Linear Circuit Devices for Applications in Battery Powered Wireless Systems

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INTRODUCTION

Conventional wisdom says smaller is better where battery operated wireless systems are concerned. Higher silicon integration and smaller package technology have shrunk system electronics to the point where system size is dictated by the size of the battery pack and user interface (keyboard and display).

Reducing the size of the user interface in consumer devices, such as, cellular phones and pagers is largely an ergonomic issue. On the other hand, reducing battery size means reducing the number (or size) of the cells in the pack, or changing to a higher energy density battery chemistry, such as, Lithium-Ion (Li-Ion). Both options result in battery size reduction at the expense of lower battery energy capacity and/or lower terminal voltage. Reduced battery terminal voltage is one factor hastening the departure from 5V to 3V (and lower) system supplies.

Another more predominant factor has been the migration to sub-3V supply voltages by the digital supply base at large (i.e., suppliers of processors, memory, and logic). As these devices grew in complexity and speed, the transistor geometries used in fabricating these circuits had lower breakdown voltages and therefore required lower supply voltages. As a result, an industry-wide progression to lower supply voltages was established. Today, low voltage processors, logic, and memory are readily available from a number of different suppliers. These devices not only offer low supply voltage operation, but also often have low power standby modes that suspend operation and reduce supply current. For example, most low power microcontrollers have a low power "sleep" mode, where normal operation is suspended and supply current is dramatically reduced.

Analog circuit functions in wireless systems have also been migrating to lower supply voltages. Like their digital counterparts, these analog functions must also be driven to low power modes at various times to conserve battery life. Various semiconductor vendors have responded to this need with an assortment of linear device products that combine op-amps, comparators, and voltage references in single-package configurations. These products allow the user to create any number of analog circuits with complete flexibility, while still retaining the size and benefits of integration. These linear devices are particularly useful in the power management, radio, and audio sections of battery operated wireless devices such as cellular phones. Microchip's extensive linear device familiy may be applied to solving problems in various sections of battery operated wireless devices.

LINEAR CIRCUIT DEVICES FAMILY

Microchip Technology offers linear circuit devices that combine op amps, comparators and voltage references into a single package. These devices can operate from supply voltages as low as 1.4V, and their operating currents can be as low as 600 nA depending on the device. These products are available in a variety of packages ranging from a 5-pin SC-70 to a 16-pin QSOP. Table 1 summarizes the family of linear circuit products offered by Microchip Technology.

Because of lower supply voltage requirements in battery powered wireless applications, a greater emphasis is placed on rail-to-rail amplifier and comparator inputs and outputs. In addition, these inputs are frequently used to monitor the battery or power supply voltage, making low input bias current a requirement. Several members of the linear circuit family have rail-to-rail inputs and outputs with input currents of 100 pico-amperes (pA) - perfect for battery-level monitoring and other applications requiring low input loading. Figure 1 depicts a precision battery, low battery and dead monitoring circuit. Typically, the battery low output warns the user that a battery-dead condition is eminent. Battery-dead typically initiates a forced shutdown to prevent operation at low internal supply voltages (which can cause unstable system operation).

The circuit in Figure 1 uses a single TC1043 (one op-amp unused) and only six external resistors. AMP 1 is a simple buffer, while CMPTR1 and CMPTR2 provide precision voltage detection using V_R as a reference. Resistors R_2 and R_4 set the detection threshold for $\overline{\text{BATT LOW}}$, while resistors R_1 and R_3 set the detection threshold for $\overline{\text{BATT FAIL}}$. The component values shown assert $\overline{\text{BATT LOW}}$ at 2.2V (typical) and $\overline{\text{BATT FAIL}}$ at 2.0V (typical). Total current consumed by this circuit is typically 22 µA at 3V. Resistors R_5 and R_6 provide hysteresis for comparators CMPTR1 and CMPTR2, respectively.

