Advanced Low Power Reference Design

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Battery Runtime Extension for GSM High Power Applications

User's Guide & Test Report

CIRCUIT DESCRIPTION

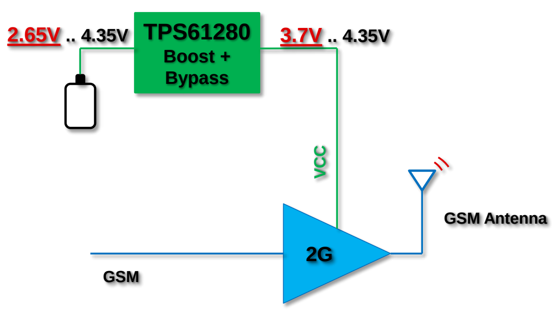
In this Reference Design, the TPS61280 Boost Converter with integrated Bypass Switch powers a Radio Frequency Power Amplifier (RFPA) in GSM Mode.
The TPS61280 RFPA Combo Board enables longer battery runtime by applying a user defined minimum supply voltage for a Radio Frequency system. The whole board features a pre-developed and tested RF compliant power application.

BENEFITS

- Pre-Developed RF Power Application
- Longer Battery runtime
- Avoiding system load dump
- Extended Voltage Range for 2G High Power operation

LINKS

TPS61280 Product Page
TPS61280 Evaluation Module
E2E Support Forum



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1 Introduction

More and more application uses batteries with a low cut off voltage. Such battery types can be Li-Ion (Nickel-Rich as well as Silicon Anode) or LiFePO4 chemistry types. This can be a great benefit for the runtime of a handset systems' charge cycle. For some subsystems, however, this means that the supply voltage can go beyond their necessary optimum supply range.

One example is a GSM transmitter in a battery powered system. This kind of RFPA (Radio Frequency Power Amplifier) requires a certain window for an optimized slot transmission on the one hand. On the other hand, a GSM pulse can cause a line dump due to the high pulse load.

The TPS61280 is a Boost Converter with adjustable input current limit. Its input voltage range goes from 2.3V to 4.8V, which covers typical battery voltage ranges. This device has an additional bypass switch integrated and features a seamless transition between bypass and boost mode.
The device is designed as a pre-regulator to guarantee a minimum supply voltage, especially for noise sensitive applications.

The TPS61280 RFPA Combo Reference Design gives a pre developed example how to supply the power rail of a GSM RFPA. The Design shows the "care-about's" in terms of analog circuitry as well as layout and board design.

2 Board Description

This Evaluation Board contains a fully functional TPS61280 Boost + Bypass and a SKY77629 Multimode Power Amplifier (MMPA) solution. The TPS61280 can supply all applicable power rails of the SKY77629. This Reference Design focuses on GSM communication. This means the main care was taken on the GSM Amplifier supply rail. Figure 1 is a picture of the whole reference design in a test setup.

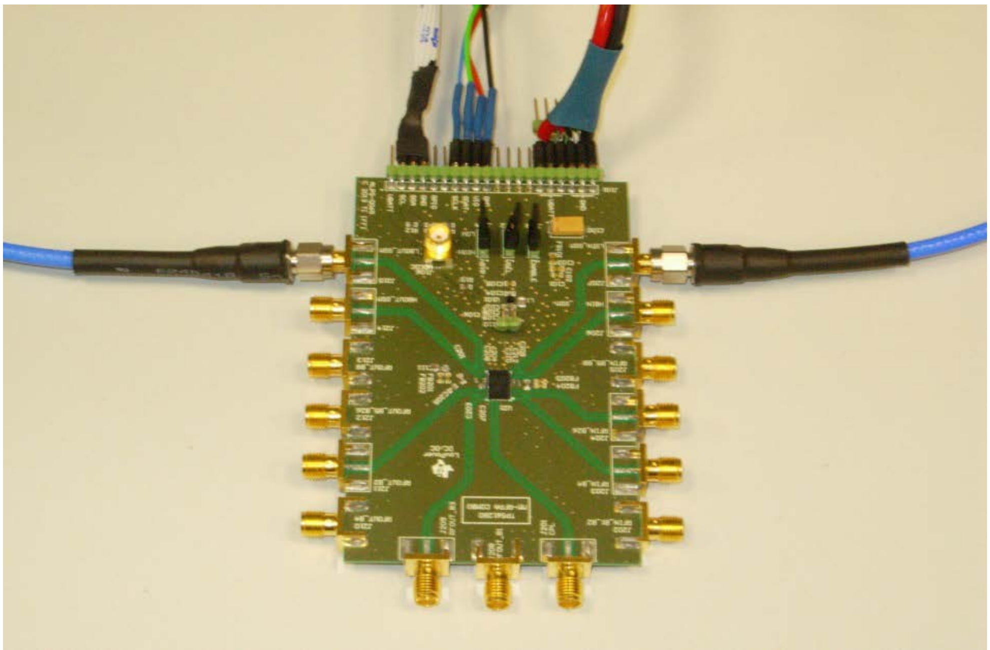


Figure 1: Picture of the board including connections

2.1 Power Block Diagram

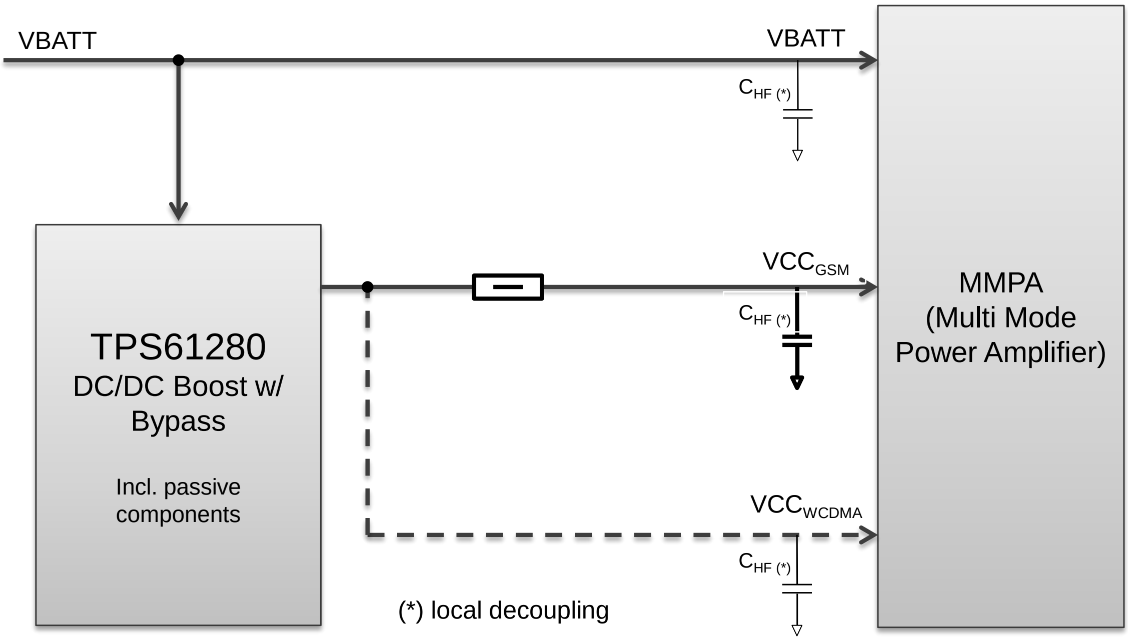


Figure 2: Board Power Block Diagram

Figure 2 shows the board's power block diagram. The TPS61280 supplies the V_{CC} rails for GSM and WCDMA bands. Due to the focus on GSM, the WCDMA rail is dotted. All rails are locally decoupled close to the PA.
As LC-Filter a ferrite bead in combination with the local coupling caps is used. The ferrite bead used is a BLM18PG121SN1 from Murata with a DC resistance of 50mΩ.

2.2 Interface Block Diagram

Figure 3 shows the Block Diagram of the whole Reference Design.
The power parts are illustrated in blue. The input rail V_{BATT} supplies the Boost + Bypass Converter as well as the control rail of the MMPA.
The RF path is figured in green; with the focus is on the 2G Low Band.The communication interfaces are drawn in red.

