Application Report

Optimizing the SimpleLink CC1352P for Coin Cell Operation at 10 dBm Output Power

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ABSTRACT

This application report describes how to configure the high-power PA in the SimpleLink™ CC1352P and CC2652P devices for 10 dBm operation at 2.4 GHz with a current consumption of only 22 mA. This is a suitable solution for energy constrained applications running off coin cell batteries or similar.

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1 Introduction

The SimpleLink CC1352P and CC2652P devices are multiprotocol, multi-band, Sub-1 GHz and 2.4 GHz wireless MCUs supporting Wireless M-Bus, IEEE 802.15.4g, IPv6-enabled smart objects (6LoWPAN), Thread, Zigbee®, KNX RF, Wi-SUN®, Bluetooth® 5 Low Energy, and proprietary systems. The devices contain an integrated high-power amplifier (PA) with best-in-class efficiency for long-range applications delivering up to 20 dBm.

The current consumption for 20 dBm output power at 2.4 GHz is more than 80 mA, and not suitable for applications running off of small size batteries such as coin cells. To mitigate this constraint, this application report documents how the PA can be optimized to achieve its highest efficiency at 10 dBm output power, reducing the peak current consumption to only 22 mA at 3.0 V. 10 dBm output power is selected because for several popular protocols, it is the highest allowable power level in Europe.

Two things are required to optimize the PA for 10 dBm operation: a dedicated RF matching network and dedicated radio configuration settings. The former is covered in this document, while the latter is found in the applicable SDKs and SmartRF™ Studio software.

2 RF Matching Network

The RF matching network consists of a balun and filter. The combination of the balun and filter also transforms the complex differential output impedance of the PA to 50 Ω. Furthermore, the PA is biased (powered) through the external RF network. To output 20 dBm, the PA is biased from VDDS to allow a large enough voltage swing.

To optimize the PA for 10 dBm operation, two changes must be done:

- First, the biasing is changed from VDDS to VDDR. This moves the DC operating point of the output stage and thus reduces the available output power to 10 dBm while maintaining high efficiency. Since VDDR is typically derived from the internal DCDC regulator that has very high efficiency, biasing from VDDR also reduces the overall current consumption for the radio.
- Second, update the component values in the RF matching network. Because the operating point of the PA is changed with different biasing and different output power, the optimum load impedance is also changed and thus the external matching must be adapted accordingly.

The resulting recommended schematic for 10 dBm PA operation is shown in Appendix A.1.

For this design, external load capacitors for the 48 MHz crystal should be used to reduce clock spurs.

The layout is based on the CC1352PEM-XD7793-XD24-PA24 design files. The top layer is equal to the top layer from the RF pins to the 50 Ω point, except for the biasing the RF network from VDDR instead of VDDS.

3 System Considerations

The EVM used for the test results presented in this application report, as well as in the *CC1352P SimpleLink™ High-Performance Dual-Band Wireless MCU With Integrated Power Amplifier Data Sheet* or the *CC2652P SimpleLink™ Multiprotocol 2.4 GHz Wireless MCU With Integrated Power Amplifier Data Sheet* (SWRS195), connects the PA output directly to an SMA connector. In a typical application, you would use an RF switch to combine the PA output with the regular 2.4 GHz RF matching for Rx. For an application example, see the LAUNCHXL-CC1352P-2 Design Files. To account for the typical loss in such an RF switch, the 10 dBm output power setting is tuned to output 10.5 dBm on the test EVM.

According to EN300 328 max output power is 10 dBm/MHz E.I.R.P. Depending on the data rate and antenna gain, this may limit the maximum conducted output power delivered to the antenna.

To ensure margins for passing FCC band edge requirements at 2480 MHz for Zigbee, back-off of the output power has to be evaluated.

4 Results

For performance data, see the *CC1352P SimpleLink™ High-Performance Dual-Band Wireless MCU With Integrated Power Amplifier Data Sheet* or the *CC2652P SimpleLink™ Multiprotocol 2.4 GHz Wireless MCU With Integrated Power Amplifier Data Sheet*.

For some units, the conducted output power will be higher than the ETSI and FCC limit for frequencies ranging between 200 MHz to 300 MHz. Energy in this frequency range will be attenuated by the antenna and radiated measurements will pass.

5 Settings

The following is valid for SmartRF Studio 2.19 or later.

