Maximizing Battery Life in Communications Systems

The keys are: low-voltage parts, low-drop-out regulators, plus careful hardware design and power management

by Bob Clarke

In a modern battery-powered communications system design, considerations include: the number of battery cells, the voltage change from charge to discharge, finding components with adequate performance at an operating voltage that fits within the available supply range, and minimizing the current drain. Finally, regulated voltages must be supplied to critical sections of the circuit; and the system must turn components off and on to reduce the total energy used and maximize battery life.

Assuming that the number of battery cells is a given, consider component selection. There are 3-V parts, 3.3-V parts (mostly digital), and 5-V parts. Among 3-V parts, Analog Devices has a variety of offerings suitable for communications systems, including IF subsystems, voltage regulators, A/D converters, DSP ICs, and op amps. Table 1 shows a very brief(!) listing of illustrative low-power, single-supply components for use in battery-powered communications systems.

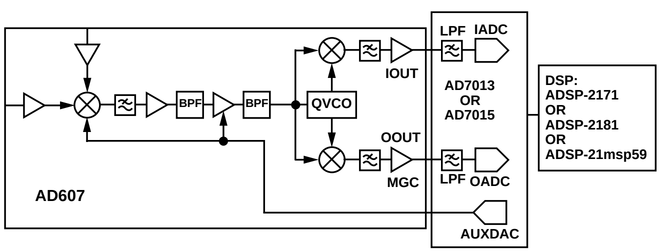

Figure 1. The AD607, AD7015, ADSP-2171 and ADM663A/ ADM666A/ADP3367 (not shown) form part of a 5-V GSM IF solution on Receive. If the AD7015 is replaced by the AD7013, the IF strip can be used in IS54, trans-European trunked radio access (TETRA), or Inmarsat satellite terminals.

Figure 1 shows a typical IF strip for GSM or IS54 that uses a mix of 3-V and 5-V parts. In the GSM version, the AD607 IF Subsystem, the AD7015 Baseband Converter, and the ADM663/ ADM666A,ADP667,ADP3367 Low-Drop-Out Regulators can all be used in 3-V or 5-V designs.

Suppose this system uses a battery whose voltage starts at 3.6 V and decreases to 3 V at end of life. Let's look at the components and their operating voltages. The AD607 operates from 5.5 V supplies down to 2.7 V supplies, so it can operate directly from the battery. Likewise, the ADM663A and ADM666A low-dropout regulators accept input voltages as low as 2 V, while the ADP3367 will accept voltages down to 2.5 V, so they too can operate from a 3-V supply. What's more, these regulators can supply from 100 mA to 300 mA output current—more than enough to power the entire

Table 1. Illustrative Single-Supply Parts for Battery-Powered Communications Systems

Description	Standard(s)	Model	Nominal Supply Volts	Fax-Code*
IF subsystem with linear IF gain control and I/Q demodulator	GSM, IS54, CDMA, TETRA, Inmarsat terminals	AD607	3, 5	1824
IF Subsystem with limited IF and RSSI output	PHS, Log-polar QPSK systems	AD608	3, 5	1825
Baseband Converter with I/Q LPFs, I/Q ADCs, and AUXDACS	IS54, TETRA, Inmarsat terminals	AD7013	5	1243
Baseband Converter with I/Q LPFs, I/Q ADCs, I/Q GMSK modulator, and AUXDACS	GSM, DCS1800	AD7015	3	1921
12-Bit ADC, 5 µs T/H amplifier, 50 kHz throughput, serial interface, 8 mW	General purpose communications	AD7883	3	1378
Low Drop-Out Linear Voltage Regulators	General purpose battery-powered) systems (GPBPS	ADM663A ADM666A	3, 5	1559
Low Drop-Out Linear V Regulators	GPBPS	ADP667	5, adj.	1917
Low Drop-Out Linear V Regulators	GPBPS	ADP3367	5, adj.	1913
Quad FET-Input Op Amp for audio, misc (500 µA per amplifier)	GPBPS	AD824	3, 5	1810
Dual FET-Input Op Amp for audio, 25 V/µs slew rate, 5 mA per amplifier	GPBPS	AD823	3, 5	1907
Dual Op Amp for audio, drives headphones directly, 2 mA per amplifier	GPBPS	OP279	5	1811

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R-F transceiver if desired (except for the power amplifier, which runs directly off the battery anyway).

