Application Note

Using a DC/DC Converter with HELP4™ and HELP3™ + Coupler Power Amplifiers

Rev 0

RELEVANT PRODUCTS

- All HELP4™ Power Amplifiers
- All HELP3™ + Coupler Power Amplifiers

HELP™ TECHNOLOGY

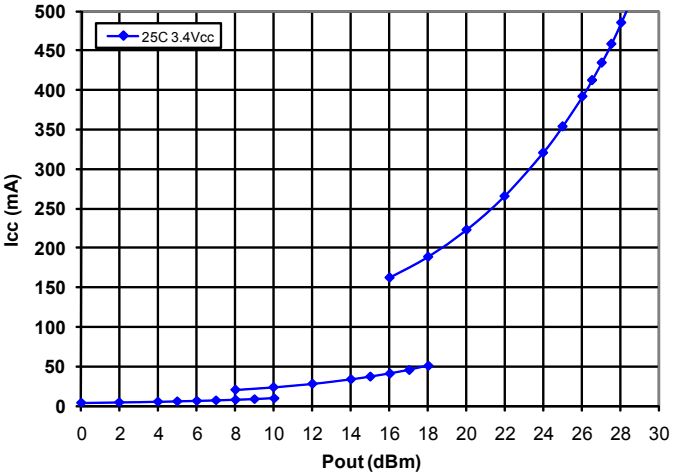
ANADIGICS' High-Efficiency-at-Low-Power (HELP™) power amplifiers have selectable bias modes that optimize efficiency for different output levels and enable low quiescent current to reduce PA current consumption over industry-standard transmit power profiles to deliver significantly increased handset talk and standby time.

The HELP4™ and HELP3™ + Coupler power amplifiers have separate RF paths for High power and for Medium and Low power operation. Power modes are selected by setting the Vmode pins to a logical high or low value as shown in Table 1. The multipath PA design can be optimized for power, linearity and efficiency over its full range of output power using a fixed supply voltage, typically 3.4V. Figure 1 shows typical performance of a HELP4™ PA in High, Medium and Low power operating modes.

Table 1: Logic Table of Operating Mode Control for HELP4™ PA

APPLICATION	P_{OUT} LEVELS	BIAS MODE	V_{ENable}	V_{MODE1}	V_{MODE2}	V_{CC}	V_{BATT}
WCDMA - low power (Low Bias Mode)	≤ +8 dBm	Low	+1.8 V	+1.8 V	+2.4 V	3.2 - 4.2 V	≥ 3.2 V
WCDMA- med power (Medium Bias mode)	7 P_{OUT} ≤ +16 dBM	Low	+1.8 V	+1.8 V	0 V	3.2 - 4.2 V	≥ 3.2 V
WCDMA - high power (High Bias Mode)	> +16 dBm	High	+1.8 V	0 V	0 V	3.2 - 4.2 V	≥ 3.2 V
Optional lower V_{CC} in low power mode	≤ +7dBm	Low	+1.8 V	+1.8 V	+1.8 V	1.5 V	≥ 3.2 V
Shutdown	-	Shutdown	0 V	0 V	0 V	3.2 - 4.2 V	≥ 3.2 V