To export the settings required, do the following in SmartRF Studio:

- Open CC1352P. Select either "BLE mode" or "IEEE 802.15.4 mode"
- In the "RF Design Based On" pulldown, select "LAUNCHXL-CC1352P-4"

The settings are characterized for BLE and Zigbee but may be used for proprietary.

> **WARNING**
> The settings can only be used with hardware where the high-power PA is biased from VDDR. If the high-power PA is biased from VDDS, and these settings are used, the PA will operate outside the recommended operating conditions.

5.1 PA table

The power table exported by SmartRF Studio will look like the following:

```
RF_TxPowerTable_Entry txPowerTable[TX_POWER_TABLE_SIZE] =
{
  {6,  RF_TxPowerTable_HIGH_PA_ENTRY(42, 0, 1, 39, 20) },
  {7,  RF_TxPowerTable_HIGH_PA_ENTRY(31, 1, 0, 20, 20) },
  {8,  RF_TxPowerTable_HIGH_PA_ENTRY(26, 1, 1, 25, 16) },
  {9,  RF_TxPowerTable_HIGH_PA_ENTRY(31, 1, 1, 31, 16) },
  {10, RF_TxPowerTable_HIGH_PA_ENTRY(38, 1, 1, 39, 16) },
    RF_TxPowerTable_TERMINATION_ENTRY
};
```

For applications that do not use this table, the output power is set in the following struct:

```
// Overrides for CMD_PROP_RADIO_DIV_SETUP_PA
uint32_t pOverridesTx20[] =
{
    // The TX Power element should always be the first in the list
    TX20_POWER_OVERRIDE(override),
    // The ANADIV radio parameter based on the LO divider (0) and front-end (0) settings
    (uint32_t)0x11C10703,
    // override_phy_tx_pa_ramp_genfsk_hpa.xml
    // Tx: Configure PA ramping, set wait time before turning off (0x2F ticks of 16/24 us = 31.3 us).
    HW_REG_OVERRIDE(0x6028,0x002F),
    (uint32_t)0xFFFFFFFF,
};
```

With an *override* value from the table below:

Override	Output Power [dBm]
0x104F66	10.5
0x103F5F	9.5
0x10335A	8.5
0x14285F	7.5
0x144F2A	6.5

5.2 Overrides

A total of 3 lines in the override lists are different between the +10 dBm mode and the nominal settings for the high-power PA. The lines that are different are marked in italic in the code below:

```
// Overrides for CMD_BLE5_RADIO_SETUP_PA
uint32_t pOverridesTxStd[] =
{
    // The TX Power element should always be the first in the list
    TX_STD_POWER_OVERRIDE(0x7217),
    // The ANADIV radio parameter based on the LO divider (0) and front-end (0) settings
    (uint32_t)0x05320703,
    // override_txstd_settings.xml
    // Bluetooth 5: Set RTIM offset to default for standard PA
    (uint32_t)0x00008783,
    // Bluetooth 5: Set IPEAK = 3 and DCDC dither off for TX
    (uint32_t)0x00F388D3,
    // Bluetooth 5: Set synth mux to default value for standard PA
    (uint32_t)0x050206C3,
    // Set TXRX pin to 0 in RX and high impedance in idle/TX.
    HW_REG_OVERRIDE(0x60A8,0x0401),
    (uint32_t)0xFFFFFFFF
};
// Overrides for CMD_BLE5_RADIO_SETUP_PA
uint32_t pOverridesTx20[] =
{
    // The TX Power element should always be the first in the list. Will be overwritten by smartRF
studio
    TX20_POWER_OVERRIDE(0x413D982B),
    // The ANADIV radio parameter based on the LO divider (0) and front-end (0) settings
    (uint32_t)0x01C20703,
    // override_tx20_settings.xml
    // Bluetooth 5: Set RTIM offset to 3 for high power PA
    (uint32_t)0x00038783,
// Bluetooth 5: Set IPEAK = 7 and DCDC dither off for TX
    (uint32_t)0x00F788D3,
    // Bluetooth 5: Set synth mux for high power PA
    (uint32_t)0x010206C3,
    // Set TXRX pin to 0 in RX/TX and high impedance in idle.
    HW_REG_OVERRIDE(0x60A8,0x0001),
// Set VCTRIM = 0 for HPA
ADI_REG_OVERRIDE(1,26,0xF,0x0),
    (uint32_t)0xFFFFFFFF
};
```

A Design Details

A.1 Schematic

Figure A-1 shows the schematic for the board used for testing. Only the 10 dBm 2.4 Ghz path has been tested on this specific board.