TABLE 1: MICROCHIP LINEAR DEVICES FAMILY

Part No.	Description	Comparators (Output)	Op Amps (GBWP)	Reference	Shutdown	Rail-to-Rail I/O	Total Active Supply Current (µA)
TC1025	Dual Comparator	2 Push-Pull	—	—	—	X	8
TC1026	Comparator, Op Amp and Reference	1 Push-Pull	1 (90 kHz)	X	—	X	12
TC1027	Quad Comparator and Reference	4 Push-Pull	—	X	—	X	18
TC1028	Dual Comparator and Reference with Shutdown	2 Push-Pull	—	X	X	X	10
TC1029	Dual Op Amp	—	2 (90 kHz)	—	—	X	12
TC1030	Quad Op Amp with Shutdown Modes	—	4 (90 kHz)	—	X	X	20
TC1031	Single Comparator with Hysteresis and Reference with Shutdown	1 Push-Pull	—	X	X	X	6
TC1034	Single Op Amp	—	1 (90 kHz)	—	—	X	6
TC1035	Single Op Amp with Shutdown	—	1 (90 kHz)	—	X	X	6
TC1037	Single Comparator	1 Push-Pull	—	—	—	X	4
TC1038	Single Comparator with Shutdown	1 Push-Pull	—	—	X	X	4
TC1039	Single Comparator and Reference	1 Push-Pull	—	X	—	X	6
TC1040	Dual Comparator and Reference with Shutdown	2 Push-Pull	—	X	X	X	10
TC1041	Dual Comparator with Hysteresis and Reference	2 Push-Pull	—	X	—	X	10
TC1043	Dual Comparator, Dual Op Amp and Reference with Shutdown	2 Push-Pull	2 (90 kHz)	X	X	X	16
MCP601	Single Op Amp	—	1 (2.8 MHz)	—	—	—	230
MCP602	Dual Op Amp	—	2 (2.8 MHz)	—	—	—	460
MCP603	Single Op Amp with Chip Select	—	1 (2.8 MHz)	—	X	—	230
MCP604	Quad Op Amp	—	4 (2.8 MHz)	—	—	—	920
MCP606	Single Op Amp	—	1 (155 kHz)	—	—	—	18.7
MCP607	Dual Op Amp	—	2 (155 kHz)	—	—	—	37.4

TABLE 1: MICROCHIP LINEAR DEVICES FAMILY (CONTINUED)

Part No.	Description	Comparators (Output)	Op Amps (GBWP)	Reference	Shutdown	Rail-to-Rail I/O	Total Active Supply Current (µA)
MCP608	Single Op Amp with Chip Select	—	1 (155 kHz)	—	X	—	18.7
MCP609	Quad Op Amp	—	4 (155 kHz)	—	—	—	74.8
MCP616	Single Bi-CMOS Op Amp	—	1 (190 kHz)	—	—	—	19
MCP617	Dual Bi-CMOS Op Amp	—	2 (190 kHz)	—	—	—	38
MCP618	Single Bi-CMOS Op Amp with Chip Select	—	1 (190 kHz)	—	X	—	19
MCP619	Quad Bi-CMOS Op Amp	—	4 (190 kHz)	—	—	—	76
MCP6001	Single Op Amp	—	1 (1 MHz)	—	—	X	108
MCP6002	Dual Op Amp	—	2 (1 MHz)	—	—	X	216
MCP6004	Quad Op Amp	—	4 (1 MHz)	—	X	X	432
MCP6021	Single Op Amp with Mid-Supply	—	1 (10 MHz)	—	—	X	1000
MCP6022	Dual Op Amp	—	2 (10 MHz)	—	—	X	2000
MCP6023	Single Op Amp with Mid-Supply and Chip Select	—	1 (10 MHz)	—	X	X	1000
MCP6024	Quad Op Amp	—	4 (10 MHz)	—	—	X	4000
MCP6041	Single Op Amp	—	1 (14 kHz)	—	—	X	0.6
MCP6042	Dual Op Amp	—	2 (14 kHz)	—	—	X	1.2
MCP6043	Single Op Amp with Chip Select	—	1 (14 kHz)	—	X	X	0.6
MCP6044	Quad Op Amp	—	4 (14 kHz)	—	—	X	2.4
MCP6141	Single Op Amp ($G \geq 10$)	—	1 (100 kHz)	—	—	X	0.6
MCP6142	Dual Op Amp ($G \geq 10$)	—	2 (100 kHz)	—	—	X	1.2
MCP6143	Single Op Amp with Chip Select ($G \geq 10$)	—	1 (100 kHz)	—	X	X	0.6
MCP6144	Quad Op Amp ($G \geq 10$)	—	4 (100 kHz)	—	—	X	2.4

