step | | | |
| | | 100 | fc - 8 * PLL Step | | | |

**FIGURE 1: CONFIGURATION REGISTER WRITE**

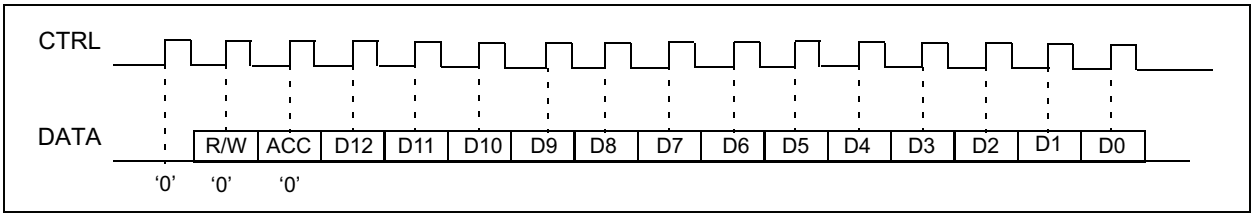
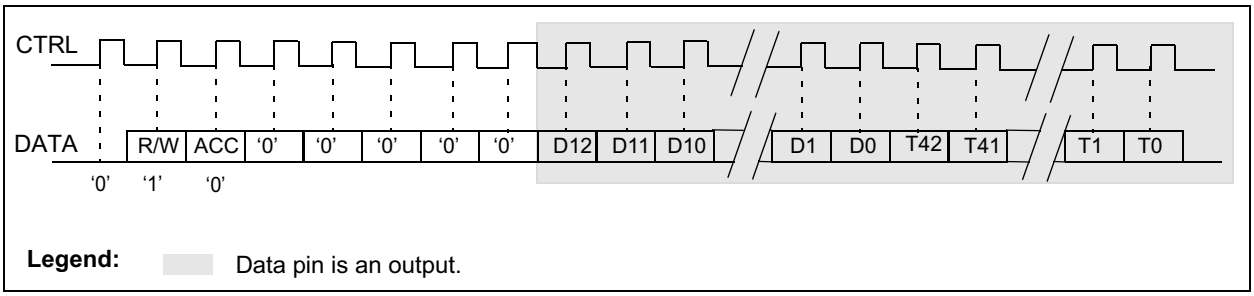



**FIGURE 2: CONFIGURATION REGISTER READ**




## POWERING-ON THE TRANSMITTER

When the transmitter is not active (no RF emission), the entire transmitter section is in Sleep mode.

When using the Advanced mode, the transmitter can be placed in Transmit mode in two ways. This is dependent of the bit D12 in the Configuration Word (Tx mode).

1. When Tx Mode = 0: a rising edge on the DATA line activates the start-up process. The DATA pin must be held high for a period longer than the transmitter start-up time (2 ms). After this start-up pulse, the transmitter is ready to send data over-the-air. The transition back to Sleep mode is done automatically after an inactivity period, in which the DATA line is held low. This power-off time is programmable using the D3 bit in the Configuration register. The available settings are 2 ms and 20 ms. If the transmitter implements KEELOQ®, we recommend using a power-off time of 20 ms. This is because a typical KEELOQ pocket includes a 2 ms header, which could be interpreted by the transmitter as a time-out period and the transmitter will shut down.
2. When Tx Mode = 1: When setting the D12 bit to logic 1 (by writing to the Configuration register), the transmitter will be placed directly into Transmit mode. After setting the bit, a transmitter start-up time (2 ms) is required. After this start-up period the transmitter is ready to send data over-the-air. The transmitter will remain in Transmit mode until bit D12 is set back in logic zero. The above (when D12 = 0) power-off time is applied (2 or 20 ms).