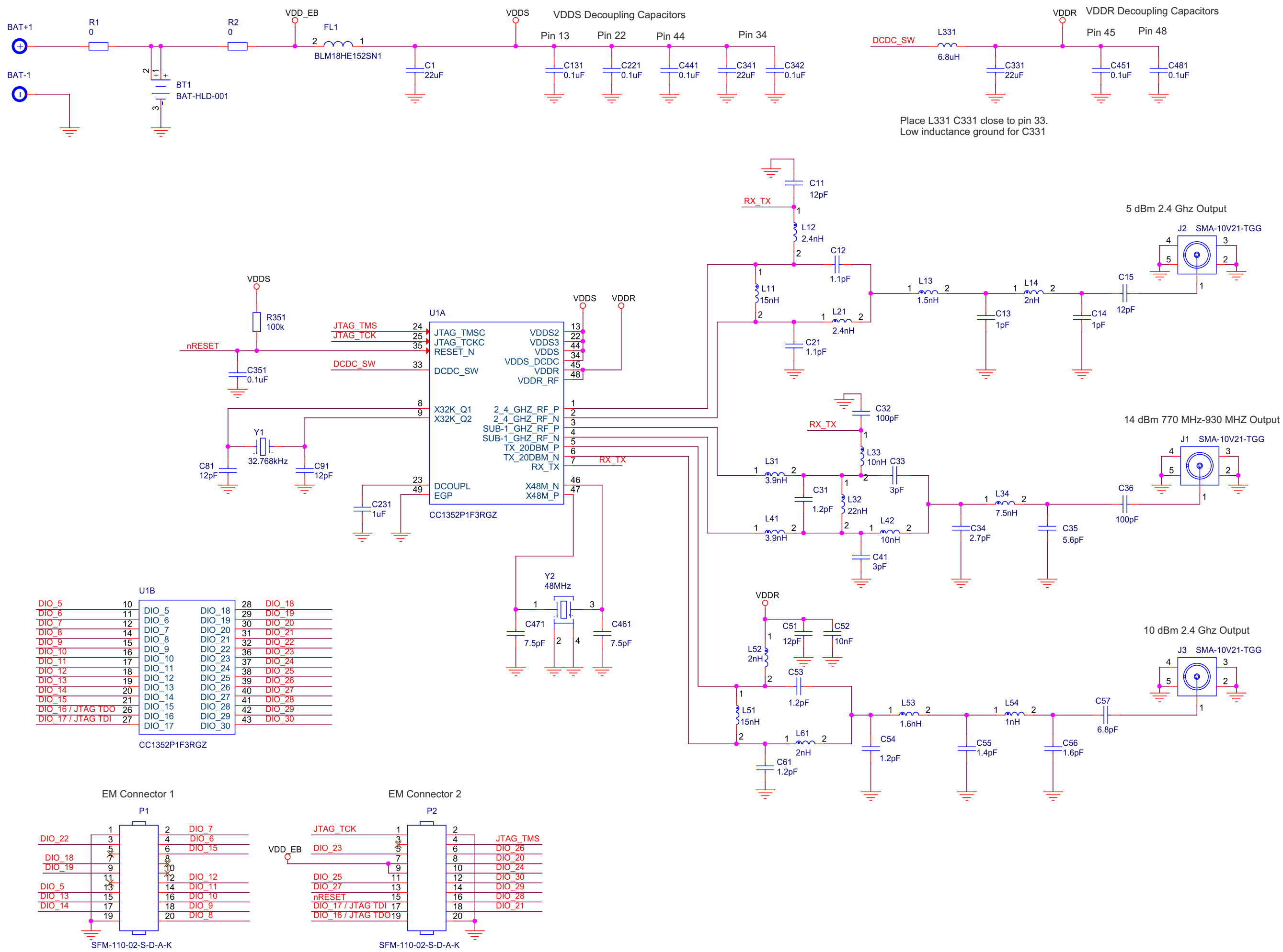

Figure A-1. CC1352PEM-XD7793-XD24-PA24_10dBm Schematic

A.2 Layout

The two plots below show the layout. Figure A-2 shows the layout of the full board used for testing. Figure A-3 shows a zoomed in version showing the VDDR traces.

