

Analog Microcontroller Forms Heart of Low-Cost, High-Efficiency PA Monitor

By Neil Zhao, Mariah Nie, and Ning Jia

Introduction

In view of the looming global energy crisis and an increasing desire to protect our fragile environment, saving energy is crucial for efficient wireless network operation. The power amplifier (PA) is the core of base stations and repeaters and can account for more than half of their total power consumption. Monitoring and controlling the PA can improve efficiency and reduce operating costs; can maximize output power and achieve the highest possible linearity; and can allow the system operator to discover and solve problems, thus improving reliability and maintainability.

ADI has three options for implementing a [PA monitor](#):¹ a discrete solution, an integrated solution based on the [AD7294](#)² 12-bit monitor and control system, and an integrated solution based on the [ADuC7026](#) precision [analog microcontroller](#).³ The discrete solution requires many parts, a complicated PCB layout, and more PCB area, all of which lead to higher cost. The AD7294 has a higher level of integration, lower cost, and higher reliability, but it needs an external microcontroller (MCU) to implement the functions. The ADuC7026 shares many of benefits of the AD7294, but it includes the MCU. In addition, the ADuC7026 supports external synchronized sampling, which is useful for TD-SCDMA applications.

This article describes a reference design—based on the ADuC7026—that realizes the functions of monitoring and controlling the power amplifier, including configuring the output power, monitoring the voltage standing wave ratio (VSWR), monitoring the laterally diffused metal oxide semiconductor (LDMOS) drain current and temperature, and signaling an alarm when a parameter is over a predefined threshold.

System Block Diagram

Figure 1 shows the block diagram of the PA monitor. The RF signal passes through the voltage-variable attenuator (VVA), the [ADL5323](#) predriver, the power amplifier, and the bidirectional coupler before it is transmitted by antenna. The ADuC7026 MCU samples the temperatures and currents of the two LDMOS stages in the PA module, as well as the forward- and reverse power of the PA module. The MCU sends the sampled data to the PC for display in the user interface (UI). The operator can adjust the system parameters through the UI.

PA Monitor Module

Temperature Monitoring: The power amplifier's power consumption influences its performance. The PA sometimes operates at a high quiescent point but at low output power. Lots of energy is wasted heating the LDMOS devices, thus decreasing their reliability. Monitoring the PA temperature and adjusting its operating point can achieve best system performance.

Figure 2 shows the functional block diagram of the temperature monitor, which uses the [ADT75](#) digital temperature sensor to monitor the temperature of the two LDMOS stages. Available in 8-lead MSOP and SOIC packages, the ADT75 digitizes the temperature to a resolution of 0.0625°C. Its shutdown mode reduces the typical supply current to 3 μ A.

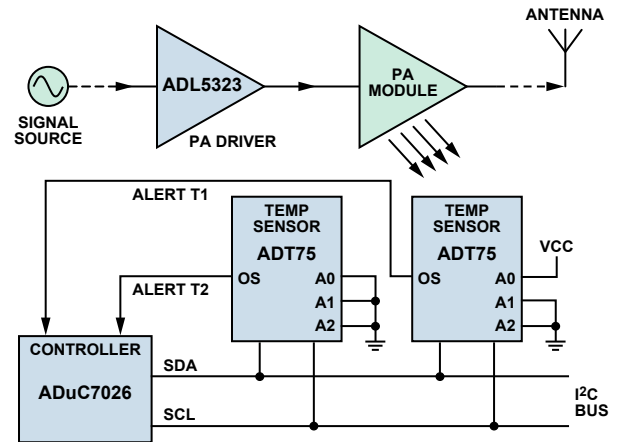


Figure 2. Temperature monitor functional block diagram.