TABLE 1: MICROCHIP LINEAR DEVICES FAMILY (CONTINUED)

Part No.	Description	Comparators (Output)	Op Amps (GBWP)	Reference	Shutdown	Rail-to-Rail I/O	Total Active Supply Current (µA)
MCP6541	Single Comparator	1 Push-Pull	—	—	—	X	0.6
MCP6542	Dual Comparator	2 Push-Pull	—	—	—	X	1.2
MCP6543	Single Comparator with Chip Select	1 Push-Pull	—	—	X	X	0.6
MCP6544	Quad Comparator	4 Push-Pull	—	—	—	X	2.4
MCP6546	Single Comparator	1 Open-Drain	—	—	—	X	0.6
MCP6547	Dual Comparator	2 Open-Drain	—	—	—	X	1.2
MCP6548	Single Comparator with Chip Select	1 Open-Drain	—	—	X	X	0.6
MCP6549	Quad Comparator	4 Open-Drain	—	—	—	X	2.4

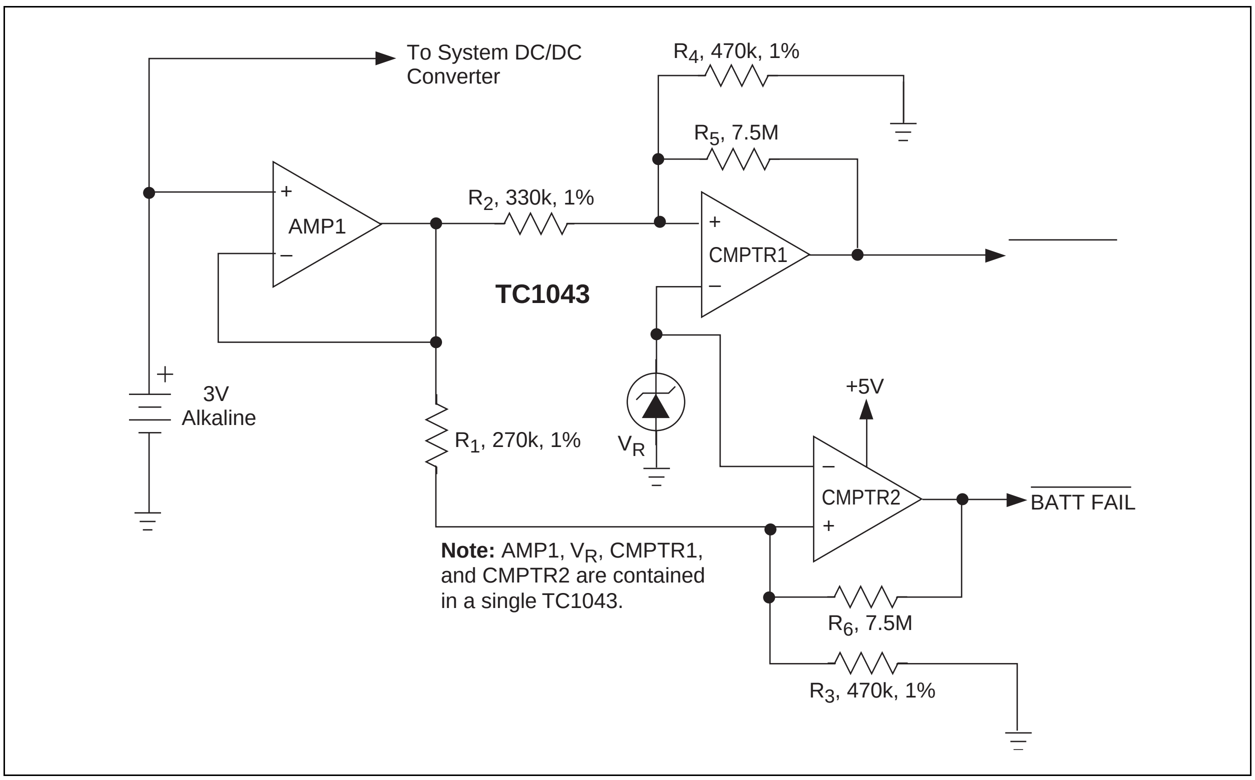

FIGURE 1: *Precision Battery Monitor*

RF APPLICATION

Bias Supply Generation for a Gallium Arsenide (GaAs) Power Amplifier

Many cellular phones use Gallium Arsenide (GaAs) technology in their transmitter section. Most GaAs Power Amplifiers (PAs) require a negative voltage supply for operation, whether it is generated internally or taken from an external source. This voltage is used in the PA for DC biasing of internal gates of the GaAs FETs, and usually has two major performance requirements: It must be low noise, and it must be adjustable. The low noise requirement is to meet strict out-of-band rejection limits for the PA. If the PA receives a noisy bias supply, it will inevitably transmit some of the noise to its output. Depending upon the PA's power supply rejection ratio, the bias voltage may require <1 mVp-p ripple/noise.

The schematic shown in Figure 2 illustrates a typical GaAs PA circuit, including the negative bias sub-circuit of interest. The main power source is a single +3.6V Li-Ion cell. The voltage of commercially available battery packs can be as high as +4.2V or as low as +2.8V. This circuit will work under any condition within this range. Since digital wireless standards such as TDMA and CDMA operate the transmit section in "burst mode," the PA circuit will be switched off most of the time. Therefore, a digitally controlled power switch is included (high-side N-Channel FET switch). 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.