Figure 1: AWT6621 - I_{CC} vs. P_{OUT}



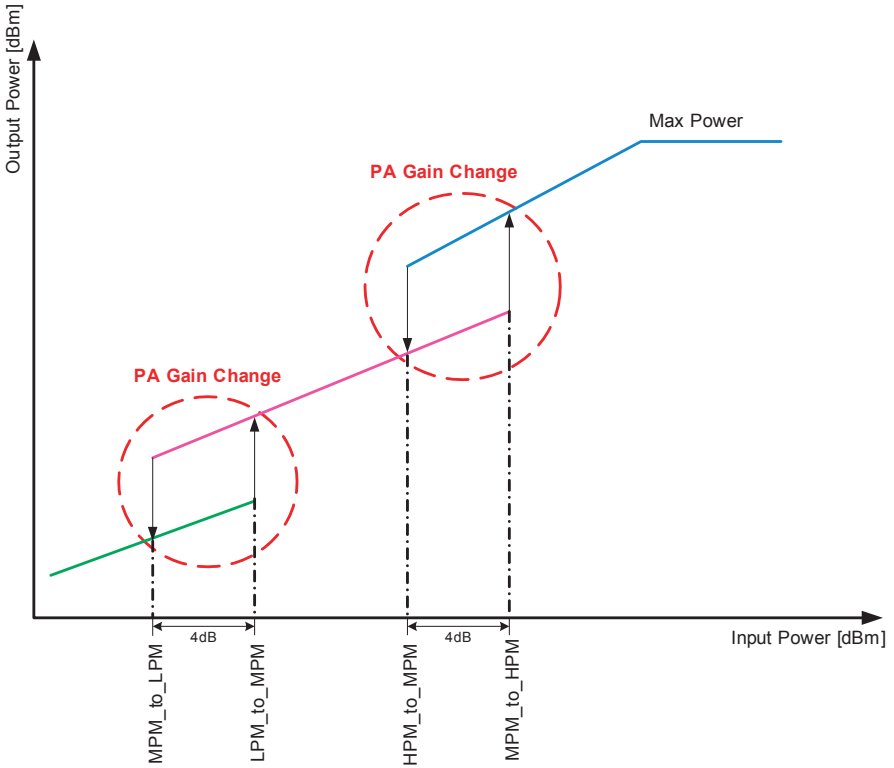


Figure 2: Output Power vs. Input Power with Gain Switching

SMPS APPLICATION WITH HELP™ PAS

HELP™ power amplifiers are typically switched between High and Medium Power Modes at an output of 16 dBm or higher. Low to Mid Power switching typically occurs around 7 dBm. Mode switching improves the PA's efficiency and reduces current consumption in low/medium powers by changing the amplifier load line working from a fixed supply voltage.

Figure 2 illustrates the characteristics of the HELP4™ gain switching. It suggests that the switching point at which the PA changes from a higher gain to a lower gain is separated by 4 dB hysteresis from the switching point where the PA rises from a lower gain to a higher gain. It's recommended to implement the hysteresis in order to avoid the PA oscilitating at the same switching point.

Because the RF system design must ensure that the required ACLR specification is met across all power levels, it is important to maintain a PA supply voltage that allows margin to the system ACLR specification. Often, there is enough ACLR margin at backed-off power within each power mode that can be "traded" for power consumption by reducing the PA collector voltage to bring the amplifier closer to saturation.

An SMPS or DC/DC converter can be used to reduce the collector voltage at the V_{CC} pin of a HELP3™ or HELP4™ PA to bring the PA closer to saturation in the lower range of each power mode, and thereby reduce the PA's current consumption. In this kind of application, Pin 10 is connected to the SMPS while Pin 1 remains connected to Vbatt to drive the internal voltage regulator. **Figure 3** illustrates the placement of this additional component in the PA's application circuit.

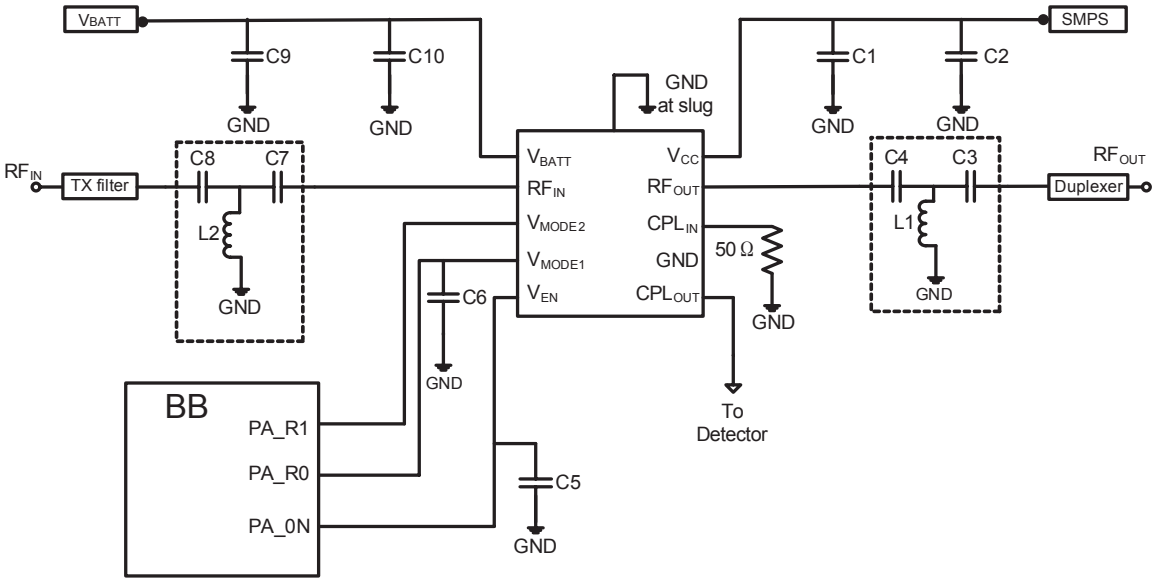


Figure 3: Typical Application Circuit with SMPS

Figure 4 shows typical ACLR performance of a HELP4™ PA in this application. Note that, in the lower portion of the High Power Mode, the PA collector voltage (V_{CC}) can be reduced below 3.4 V without failing a minimum ACLR requirement. Similar data was collected for the Mid Power Mode (**Figure 5**) and the Low Power Mode (**Figure 6**).