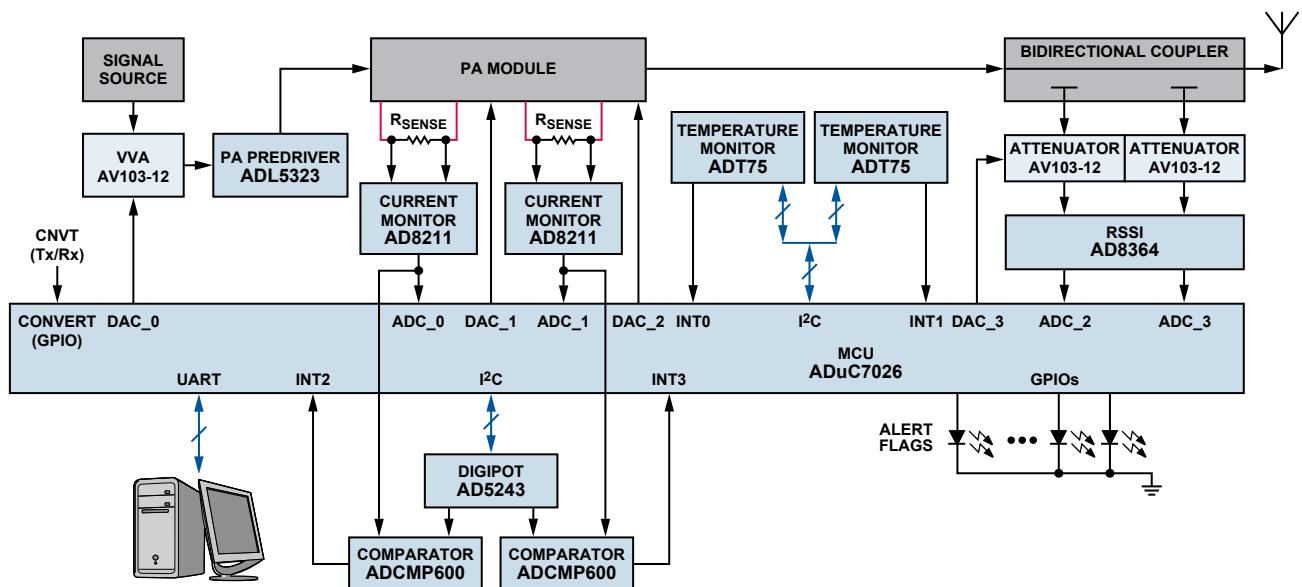


Figure 1. System block diagram.