When using the Preset mode, only the automatic start-up mode is available. The DATA pin must be held high for a period longer than the transmitter start-up time (2 ms). After this start-up pulse, the transmitter is ready to send data over-the-air. The transition back to Sleep mode is done automatically after a period of 2 ms (when using the preset mode for 433 MHz OOK), or 20 ms (when using the preset mode for 868 MHz FSK).

## TRANSMITTER CONFIGURATION

The transmitter can be configured by writing to the Configuration register. The following codes show a transmitter configuration example.

The following definitions (Example 1) can be found in the *12LF1840T48ASettings.h* file:

**EXAMPLE 1:**

```
#define T48_AUTO_WAKE_UP    0b0000000000000
#define T48_FORCED_TX       0b1000000000000
#define T48_FREQ_41800      0b0000000000000
#define T48_FREQ_43342      0b0001000000000
#define T48_FREQ_43392      0b0010000000000
#define T48_FREQ_86400      0b0011000000000
#define T48_FREQ_86830      0b0100000000000
#define T48_FREQ_86865      0b0101000000000
#define T48_FREQ_86895      0b0110000000000
#define T48_FREQ_86985      0b0111000000000
#define T48_MOD_FSK         0b0000000000000
#define T48_MOD_OOK         0b0000100000000
#define T48_DEV_10K         0b0000000000000
#define T48_DEV_12K         0b0000000100000
#define T48_DEV_20K         0b0000001000000
#define T48_DEV_25K         0b0000001100000
#define T48_DEV_40K         0b0000010000000
#define T48_DEV_50K         0b0000010100000
#define T48_DEV_80K         0b0000011000000
#define T48_DEV_100K        0b0000011100000
#define T48_TX_0dB          0b0000000000000
#define T48_TX_10dB         0b0000000010000
#define T48_TX_2mS          0b0000000000000
#define T48_TX_20mS         0b0000000001000
#define T48_TUNE_6PLL       0b0000000000011
#define T48_TUNE_4PLL       0b0000000000010
#define T48_TUNE_2PLL       0b0000000000001
#define T48_TUNE_0PLL       0b0000000000000
#define T48_TUNE_-2PLL      0b0000000000111
#define T48_TUNE__4PLL      0b0000000000110
#define T48_TUNE__6PLL      0b0000000000101
#define T48_TUNE__8PLL      0b0000000000100
```

The following functions (Example 2) can be found in the *12LF1840T48ACommands.c* file:

**EXAMPLE 2:**

```
void sendTxCommand (int cmd)
{
     sendByteTxCommand((cmd & 0xFF00) >> 8);
     sendByteTxCommand((cmd & 0x00FF));
}
void sendByteTxCommand(unsigned char cmd)
{
     char i;
     for (i=0; i<8; i++)
     {
         if (cmd & 0x80)
             RA2 = 1;
         else
             RA2 = 0;

         CTRL = 1;
         NOP();
         NOP();
         CTRL = 0;
         cmd = cmd << 1;
     }
}
```

Configuring the transmitter is done by calling the `sendTxCommand` function. This command takes as parameter a bitwise OR with the selected configuration (Example 3).

**EXAMPLE 3:**

```
sendTxCommand
(
     T48_AUTO_WAKE_UP |
     T48_FREQ_43392 |
     T48_MOD_OOK |
     T48_DEV_20K |
     T48_TX_10dB |
     T48_TX_20mS|
     T48_TUNE_0PLL
);
```

