AN808

Using the TC1142 for Biasing a GaAs Power Amplifier

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INTRODUCTION

RF bandwidths for cellular systems such as AMPS, TACS, GSM, TDMA, and CDMA range from 800MHz to 1.0GHz. To provide RF transmissions over this range of frequencies, Gallium Arsenide (GaAs) has become the technology of choice and offers several advantages over silicon technology: a much higher cutoff frequency, higher breakdown voltage, lower noise figure, and higher power-added efficiency. This translates to lower power dissipation and longer talk time for cellular subscribers.

To properly bias a GaAs Power Amplifier (PA), a negative DC bias is required. There are many methods for providing this DC bias, but in a majority of applications, a regulated bias scheme is desirable over an unregulated inverting charge pump.

APPLICATION CIRCUIT

Figure 1 shows a typical application circuit for biasing a GaAs PA in a cellular subscriber unit's transmitter. Each key component of the circuit is described below.

Single Cell Li-Ion Battery and High-Side FET Switch

The main power source of this circuit is a single +3.6V Lithium Ion (Li-Ion) cell. Commercial packs using this battery chemistry can have a voltage as high as +4.2V or as low as +2.8V. This circuit will work under any condition within this range. Digital wireless standards such as TDMA and CDMA tend to operate the transmit section in "burst mode," switching the PA circuit off most of the time. Consequently, a digitally controlled power switch is included. The main requirements of this switch are: TTL/CMOS compatible control input, low "on" resistance, and high-side switching capability. "TX_ENABLE" signifies the power switch control signal, and is generated in the subscriber unit's modem controller.