Figure 4: AWT6621- HPM ACLR Measured at Reduced V_{CC}

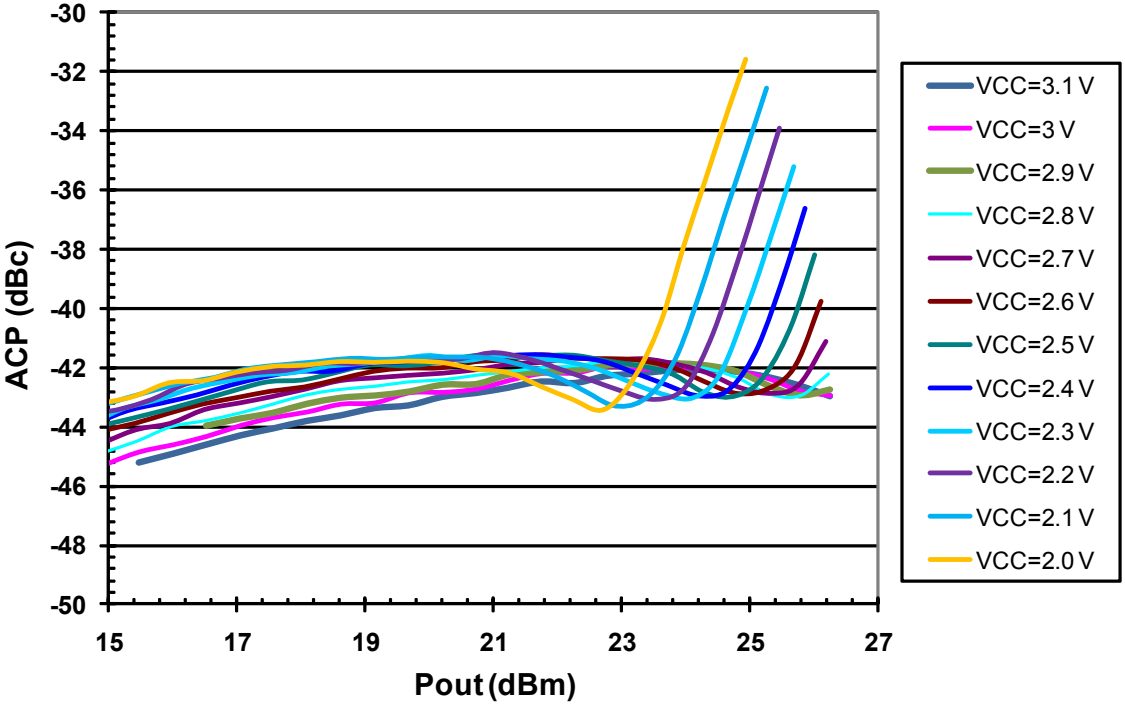


Figure 5: AWT6621- MPM ACLR Measured at reduced Vcc