The voltage inverter is the core of the bias generator. The TCM829 is used to invert the +3.6V from the battery to a -3.6V output. It is a switched capacitor (charge pump) voltage converter, and C_2 and C_3 are the only external components. The TCM829's output has a source resistance dependent on C_2 and a ripple voltage magnitude dependent on C_3. The output ripple waveform is superimposed on the nominal -3.6 DC and has a fundamental frequency of 35 kHz. Assuming a nominal 0.5 mA load current, the ripple voltage for the values of C_2 and C_3 is <15 mVp-p. This is usually too much ripple voltage to feed directly into a PA V_{DD} input, thus a filter circuit is required.

The op amp circuit centered on the TC1034 performs two functions on the raw inverted voltage from the TCM829. It acts as a ripple rejection filter and allows an external analog control voltage (CV) to set the output voltage that is applied to the PA. The TC1034 op amp is extremely suited to perform this function since it operates over a V_{DD} range of 1.8V to 5.5V. It has full rail-to-rail inputs and outputs and a quiescent current of <6 µA. Additionally, excellent power supply rejection (80 dB, typical) allows it to function as a very good ripple rejection filter. The V_{DD} is connected to Ground, and the V_{SS} to the output of the TCM829 (-3.6V). The feedback network sets a gain of -2V/V, which allows a control voltage of 0V to +1.25V to produce an output of 0V to -2.5V. With the specified component values, the TCM829 will have a DC output of -3.57V and a 35 kHz ripple of 15 mVp-p. The TC1034, with its 80 dB PSRR, will attenuate that by roughly a factor of ten-thousand, and will yield <1.5 µVp-p of ripple. This is much more acceptable for the gate bias input for the PA. The total supply current for the TCM829 and TC1034 is approximately 70 µA.