**FIGURE 3: ANTENNA DESIGN. OVERALL BOARD DIMENSIONS**

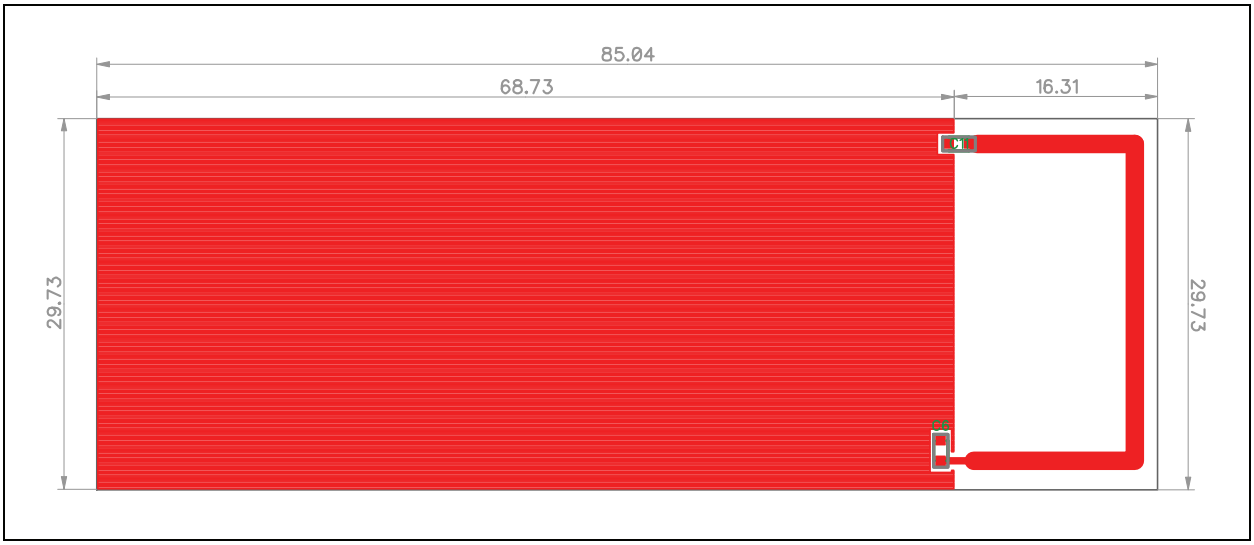
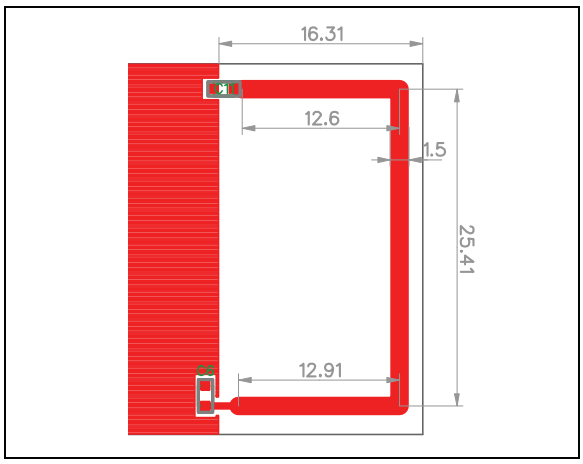


**FIGURE 4: ANTENNA DESIGN. LOOP ANTENNA DIMENSIONS**




## CONCLUSION

The PIC12LF1840T48A is a Microchip microcontroller with an integrated RF transmitter. This document helps the user design a transmitter using this device. A high level of integration combined with a large variety of RF configurations and an overall low cost make this design an ideal solution for a radio transmitter. This device is fully compatible with the existing KEELOQ security solutions.

## APPENDIX A: REVISION HISTORY

### Revision A (9/2011)

Initial Release.

### Revision B (11/2011)

Revised Title; Revised Figure 5.

## ANNEX – TRANSMITTER SCHEMATICS

A reference schematic diagram with an RF filter and matching network is provided. The component values are given for 433.92 MHz. The crystal is a low-cost 26 MHz HC-49.