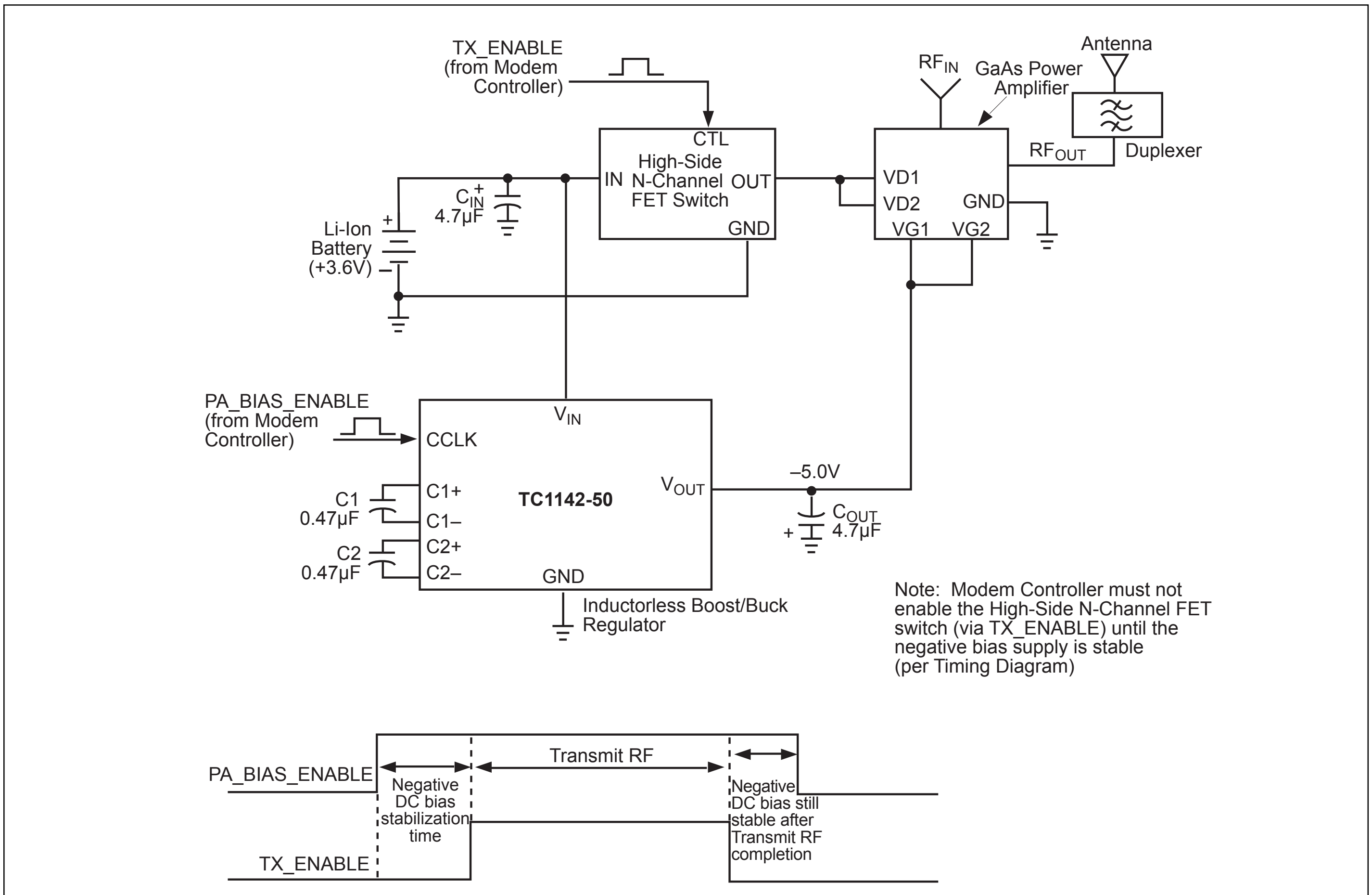

FIGURE 1: *Application circuit for biasing a GaAs power amplifier in a cellular subscriber unit's transmitter.*

Regulated Voltage Inverter

The inductorless voltage inverter is the core of the negative DC bias generator. It is a switched capacitor (charge pump) voltage converter, and the two 0.47µF flying capacitors (C1, C2) and the 4.7µF output capacitor (C_{OUT}) are the only external components required. The output current is a function of the C1, C2 flying capacitors, and the output ripple voltage magnitude is dependent on C1, C2, and C_{OUT}. The output ripple waveform is superimposed on the nominal –5.0VDC and has a fundamental frequency of 200KHz.

"PA_BIAS_ENABLE" is the power control signal for the regulated negative bias generator from the subscriber unit's modem controller. Timing requirements for this signal versus "TX_ENABLE" are shown in Figure 1.

Previously, many designers have chosen a switching regulator for this circuit application, however the TC1142 has altered this approach. Since switching regulators require inductors, they increase the installed size, generated noise, and cost of providing this negative DC bias requirement. The TC1142 provides a "boost/buck" regulated conversion from either a single-cell Li-Ion, a multi-cell Nickel Cadmium (NiCd), or a multi-cell Nickel Metal Hydride (NiMH) battery pack. Figure 2 shows a simple block diagram of the TC1142 Inductorless Boost/Buck regulator architecture. The TC1142 can be ordered to provide output voltages from –3.0V to –5.0V in 1.0V increments.

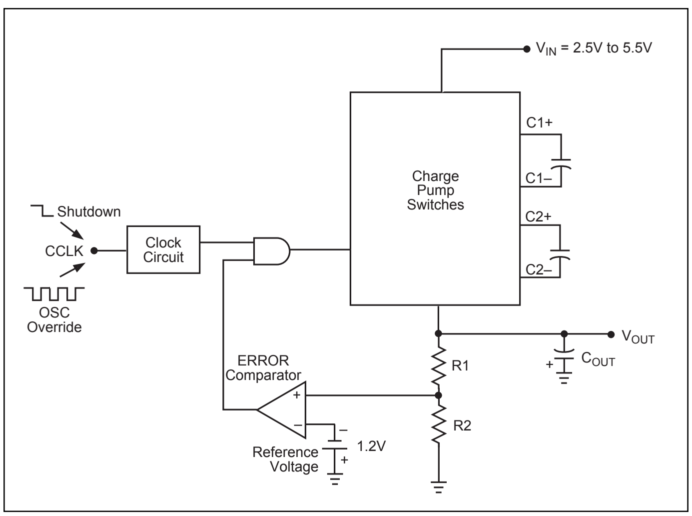

FIGURE 2: *TC1142 architecture.*

Circuit Description of Inductorless Boost/Buck Regulator

Ordinary charge pumps simply "convert" (not regulate) their input voltages. For example, a TC7660 charge pump generates a no-load output voltage of –5V when V_{IN} = +5V. However, its output voltage falls with a corresponding decrease in input voltage, an increase in output current, or both.