In practice, though, only the frequency-determining portions of the radio—the synthesizer, VCOs, and VCO buffers—require a regulated supply voltage. Specifically, the regulator irons out fluctuations in the battery's output voltage, thus isolating the varactor diode, the oscillator transistor, and the charge pump from voltage changes that would cause changes in frequency. Battery voltage fluctuations are typically caused by the power amplifier's turn-on and turn-off transients (Figure 2).

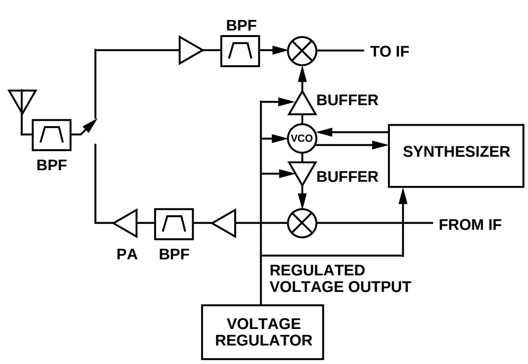

Figure 2. A voltage regulator isolates the frequency-determining elements of this RF front end from power-supply-voltage changes that can cause frequency shifts.

Thus, in a typical 3-V IF design, the ADM663A/ADM666A/ADP3367 would regulate the voltage supplying the VCOs, VCO buffers, synthesizer, and driver for the PA. Allowing 750-mV (ADM663A/666A) or 60 mV (ADP3367) dropout for the regulator, plus 50 mV, the regulated voltage can be set at 2.8 V. This assumes that a synthesizer capable of operating at voltages as low as 2.7 V is available, since its charge pump should operate from a regulated voltage.

Once caveat here: there is a potential tradeoff between VCO tuning range and minimum supply voltage, since the capacitance per volt of a given varactor and the output voltage span of the charge pump might not be sufficient to provide margin for the desired tuning span. One possible solution is a charge-pump with a built in voltage doubler. For systems operating with higher battery voltages, the ADP667 low-dropout regulator accepts inputs as low as 3.5 V with 150-mV voltage drop for 200-mA output current.

In addition to using a voltage regulator to isolate devices from fluctuations in the supply, all devices operating directly from the battery must be carefully decoupled from the power supply—regulated or unregulated—in order to avoid low-frequency oscillations and current loops. For example, when creating local ac grounds at the midpoint of the supply voltage, the user may be tempted to tie several points together and use a single point as the reference (Figure 3a). A safer technique is to use isolated, individually bypassed ac grounds (b) or a low-impedance driven ground circuit (c).

Don't forget to account for voltage drops in the PC board traces and voltage drops across any R-C decoupling networks, especially for VCOs, where any change in the oscillator supply voltage or the charge pump output voltage translates into a change in frequency.

Consider also whether or not an IC has a built-in power down or must be powered down by shutting down its supply, either using an external pass transistor or powering down the regulator.