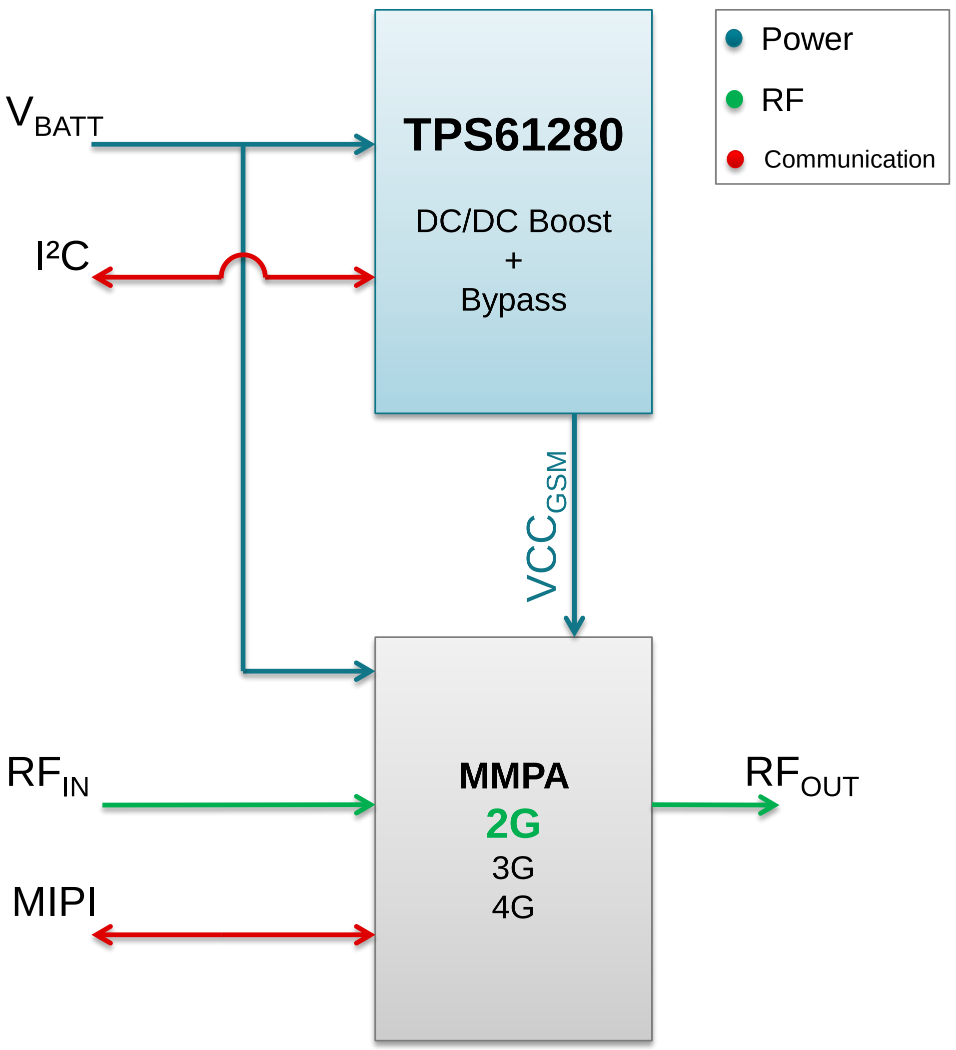


Figure 3: Reference Design Interface Block Diagram

2.3 User Interface Connection

The TPS61280 can be controlled via an I²C Interface. Therefor a USB connection interface is needed. This Interface is available on the Texas Instruments' tools web page.
TPS61280 Evaluation Board User's Guide gives a guideline how to connect and interact with the device. This Users Guide can be seen through the following link: http://www.ti.com/lit/ug/slvu955/slvu955.pdf

The Combo Board enables the user to access all available interfaces, from an RF, control signal and power perspective.
The TPS61280 is accessible via the standardized I²C Bus. For further information, please see the TPS61280 Datasheet.
The SKY77629 MMPA is able to communicate via the MIPI Interface. For further Information's, please refer to the Skyworks webpage.

2.4 Assembly drawing

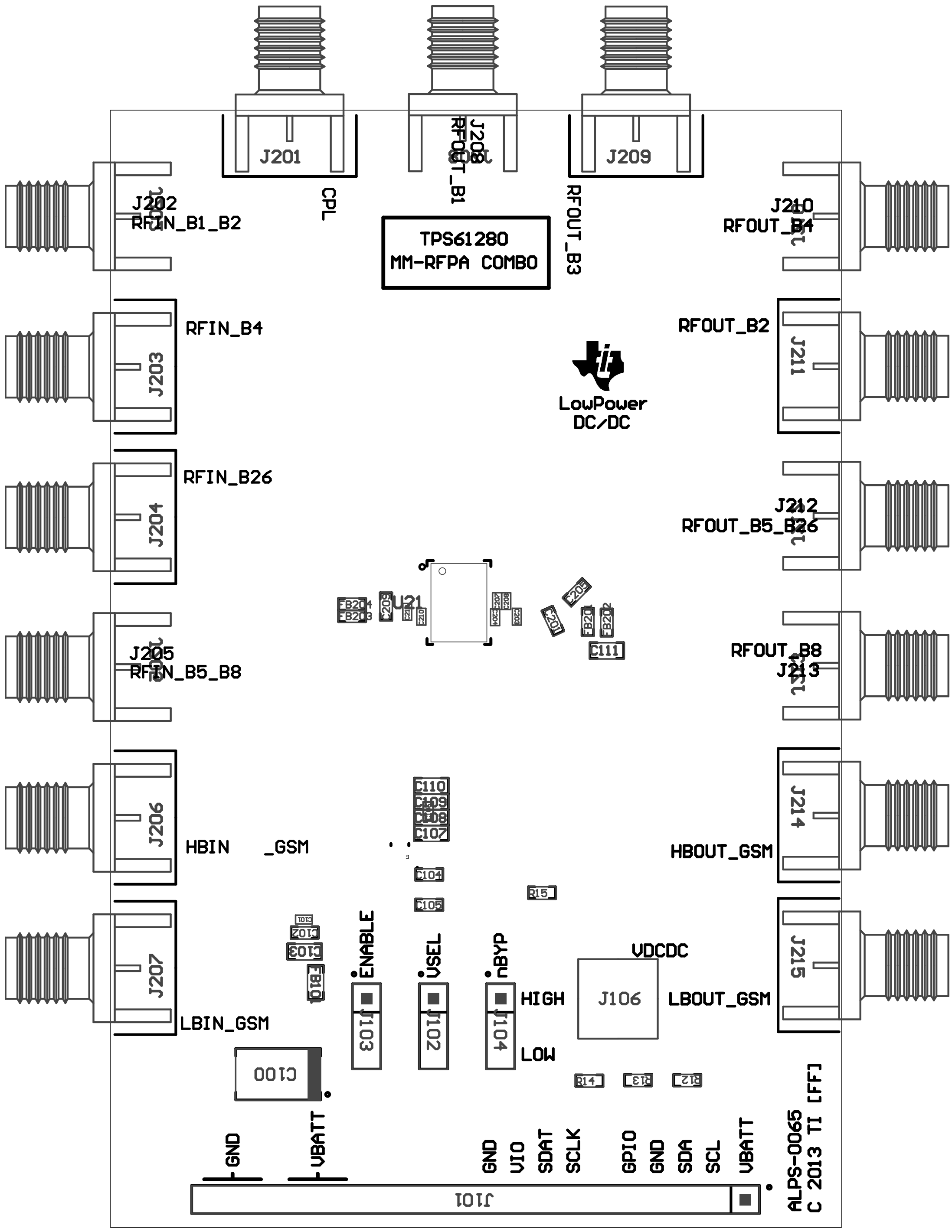


Figure 4: Assembly Drawing

2.5 Interface Connectors

PIN	Name	Description	Port direction
1 2	VBATT	Input (Battery) Voltage, 2.3V to 4.8V	Input
3	VBATT	Input Voltage Sense Line, Pin is routed close to TPS61280 Input	Observation
4	GND	GND Voltage Sense Line, Pin ir routed close to TPS61280 local ground	Observation
5 6	GND	GND connection	Input
7 .. 10		n/c	
11	GND	GND, SKY77629 MIPI Interface	n/a
12	VIO	Logic Input, SKY77629 MIPI Interface	Input
13	SDAT	Logic Input, SKY77629 MIPI Interface	Input
14	SCLK	Logic Input, SKY77629 MIPI Interface	Input
15		n/c	
16	GPIO	TPS61280 GPIO Pin	Input/Output
17	GND	Ground connection, TPS61280 I²C Interface	n/a
18	SDA	Data Line, TPS61280 I²C Interface	Input
19	SCL	Clock Line, TPS61280 I²C Interface	Input
20	VBATT	Input Voltage, TPS61280 I²C Interface	n/a