**FIGURE 5: REFERENCE DESIGN TRANSMITTER SCHEMATIC – USING THE CTRL LINE**

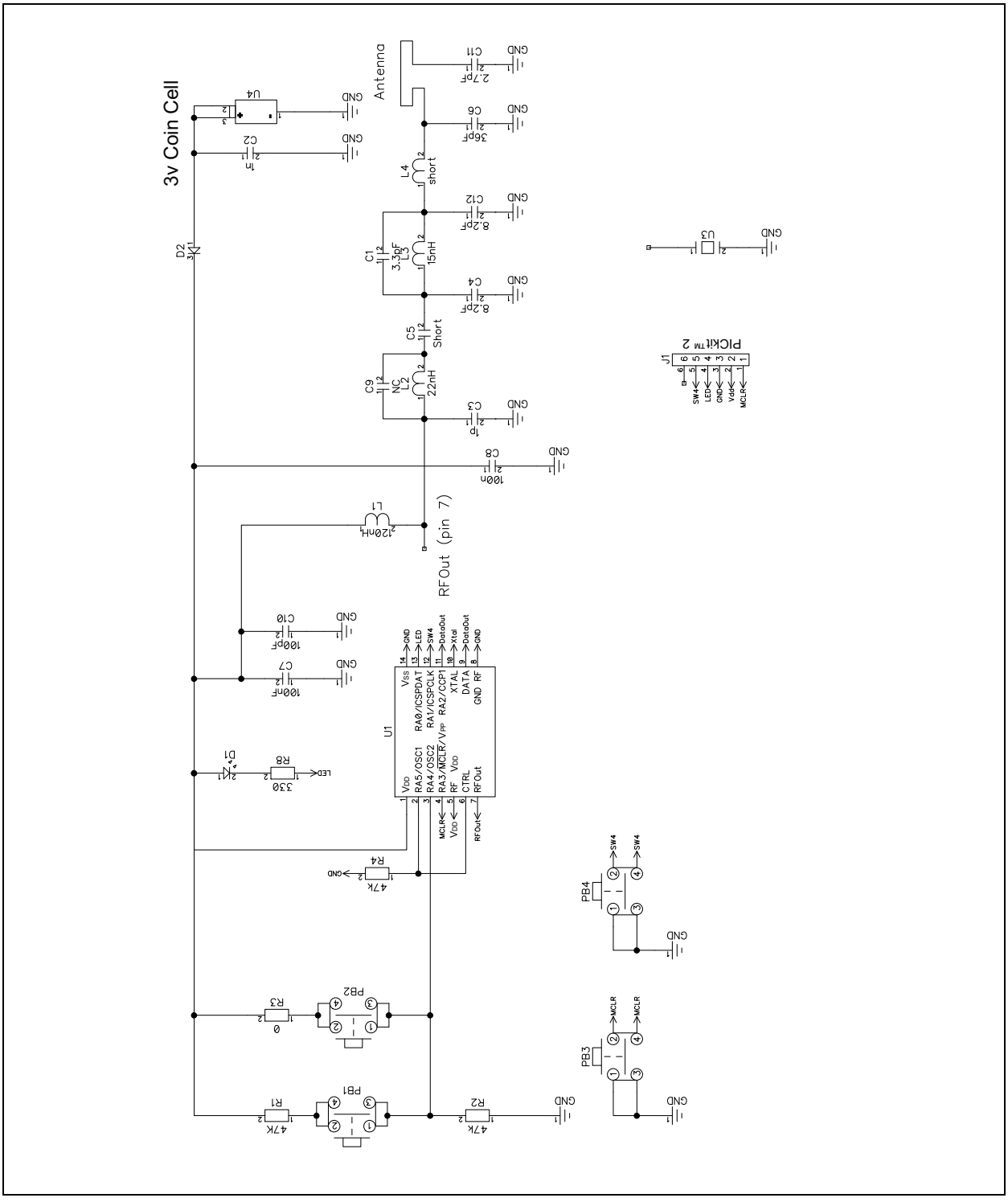
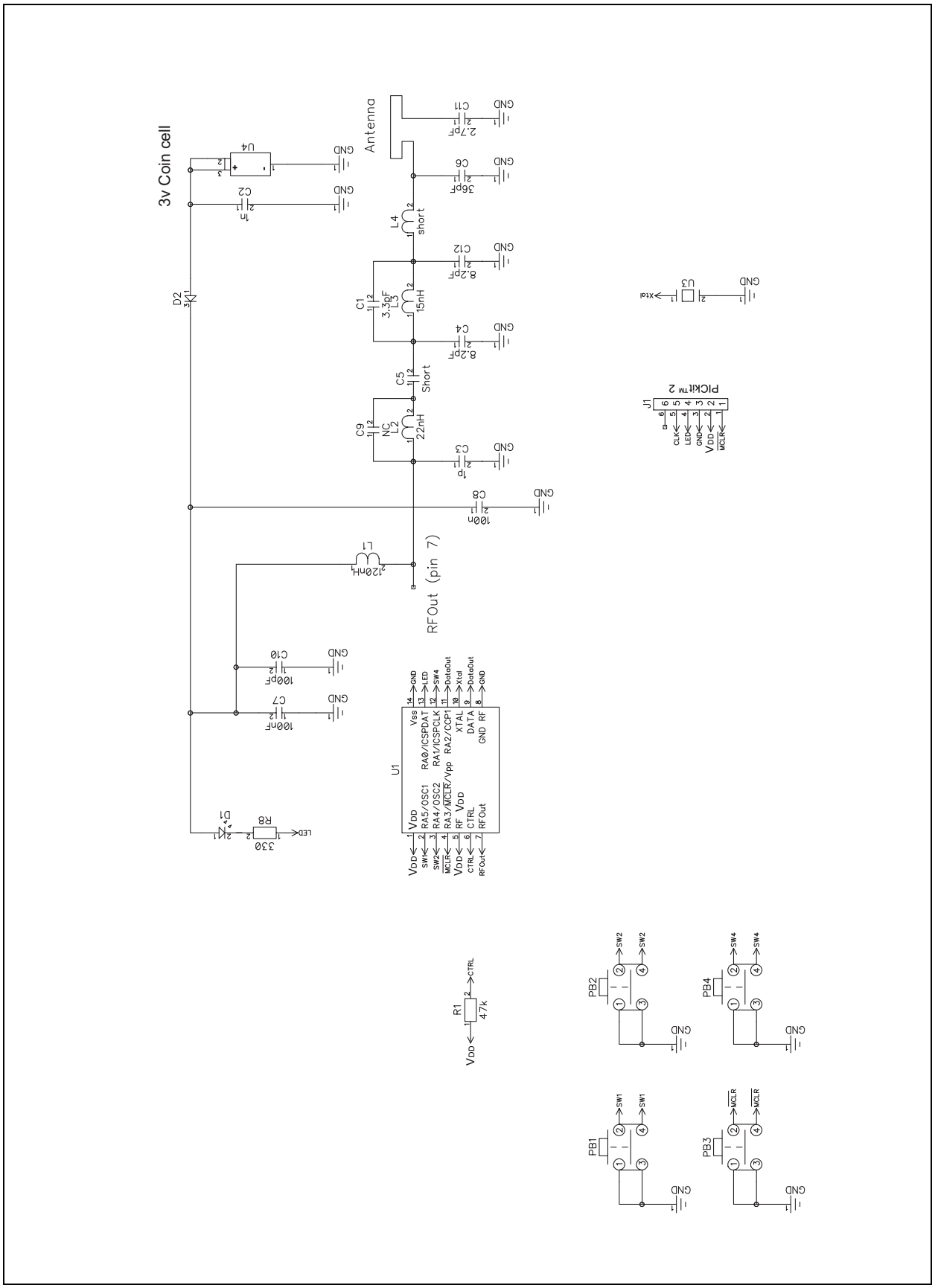


**FIGURE 6: REFERENCE DESIGN TRANSMITTER SCHEMATIC – USING THE PRESET MODE**



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