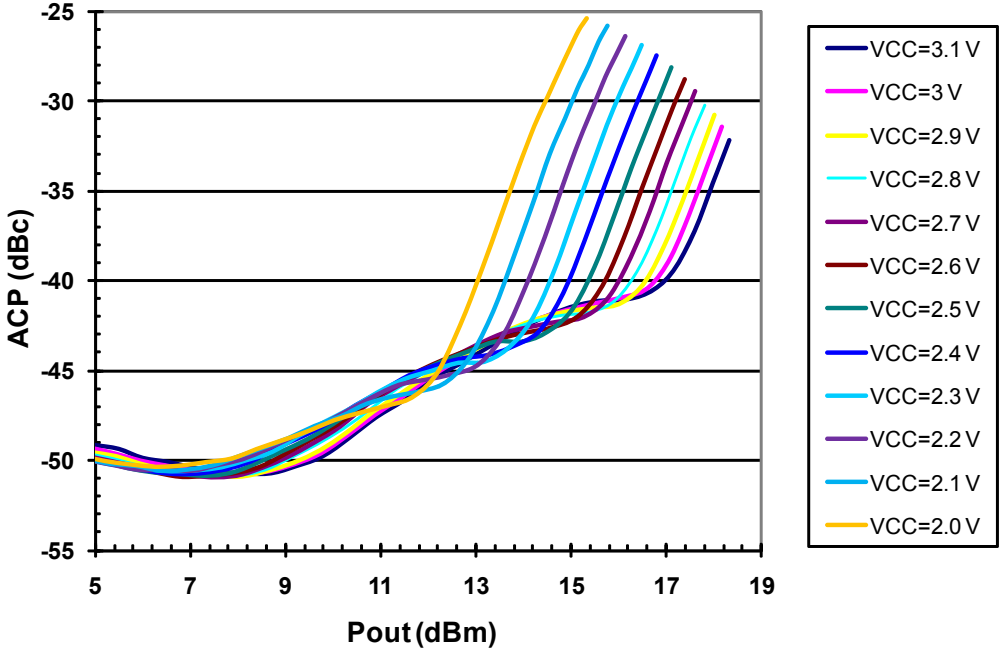
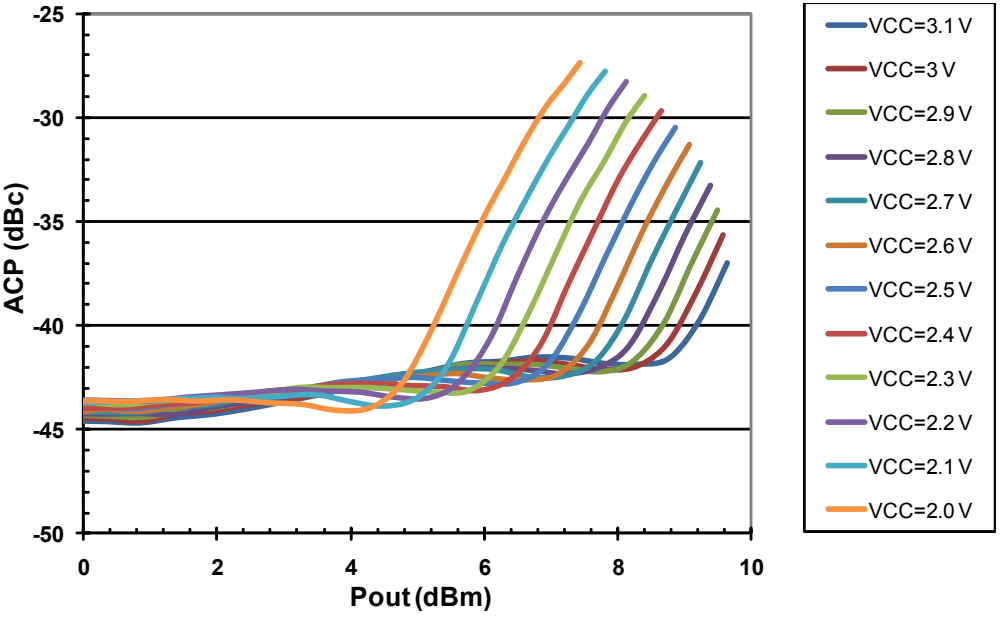


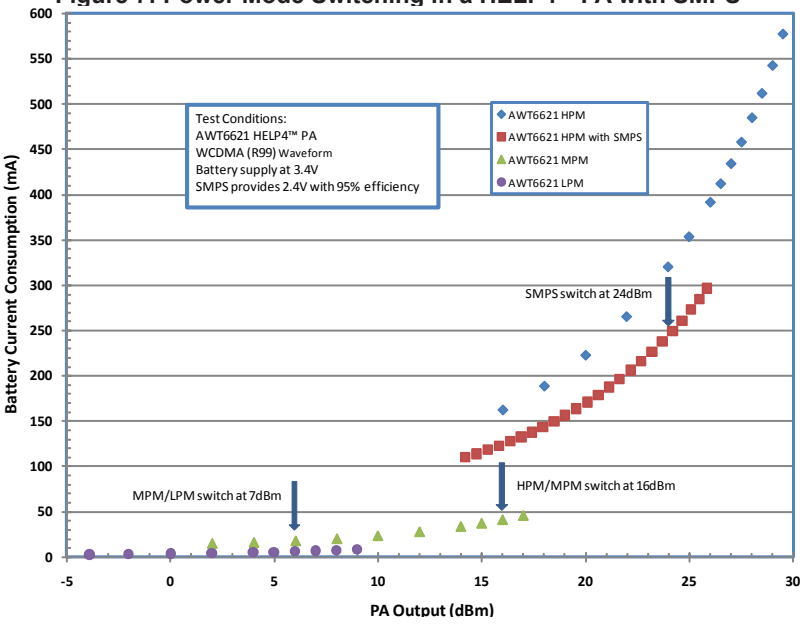
Figure 6: AWT6621- LPM ACLR Measured at reduced Vcc