Table 1: J101 Connector Pin assignment

PIN	Name	Description	Port direction
J106	VDCDC	TPS61280 Output Voltage, 50Ohm matched	Observation Point
J201	CPL		n/c
J202	RFIN_B1_B1	WCDMA band 1 & 2	Input
J203	RFIN_B4	WCDMA band 3 & 4	Input
J204	RFIN_B26	LTE band 26	Input
J205	RFIN_B5_B8	WCDMA band 5 & 8	Input
J206	HBIN_GSM	GSM high band	Input
J207	LBIN_GSM	GSM low band	Input
J208	RFOUT_B1	WCDMA band 1	Output
J209	RFOUT_B3	WCDMA band 3	Output
J210	RFOUT_B4	WCDMA band 4	Output
J211	RFOUT_B2	WCDMA band 2	Output
J212	RFOUT_B5_B26	WCDMA band 5 & 26	Output
J213	RFOUT_B8	WCDMA band 8	Output
J214	HBOUT_GSM	GSM high band	Output
J215	LBOUT_GSM	GSM low band	Output

Table 2: RF Connector descripiton

PIN	Name	Description	Port direction
J102	VSEL	Target voltage selection	Input
J103	EN	Device enable/disable	Input
J104	/BYP	Forced Bypass operation	Input

Table 3: TPS61280 Control Connectors

3 Schematics

Figure 5 through Figure 9 illustrate simplified parts of the Reference Design's schematic. For the entire schematic drawing, please refer to the document in the Reference Design web folder.

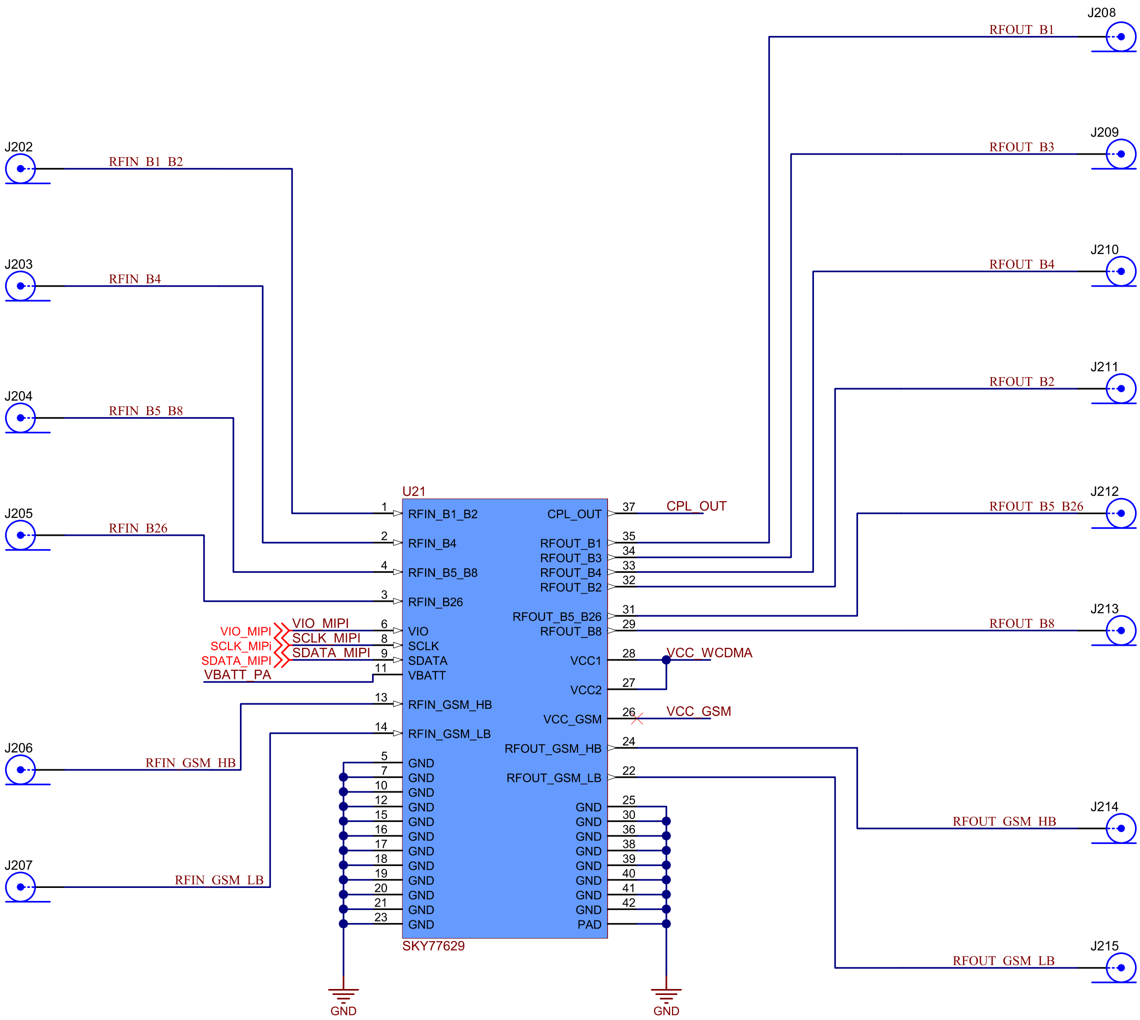


Figure 5: SKY77629 Schematic

Figure 5 shows the MMPA's schematic drawing. All RF terminals are lead trough to SMA connectors.

Figure 6 is the illustration of the power stage solution with TPS61280. The output voltage can be monitored via an impedance matched RF connector. The output rail applies several additional capacitor footprints to enable high flexibility.

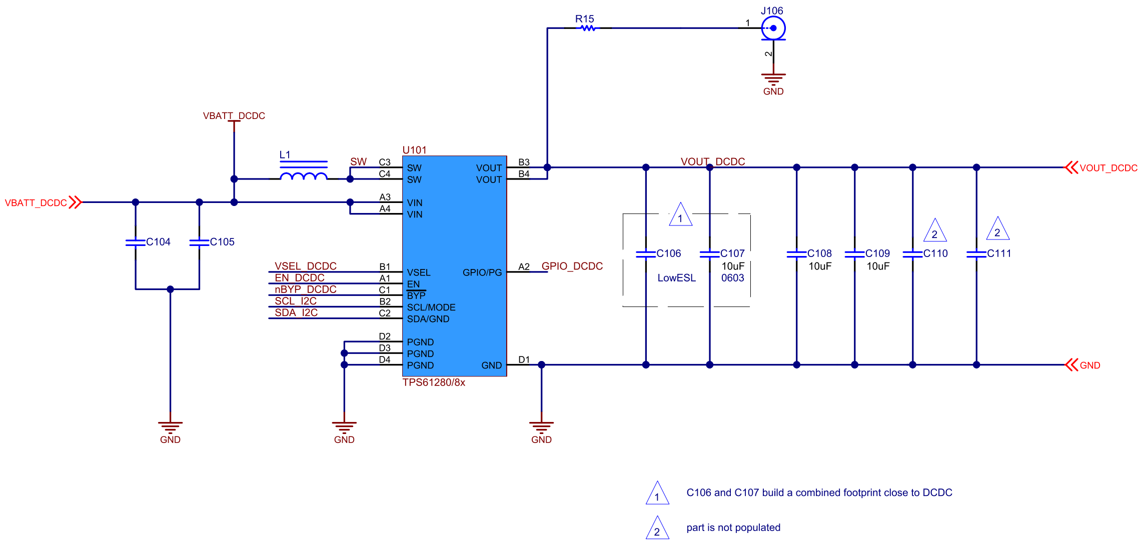


Figure 6: TPS61280 Schematic

Figure 7 shows the decoupling circuits applied to all supply rails of the Radio Frequency Power Amplifier. These circuits enable high flexibility in RF compliant power design. Both rails, $V_{CC;GSM}$ and $V_{CC;WCDMA}$ do have the ability to add a ferrite bead.