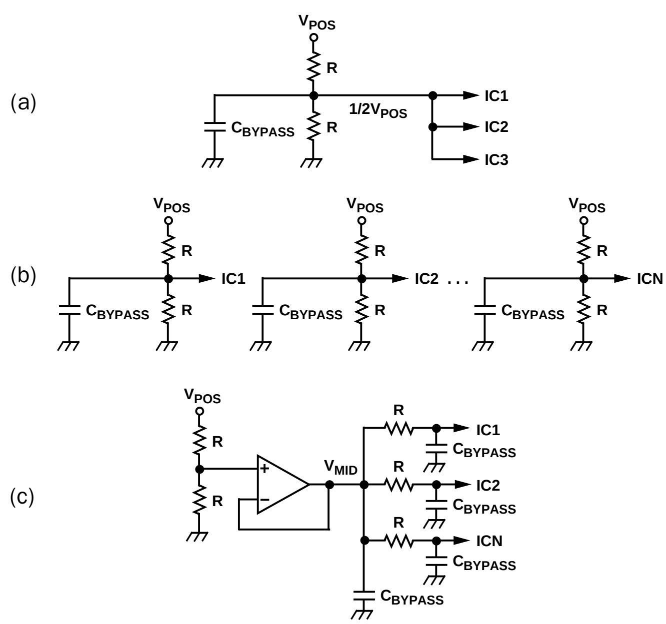

Figure 3. A single passive virtual ground is an invitation to feedback loops and instability (a). Separate, isolated grounds (b), especially when driven (c), are better. Circuit (c)'s op amp should be able to drive the capacitive load of C_{BYPASS}.

Although powering down the regulator saves power, in general, it is not wise to use its power down to turn off an individual IC to save power—the "simple" approach can cause other problems.

For example, when the supply to an IC is turned on and off, its decoupling networks must charge and discharge. The charge and discharge times add to the system's power-up and power-down times, requiring that the power be on longer than necessary just to charge and discharge the decoupling networks. Thus an IC without an internal power-down can be at a disadvantage.

But if the IC has an internal power-down, its power-supply input pin presents a high impedance to the decoupling network during shutdown, without charging and discharging the network on power-up and down or adding the decoupling network's charge and discharge time constants to the system's power up and down times.

Some ICs, like the AD607 Linear IF Subsystem IC, have internal nodes that are deliberately "held" at a specific voltage during power-down. In the AD607, the control voltage at the PLL's loop filter output is held constant during power down to minimize frequency reacquisition time upon power up.

At the system level, it is important to manage carefully which devices are powered up and especially *when* they are powered up. For example, in a cellular radio receiver, a useful order is to first power up the VCO, allow it to stabilize; then power up the synthesizer; and finally, once the synthesizer has locked, power up the rest of the Receive signal path. With this sequence, the LNA, mixer, and IF strip are left powered down until the receiver is on frequency, a process that may take several hundred microseconds. Keeping them off until the VCO is on frequency can save 400 μs of power consumption per power up cycle.

Once the signal is demodulated down to baseband, DSP, and audio I/O, the relevant ICs can be operated from unregulated battery voltage. The mixed-signal baseband converter ICs (AD7013 and AD7015, for example) have on-board bandgap voltage-references for their bias system and multiple power-down modes to minimize power. A possible difficulty is that many of these have a minimum supply voltage specification of V_S–10%, i.e., 4.5 V (5-V supply) or 3-V (3.3 V supply), as do the DSPs that follow in the signal chain.

When it comes to digital signal processing, Analog Devices has a host of DSPs in the fixed-point 2100 series that operate on single +5-V supplies, including the ADSP-2171 and ADSP-2181, and the ADSP-21msp56 and ADSP-21msp59, which have on-chip analog interfaces (ADCs and DACs for voice-band signals). The ADSP-2103, ADSP-2162 and ADSP-2164 operate on 3.3-V supplies. (The ADSP-2162 and ADSP-2164 are ROM-programmed versions of the ADSP-2103.)

For audio use, the AD824 quad FET-input op amp operates at a 3-V minimum supply voltage, provides a 2-V/μs slew rate, operates from supplies as low as 3 V, and consumes just 500 μA per amplifier. For better audio quality, but using more current, the AD823 dual-FET-input op amp provides a 25-V/μs slew rate for 5 mA per amplifier with 3-V supply. For higher-power audio output applications and 5-V supplies, the OP279 dual op amp provides a 5-V/μs slew rate, 80-mA output drive, and can drive a set of headphones. It consumes 2 mA per amplifier.