The TC1142 differs in that it uses pulse-frequency modulation (PFM) control to generate a regulated output voltage without the use of a post linear regulator. The TC1142 consists of an inverting/doubling charge pump and a feedback circuit (sampling resistors R1, R2, ERROR comparator, and associated voltage reference). When operating at full clock speed, the charge pump generates an unregulated output voltage equal to $-2V_{IN}$. The ERROR comparator inhibits operation of this charge pump (i.e. skips clock pulses) whenever the output voltage sampled by R1 and R2 is more negative than the reference voltage. The combination of the doubling pump and feedback regulation allows the absolute value of V_{OUT} to be regulated above or below that of V_{IN}. The TC1142 delivers an output voltage of –5V at a maximum of 20 mA over an input voltage range of +2.5V to +5.5V.

In order to maintain the lowest output resistance and output ripple voltage, it is recommended that low equivalent series resistance (ESR) capacitors be used. Additionally, larger values of the output capacitor and lower values of the flying capacitors will reduce the output voltage ripple.

Depending on the maximum voltage ripple allowed, the TC1142 will provide more-than-adequate regulation for most portable applications. Table 1 shows the relationship between output voltage ripple versus the two flying capacitors (C1 and C2) and the output capacitor (C_{OUT}). In each case, a 3.2V input is being converted to a –5V output.

Assuming the output is loaded to at least 20% of the maximum available current, the power efficiency of the inductorless boost/buck regulator can be estimated as the absolute value of the regulated voltage, divided by twice the input voltage. Thus, for a 3.6V battery input generating a –5V output, the efficiency of the inductorless boost/buck regulator will be approximately 70%.

C1, C2 (µF)	C_{OUT} (µF)	V_{IN} (V)	V_{OUT} (V)	V_{RIPPLE} (mV)
0.01	4.7	3.2	–5	14.6
0.22	4.7	3.2	–5	31.4
0.33	4.7	3.2	–5	46.1
0.47	4.7	3.2	–5	63.9
0.68	4.7	3.2	–5	88.7
1.0	4.7	3.2	–5	123.2
0.1	10	3.2	–5	7.0
0.22	10	3.2	–5	15.1
0.33	10	3.2	–5	22.4
0.47	10	3.2	–5	31.5
0.68	10	3.2	–5	44.7
1.0	10	3.2	–5	63.8

TABLE 1: *Voltage ripple vs. C1/C2 flying capacitors and output capacitor C_{OUT}. ESR = 0.1Ω, I_{OUT} = 20mA.*

GaAs PA, Duplexer, and Antenna

The GaAs PA radiates RF energy through a tuned bandpass filter (i.e. duplexer) to the subscriber unit's antenna port. Depending on the cellular standard and the power class of the subscriber unit, different power levels are required of GaAs PAs. For instance, a Class III AMPS subscriber unit must be able to radiate a minimum power level of +28dBm through the antenna. A CDMA Class III subscriber unit, in comparison, has a lower minimum power level requirement of +23dBm. Since the GaAs PA must be able to efficiently meet these industry standard power requirements, the RF losses in the duplexer must also be considered in the design of the PA.

SUMMARY

GaAs has become the technology of choice over silicon in cellular telephone power amplifier applications. With GaAs technology, lower noise figures, higher cutoff frequencies, and higher power-added efficiency allow the cellular user increased talk time as compared to silicon PAs.

GaAs PAs require a negative DC bias, and the TC1142 offers significant advantages over inductor-based switchers or unregulated charge pumps: lower generated noise; smaller installed size; lower installed cost; and excellent output regulation for subscriber units which operate in most existing worldwide cellular standards.

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