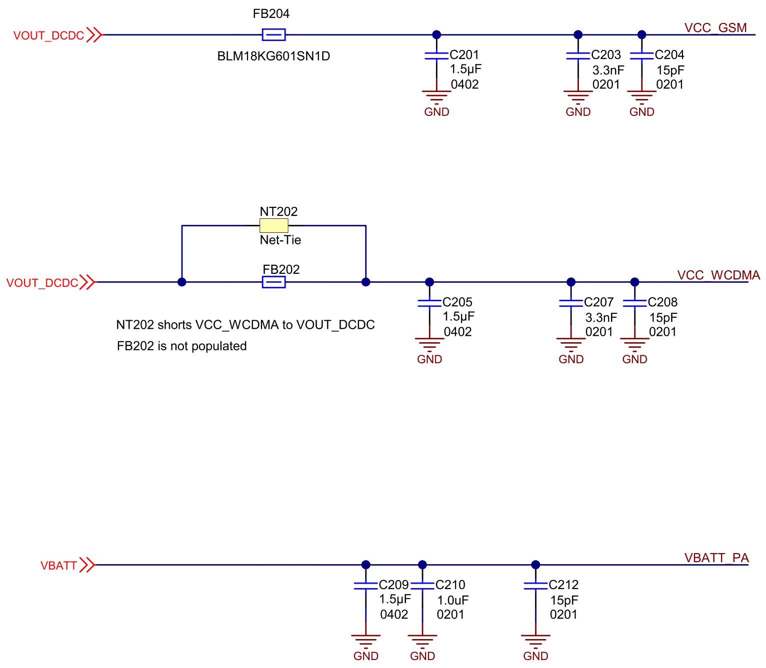


Figure 7: Decoupling Circuits Schematic

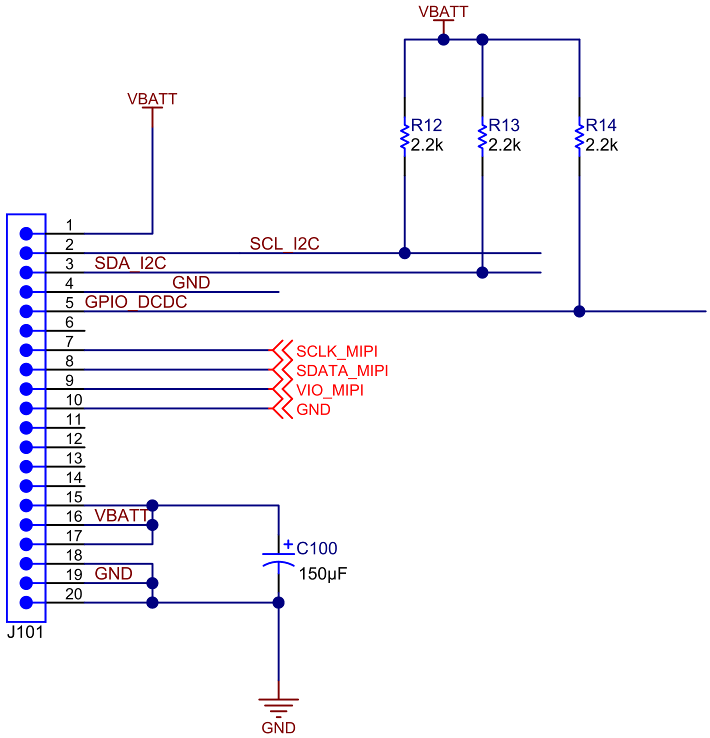


Figure 8: 20-Pin-Connector Interface Schematic

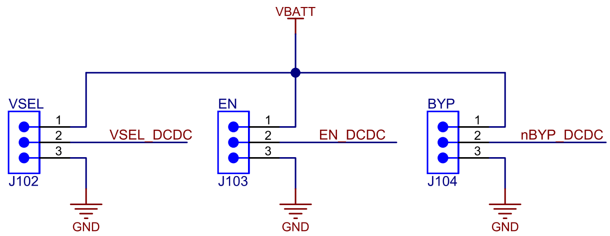


Figure 9: TPS61280 I/O Connectors

Figure 8 and Figure 9 show the circuit for the I/O and Power Interface connections. The Pin assignment and a detailed terminal description can be found in section 2.5.

4 Layout

This board is designed to apply an optimized RF performance. The 6-layer board stack-up reflects this by a 50Ω matching on the one hand. On the other hand it reflects an industrial practicable state of the art stack-up.

4.1 Layer Stack-up

Figure 10 shows the way the board is fabricated with the whole 6 layer stack-up.

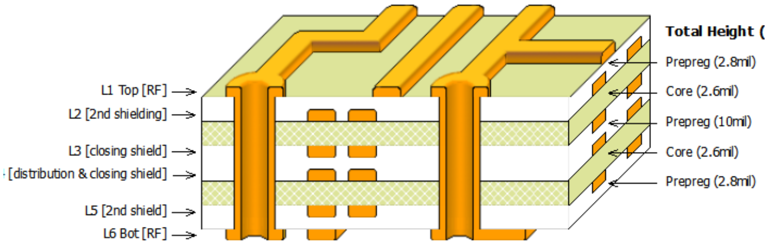


Figure 10: CAD Board RF Stack-up

Figure 11 shows a profile sketch of the routing basics. The red rectangle represents the RF traces. This traces are basically routed with a defined distance to the ground planes (shown in gray) on the same layer and the next inner layer. Only the nest but one layer is fully flooded. This achieves a highly matched coupling for this micro-strip line.

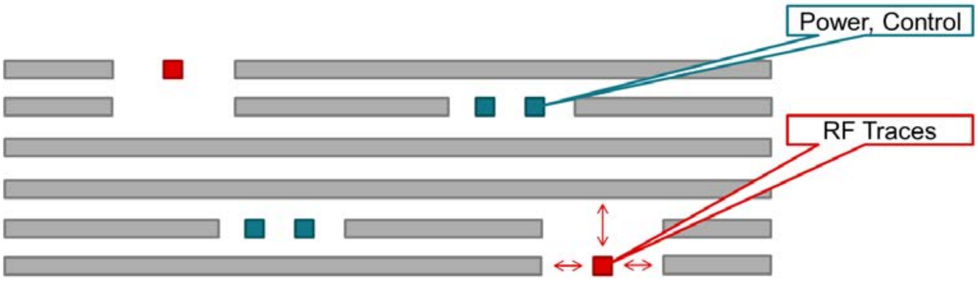


Figure 11: RF Stack-up

4.2 Layer routing

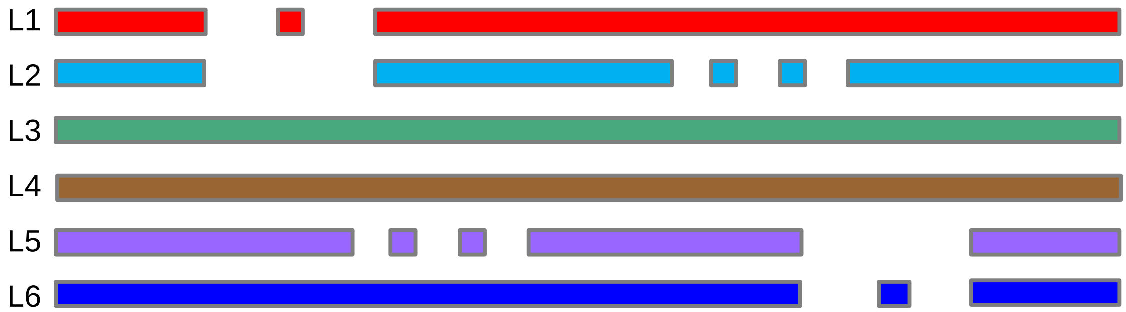


Figure 12: Corresponding Layer set

Figure 12 shows a profile sketch of the entire layers. The color is corresponding to the colors of the board layer, shown in Figure 13 to Figure 18.