Using a DC/DC Converter with HELP4™ & HELP3™ + Coupler Power Amplifiers

Because HELP™ architecture is designed to improve efficiency at low and medium powers, and because ACLR and gain change between power modes, the greatest benefit of using a SMPS with a HELP4™ or HELP3™ plus Coupler PA is found in High Power mode. If a reduced supply voltage is available, a "fourth" power mode can be created from a lower power portion of HPM, as shown in Figure 7.

Figure 7: Power Mode Switching in a HELP4™ PA with SMPS



The benefit of reducing V_{CC} in this way can be seen by calculating the average current consumption over a standard power profile like DG09. Assuming high efficiency in the SMPS or DC/DC converter, reducing the supply voltage to a HELP4™ PA like AWT6621 in the lower power portion of HPM provides a 10 – 15% reduction in battery current, as shown in Table 2. Reducing the supply voltage to a HELP3™ plus Coupler PA like AWU6601 has a similar benefit.

Table 2: Improved Current Consumption over DG09 Profile

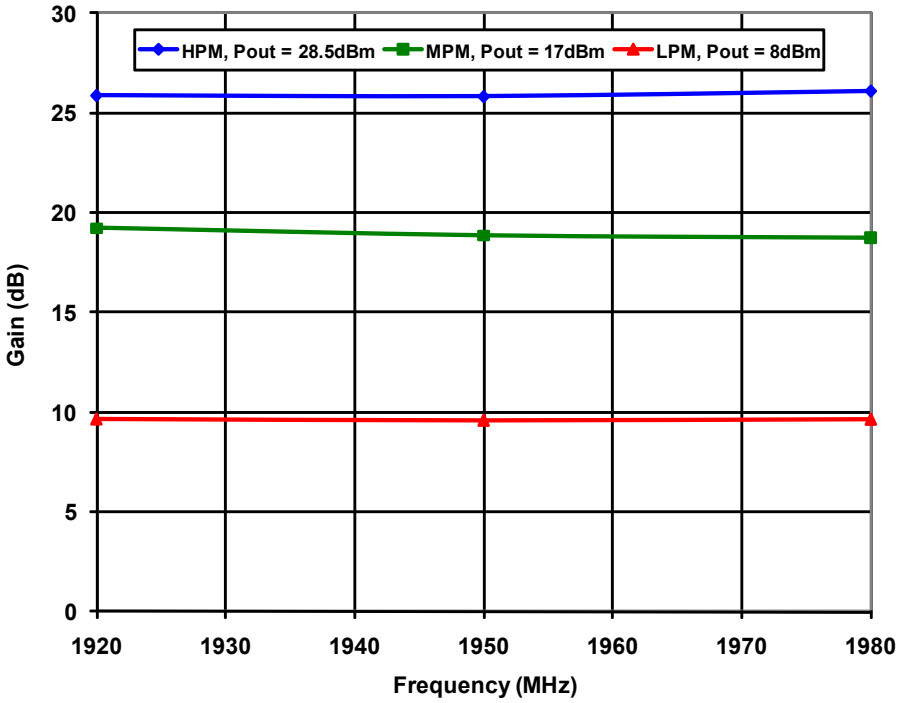
Technology	Power Amplifier	Quiescent Current	Average over DG09
HELP3™ + Coupler	AWU6601 at 3.4 V	8.0	30.1
HELP3™ + Coupler with SMPS	AWT6601 with SMPS at 2.4 V for Iqc and some HPM	6.2	26.7
HELP4™	AWT6621 at 3.4 V	1.8	21.4
HELP4™ with SMPS	AWT6621 with SMPS at 2.4 V for Iqc and some HPM	1.4	18.7

Additional benefits in average current consumption can be obtained by operating the SMPS from a battery voltage above 3.4V and by using the SMPS to reduce Vcc in the lower power portions of the Medium and Low Power Modes as well as the High Power Mode. Careful adjustment of Vcc over the entire range of the DG09 power profile has been shown to reduce average current as much as 50%. Consult ANADIGICS Applications Engineering for advice on your application.