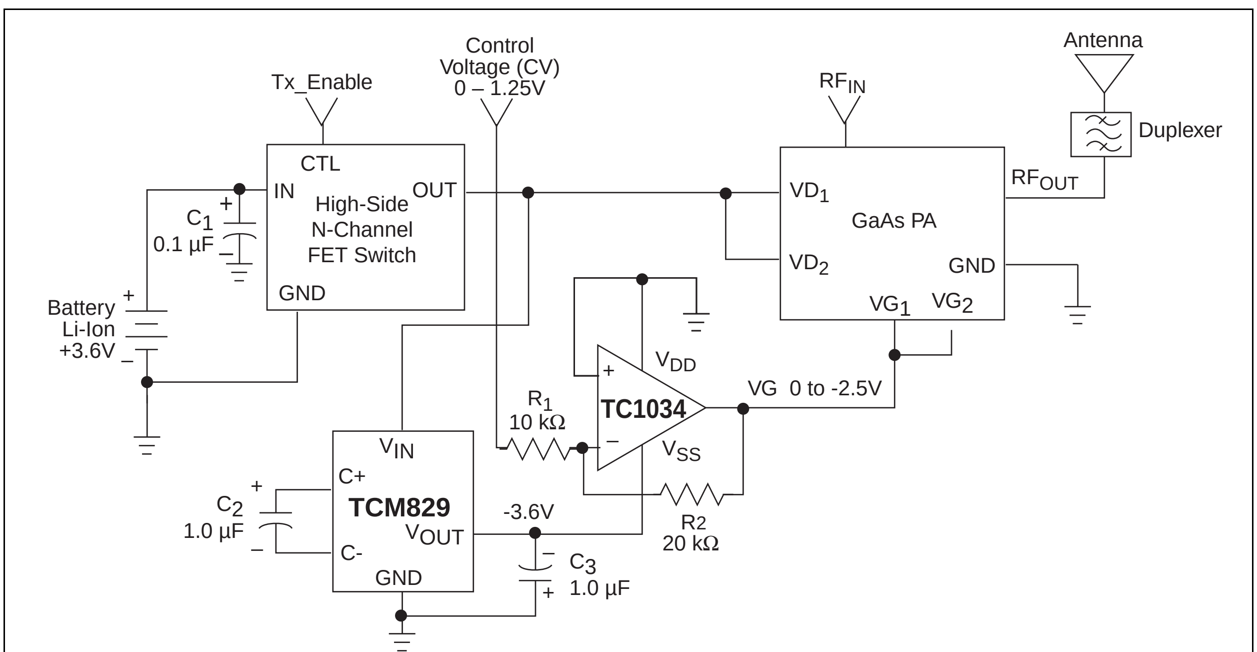

FIGURE 2: *Bias Supply Generation for GaAs Power Amplifier*

AUDIO APPLICATION

Voice Band Receive Filter

The majority of spectral energy for human voices is found to be in a 2.7 kHz frequency band from 300 Hz to 3 kHz. To properly recover a voice signal in applications such as radios, cellular phones, and voice pagers, a low power bandpass filter that is matched to the human voice spectrum can be implemented using the MCP607 dual op-amp. Figure 3 shows a unity gain, multi-pole Butterworth filter with ripple less than 0.15 dB in the human voice band. The lower 3 dB cutoff frequency is 70 Hz (single order response, while the upper 3 dB cutoff frequency is 3.5 kHz (fifth order response)).

SUMMARY

Linear circuit devices offer the user the benefits of integration with the flexibility of discrete circuits. Their low voltage, low power operation makes them ideal for battery powered systems, saving space, power, and cost. Linear circuits are often used in power management, radio, and audio sections of low voltage wireless consumer devices.

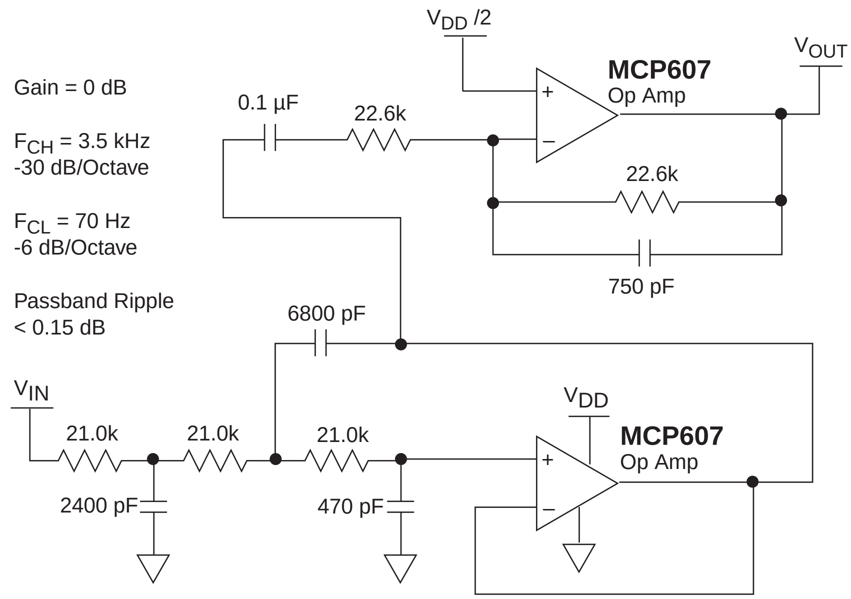

FIGURE 3: *Multi-pole Butterworth Voice Band Receive Filter*

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