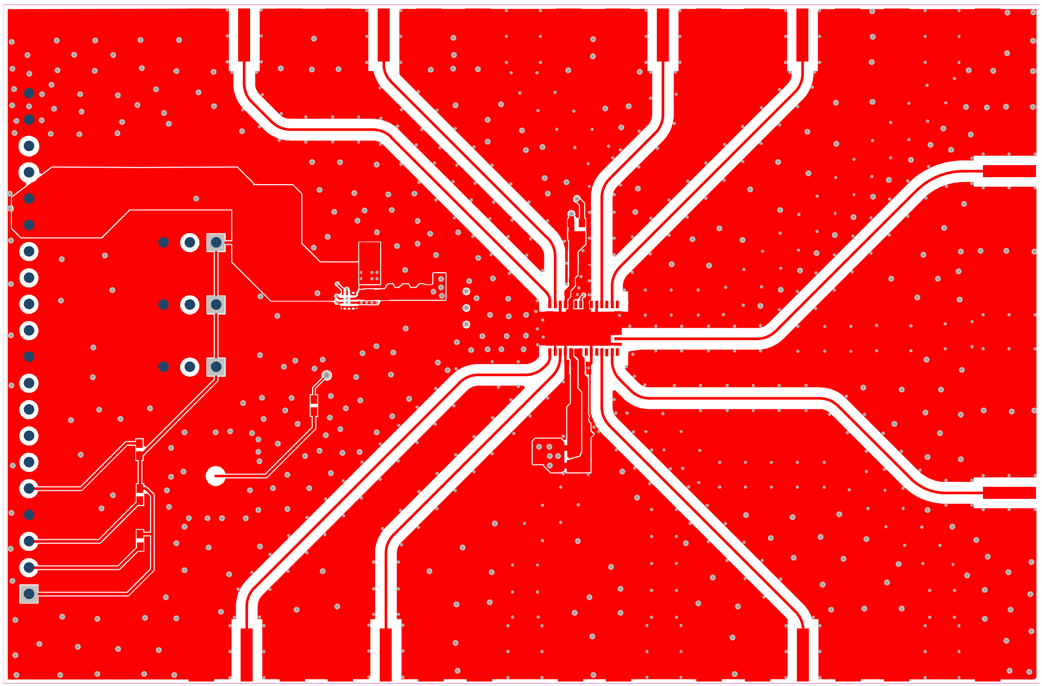


Figure 13: Layer 1, Top

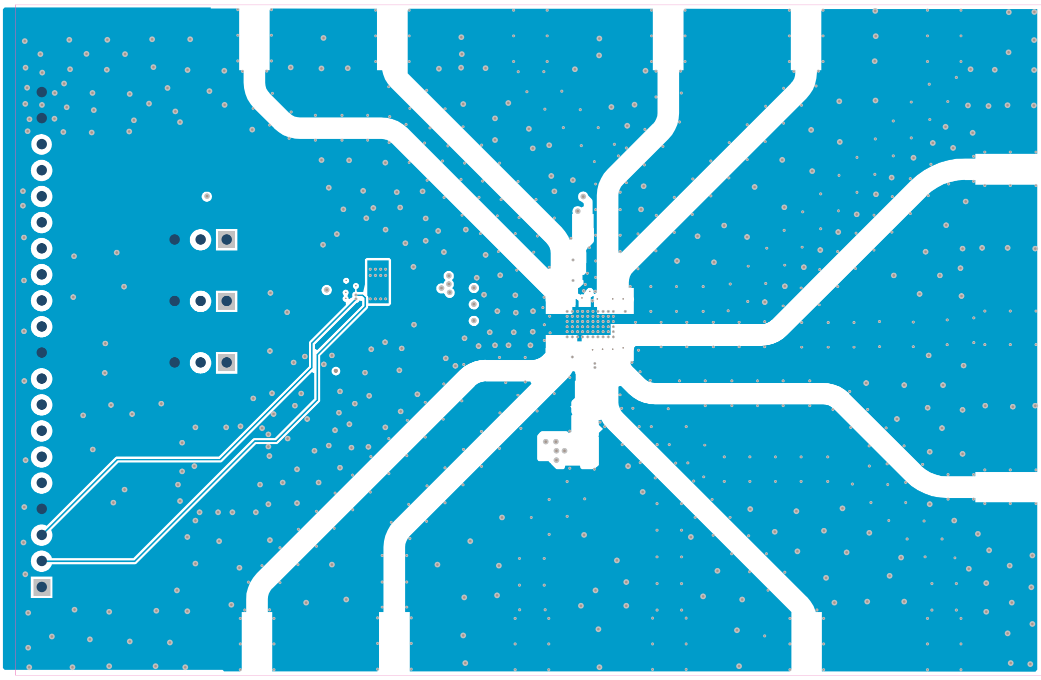


Figure 14: Layer 2

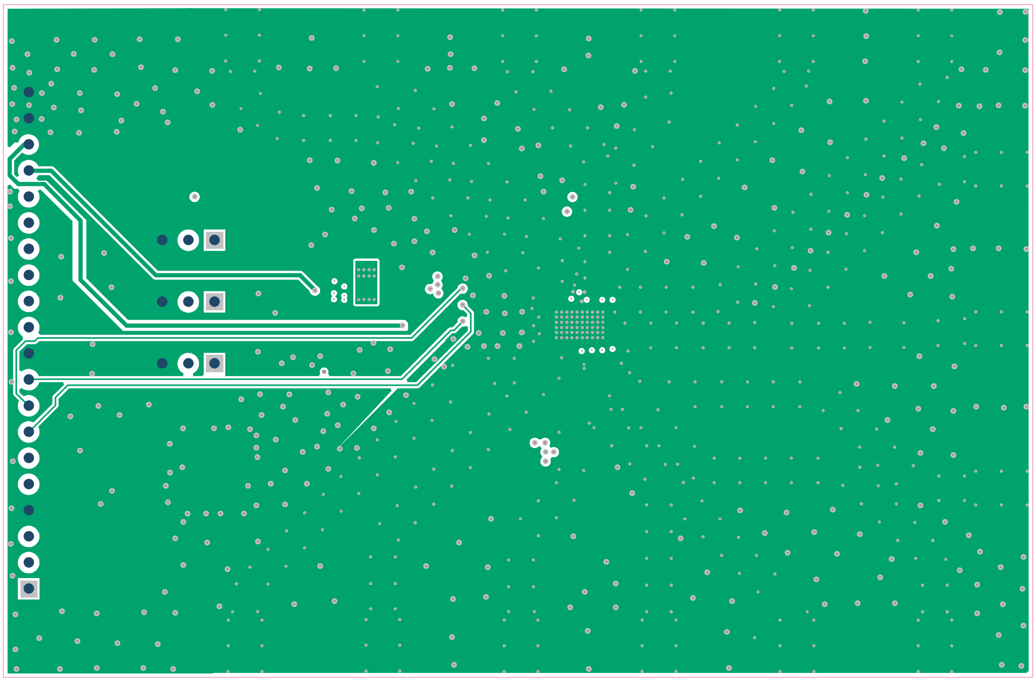


Figure 15: Layer 3

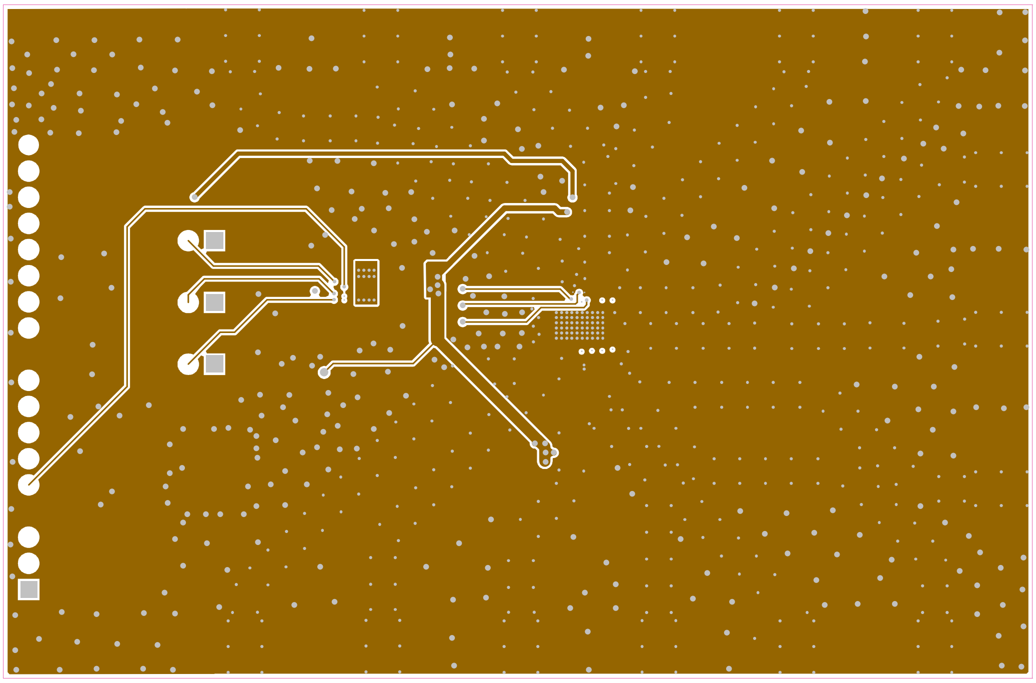


Figure 16: Layer 4

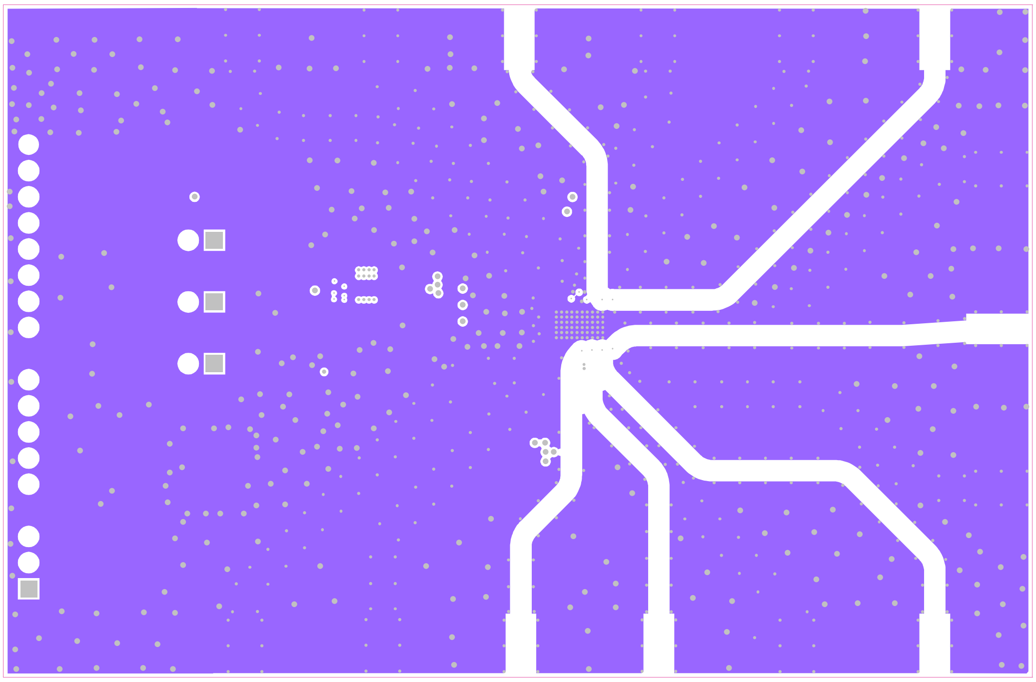


Figure 17: Layer 5

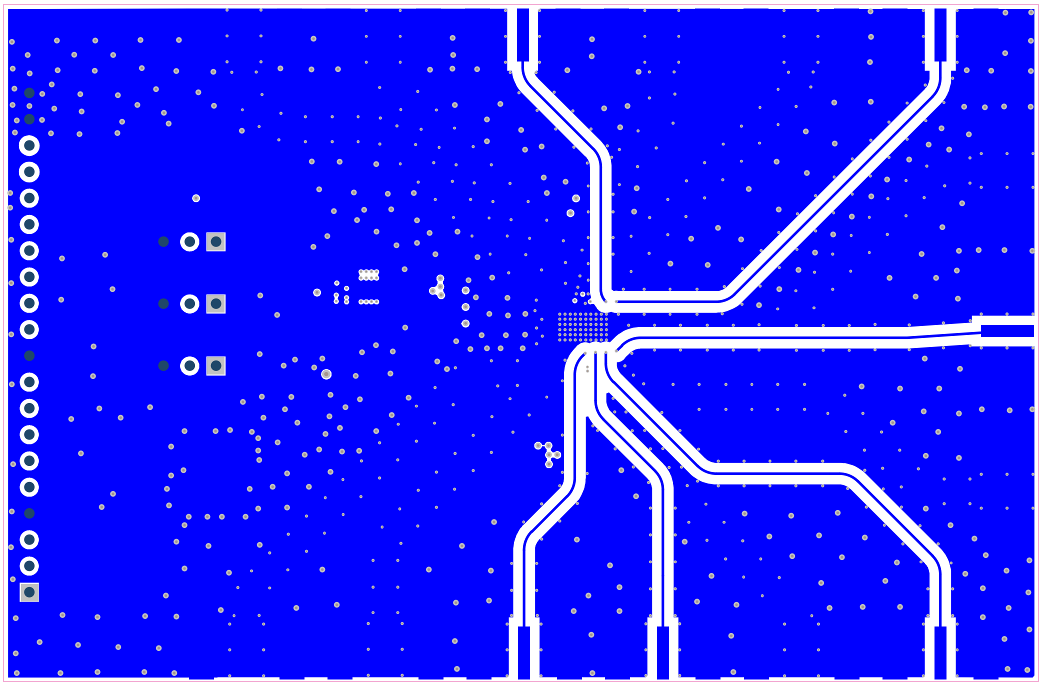


Figure 18: Layer 6, Bottom

5 Measurement Setup

This section shows the setup used for each measurement. Two block diagrams show the way the device and the measurement equipment is connected.

5.1 Block Diagrams

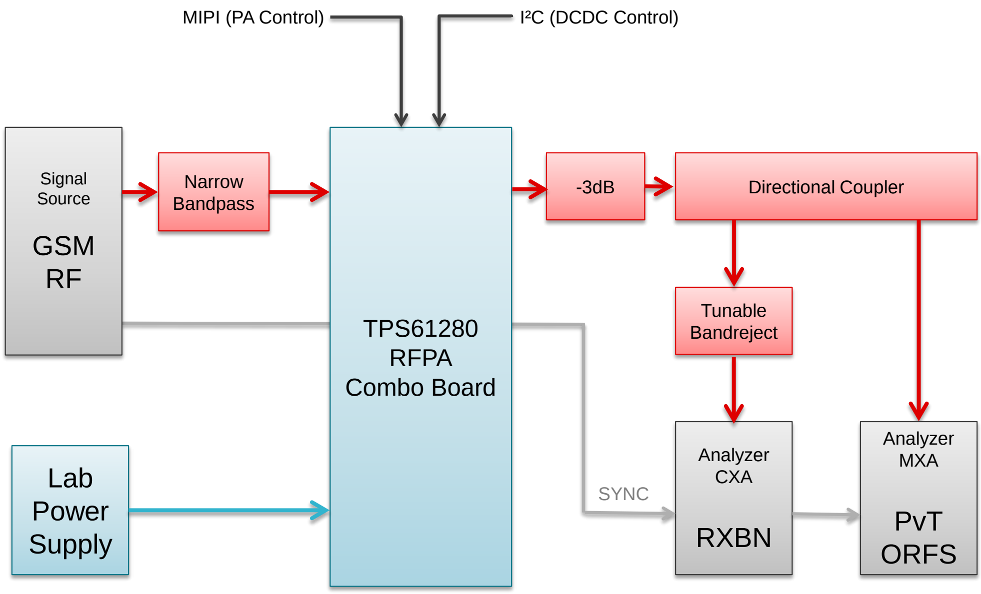


Figure 19: RXBN Test Setup