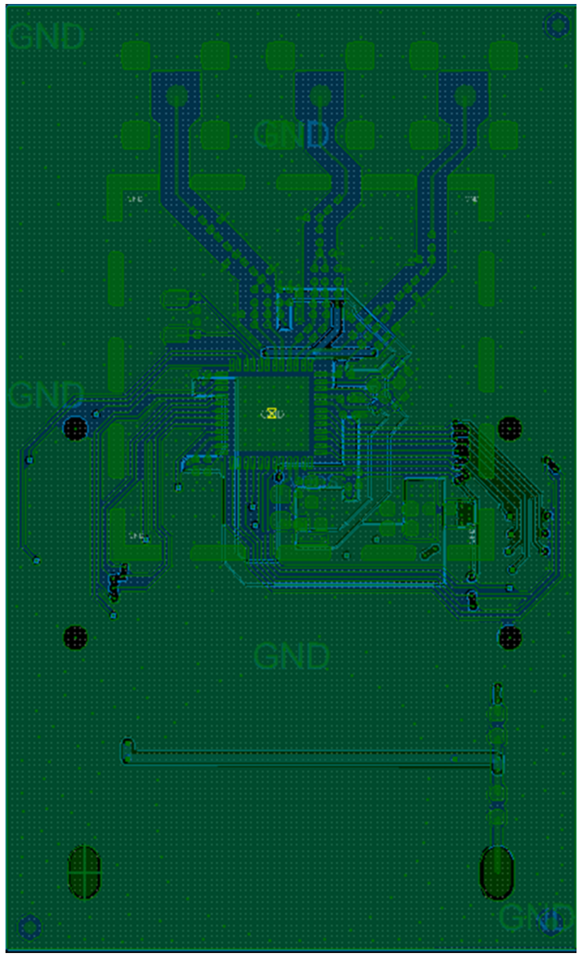

Figure A-2. CC1352PEM-XD7793-XD24-PA24_10dBm Layout, Full

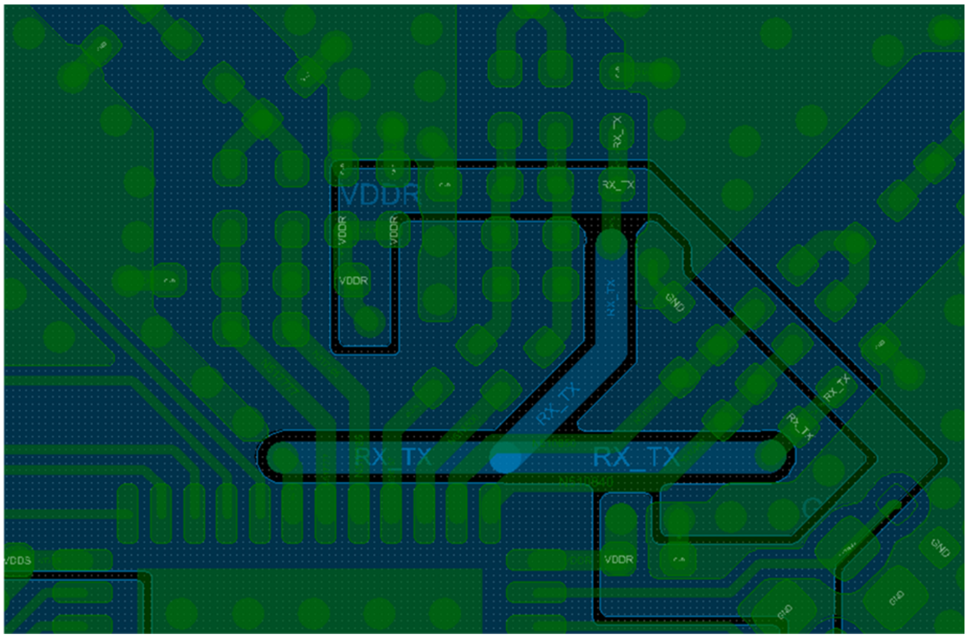

Figure A-3. CC1352PEM-XD7793-XD24-PA24_10dBm Layout, Zoomed

B References

- LAUNCHXL-CC1352P-2 Design Files
- Texas Instruments: *CC1352P SimpleLink™ High-Performance Dual-Band Wireless MCU With Integrated Power Amplifier Data Sheet*
- Texas Instruments: *CC2652P SimpleLink™ Multiprotocol 2.4 GHz Wireless MCU With Integrated Power Amplifier Data Sheet*

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (November 2019) to Revision C (December 2020) **Page**

- Updated the numbering format for tables, figures and cross-references throughout the document....................2
- Update was made in Section 5...3