GAIN VS. FREQUENCY

The PA gain is a function of frequency. At the same time, the Gain vs. Frequency response may vary at the different power levels. **Figure 8** shows an example of Gain vs. Frequency response for AWT6621, at each power mode. Variation of gain over the band in each power mode must be considered when using a DC/DC converter or SMPS to regulate the PA supply.

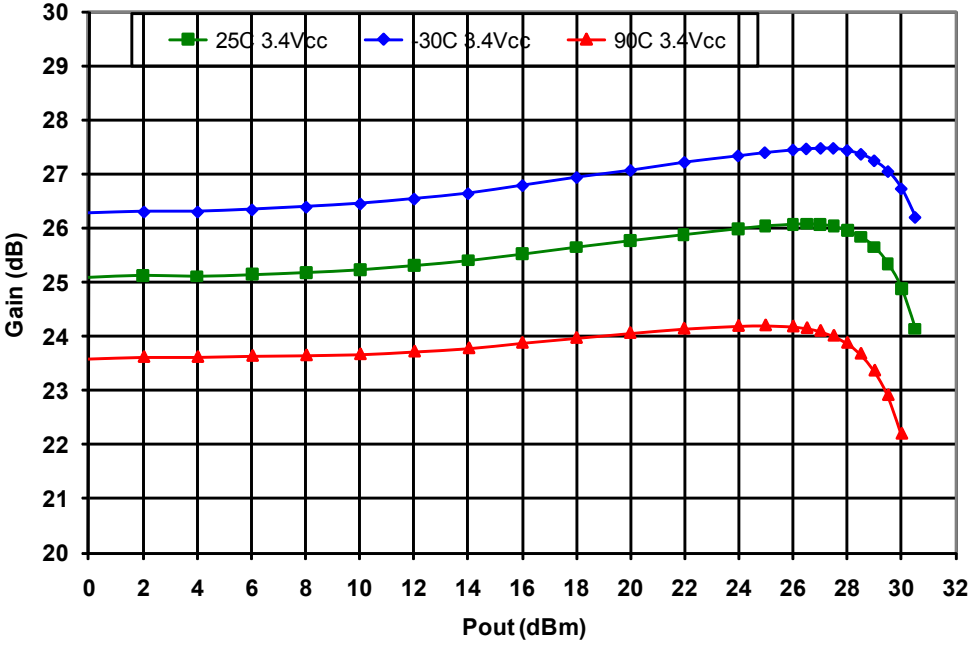
Figure 8: Variation of PA Gain vs Frequency



GAIN vs TEMPERATURE

The PA gain changes as a function of temperature. It can be seen from **Figure 9** that AWT6621 HPM gain varies approximately 3 dB over a temperature range of 100 degrees (from -10 °C to +90 °C). The effect of gain offset over temperature can be pronounced in ILPC test, around the gain switching point. If the PA is calibrated in LPM first and then move up to MPM and HPM, it may experience problems in ILPC step E. Likewise, if the PA is calibrated from HPM to LPM, it might see a problem in ILPC step F. Adjustments to temperature compensation parameters may be necessary to offset changes in gain step size when using a DC/DC converter or SMPS to control the PA in different power mode states.

Figure 9: AWT6621, Gain in HPM at 3 Temperatures



Recommended PA turn-on and turn-off sequences

Refer to **Figure 10** for recommended system level power up/down sequence.

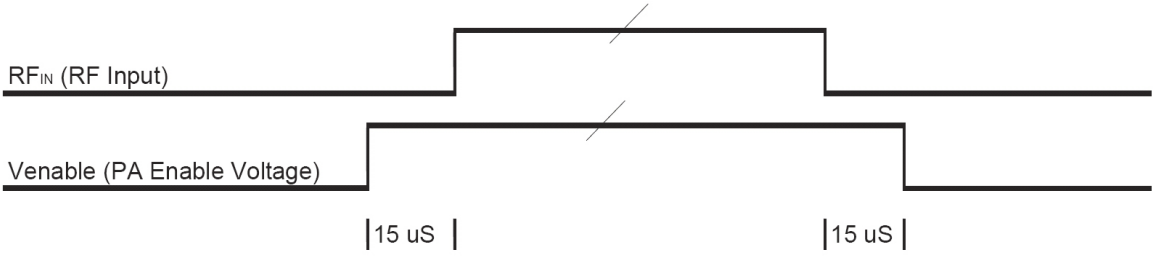


Figure 10: Recommended Turn-On/Off Sequence

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