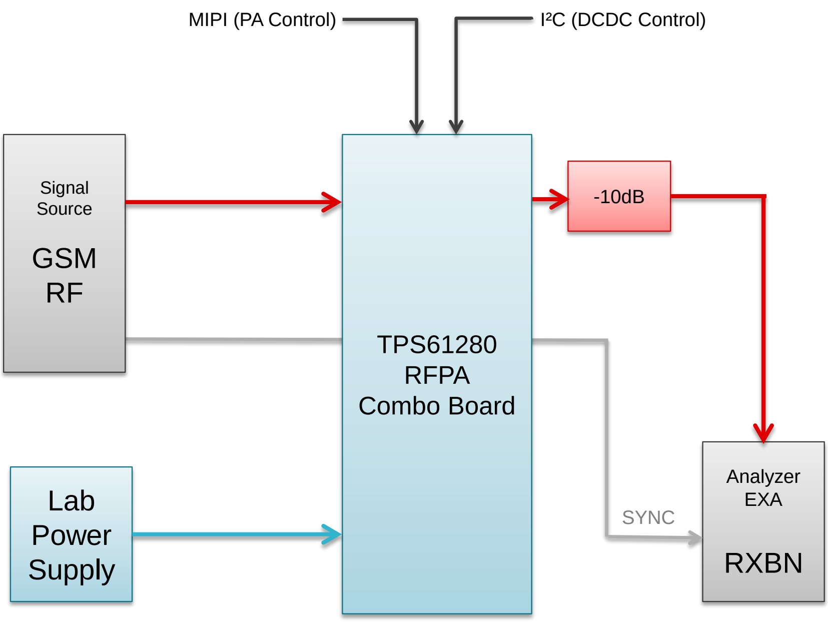


Figure 20: PvT & ORFS Test Setup

6 GSM Measurements

6.1 Power vs. Time, PvT

The GSM measurement Power vs. Time (PvT) shows the behavior of the RFPA's output when applying a single slot. The Power ramp up- and down-curve has to be in certain time-domain window. The measurement reflects this by the green boarders in the figure below.
For this measurement a Input Voltage of 2.7V is applied. The Boost Converter is supposed to boost up the voltage to 3.7V.
This is a Single-Slot GSM 900 PvT Measurement. F_{TX} = 890.2MHz, which is the first frequency slot within the GSM 900 Band.

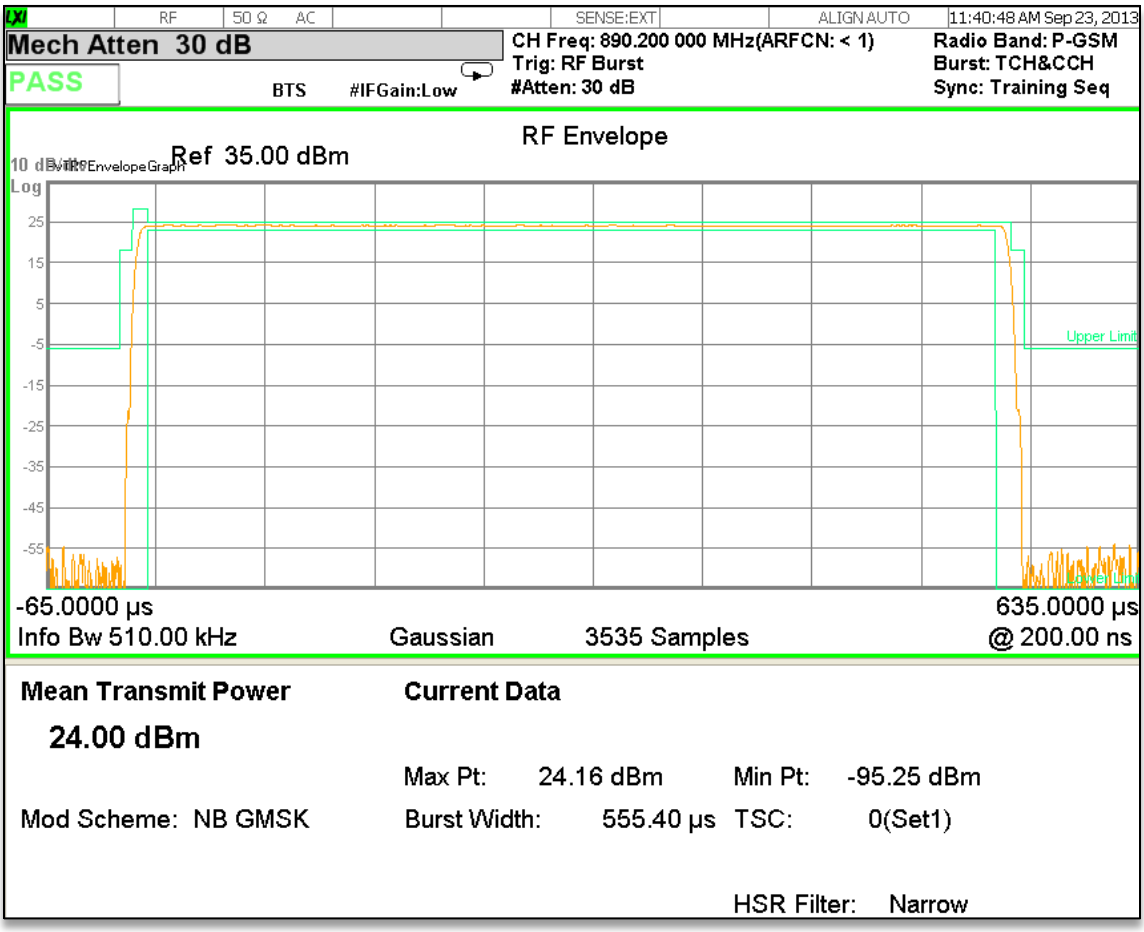
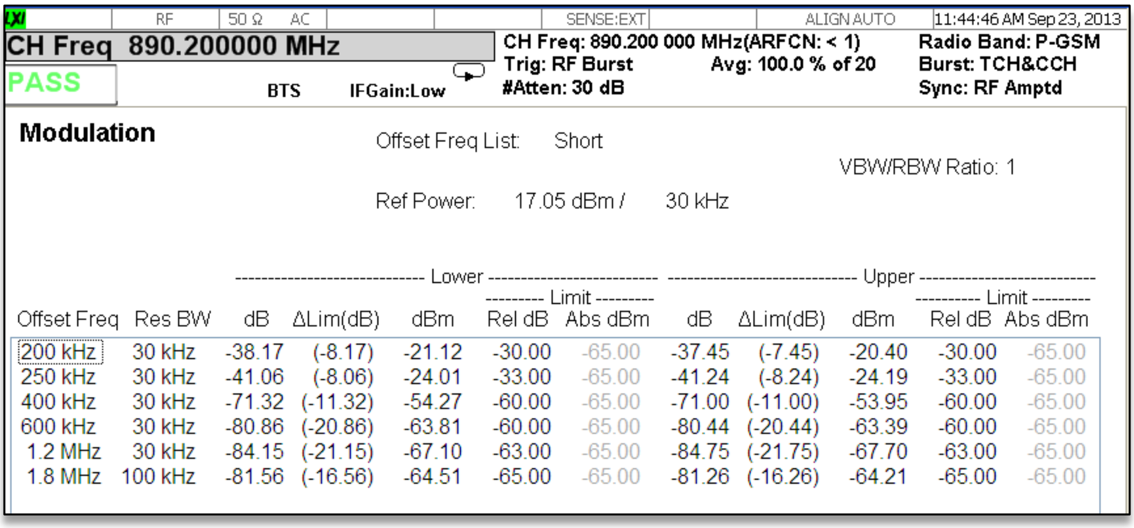


Figure 21: PvT, 34dBm P_{OUT}

6.2 Output Radio Frequency Spectrum, ORFS

The following Figure 22 shows the measurement table of the GSM Output Radio Frequency Spectrum for transmission. Every row reflects the specification corner with its measured values and the necessary attenuation.



RF | 50 Ω AC | SENSE:EXT | ALIGN AUTO | 11:44:46 AM Sep 23, 2013

CH Freq 890.200000 MHz
PASS
BTS IFGain:Low
CH Freq: 890.200 000 MHz(ARFCN: < 1)
Trig: RF Burst Avg: 100.0 % of 20
#Atten: 30 dB
Radio Band: P-GSM
Burst: TCH&CCH
Sync: RF Amptd

Modulation

Offset Freq List: Short

VBW/RBW Ratio: 1

Ref Power: 17.05 dBm / 30 kHz

		Lower			Limit		Upper			Limit	
Offset Freq	Res BW	dB	ΔLim(dB)	dBm	Rel dB	Abs dBm	dB	ΔLim(dB)	dBm	Rel dB	Abs dBm
200 kHz	30 kHz	-38.17	(-8.17)	-21.12	-30.00	-65.00	-37.45	(-7.45)	-20.40	-30.00	-65.00
250 kHz	30 kHz	-41.06	(-8.06)	-24.01	-33.00	-65.00	-41.24	(-8.24)	-24.19	-33.00	-65.00
400 kHz	30 kHz	-71.32	(-11.32)	-54.27	-60.00	-65.00	-71.00	(-11.00)	-53.95	-60.00	-65.00
600 kHz	30 kHz	-80.86	(-20.86)	-63.81	-60.00	-65.00	-80.44	(-20.44)	-63.39	-60.00	-65.00
1.2 MHz	30 kHz	-84.15	(-21.15)	-67.10	-63.00	-65.00	-84.75	(-21.75)	-67.70	-63.00	-65.00
1.8 MHz	100 kHz	-81.56	(-16.56)	-64.51	-65.00	-65.00	-81.26	(-16.26)	-64.21	-65.00	-65.00

Figure 22: ORFS, 34dBm P_{OUT}

6.3 Receive Band Noise, RXBN

Figure 23 and Figure 24 show measurements verifying the headroom in terms of noise in the appropriate receive band. In this measurement, the transmission frequency is 915MHz. The corresponding receive channel is 45MHz higher at 960MHz.

The whole plot in Figure 23 verifies the noise rejection in this band as well as the spurious noise in the adjacent channels. The several traces reflect different V_{IN} to V_{OUT} ratios at the boost converter.

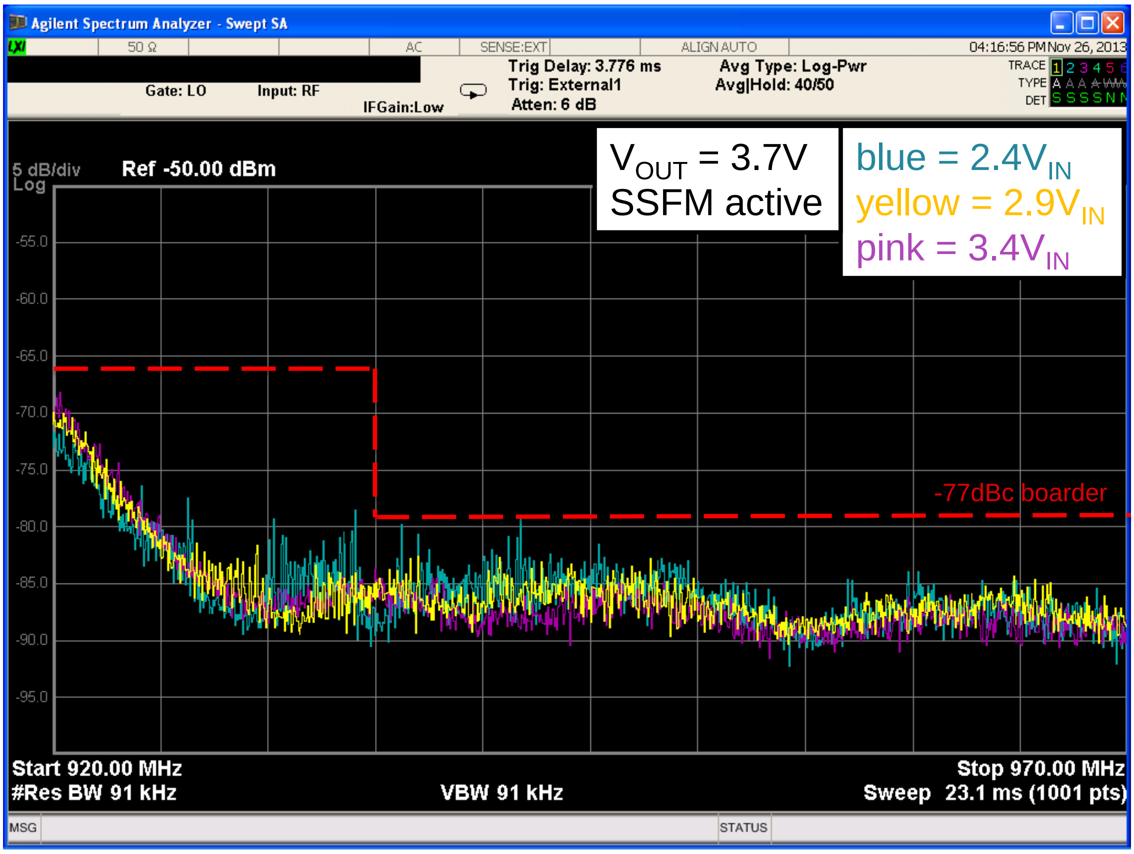


Figure 23: Receive Band Noise 34dBm P_{OUT}, several input voltages

The TPS61280 features a frequency dithering at the switching clock. This feature is called Spread Spectrum Frequency Modulation (SSFM) and expands the emitted RF spectrum over a broader frequency range. This reduces EMI peaks in the output spectrum significantly. Please refer to TPS61280 datasheet for more information's.
Figure 24 shows the noise critical RXBN measurement with this feature disabled (yellow) as well as SSFM enabled (magenta).

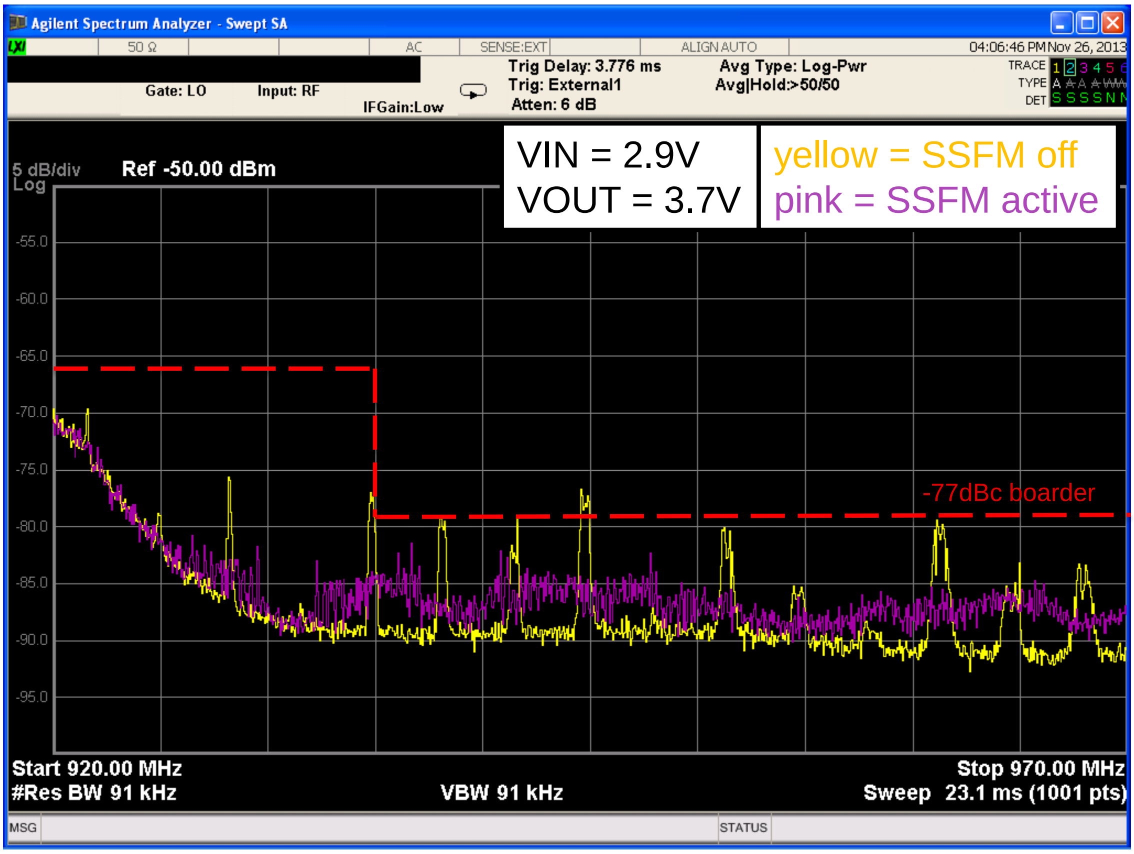


Figure 24: Receive Band Noise 34dBm P_{OUT}, Spread Spectrum effect

7 Appendix

7.1 References

1) TPS61280 Datasheet, Texas Instruments 2013
2) TPS61280EVM-585 User's Guide, Texas Instruments 2013
3) GSM Technical Specification, ETSI 1996

7.2 Related Links and Web sites

www.ti.com/power
www.ti.com/products/tps61280
http://e2e.ti.com/support/power_management/default.aspx
http://www.skyworksinc.com/Product.aspx?ProductID=1623

7.3 Acronyms

DUT	Device under Test
EVM	Evaluation Module
GMSK	Gaussian Minimum Shift Keying
GSM	Global System for Mobile Communications
MMPA	Multi-Mode Power Amplifier
ORFS	Output Radio Frequency Spectrum
PA	Power Amplifier
PvT	Power versus Time
RF	Radio Frequency
RFPA	Radio Frequency Power Amplifier
RXBN	Receive Band Noise
SSFM	Spread Spectrum Frequency Modulation
WCDMA	Wideband Code Division Multiple Access