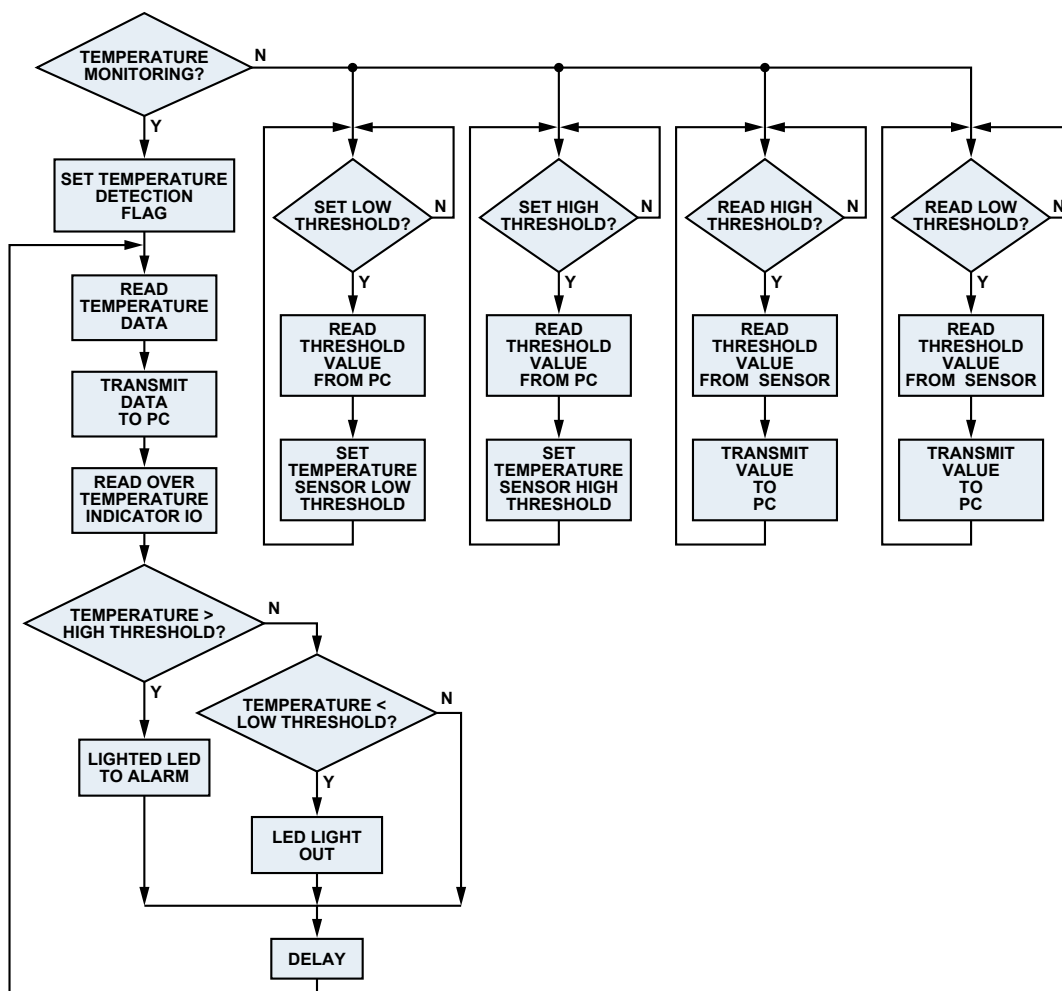


Figure 3. Flow chart for temperature monitoring routine.

Figure 3 shows the flow chart for the temperature monitoring routine. After receiving the temperature detection command, the ADuC7026 MCU sets the temperature detection flag. Next, it reads the temperature data from the ADT75 via the I²C® bus and transmits the data to the PC. Then, it looks at the ADT75's overtemperature pin (OS/ALERT) and turns on an LED if the temperature is over the threshold. If the ADuC7026 receives the configure temperature threshold command, it reads the configuration data from the PC and writes the threshold temperature to the ADT75 via the I²C bus. If the microcontroller receives the read temperature threshold command, it reads the threshold temperature from the ADT75 and transmits it to the PC.

Current Monitoring: The PA performance can be improved by keeping the LDMOS drain current stable over time and temperature; this also maintains the output power in the expected range. The temperature and high-voltage supply influence the drain current; the high-voltage supply also influences the drain voltage. The LDMOS drain current can be measured with a high-voltage current-shunt monitor. If the drain current is continuously monitored, an operator can readjust the gate voltage when a voltage surge occurs on the high-voltage supply to keep the LDMOS working at the best operating point.

Figure 4 shows the functional block diagram of the current monitor, which uses the AD8211 precision high-voltage current-shunt amplifier to sample the drain current of the two LDMOS stages in the PA module. The AD8211 features a fixed gain of 20 V/V, with a typical $\pm 0.5\%$ gain error over the entire temperature range. The buffered output voltage, which directly

interfaces with typical analog-to-digital converters, is sampled by the ADuC7026's on-chip ADC. The drain current threshold is set by the AD5243 digital potentiometer, which is controlled by the ADuC7026 via the I²C bus. The output of the ADCMP600 comparator determines when the drain current is over or under the threshold. The system lights the corresponding LED to alert the operator if the drain current is over the threshold.

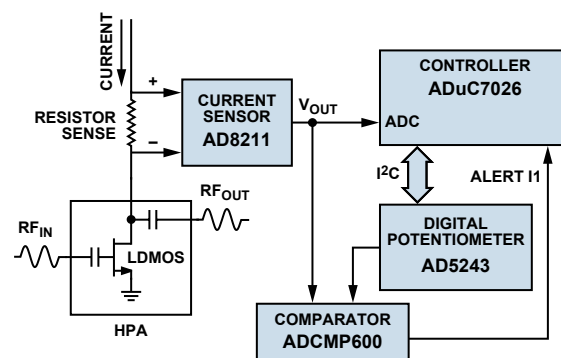


Figure 4. Current monitor functional block diagram.

VSWR Monitoring: VSWR, a key parameter in antenna systems, provides a measure of the match between all of the elements in the antenna system. Reverse power influences the PA's output power, and the transmitted signal is distorted if it is too high. So, it is necessary to monitor VSWR to maintain optimal performance in base stations.

Figure 5 shows the functional block diagram of the VSWR monitor, which uses a bidirectional coupler and the AD8364 dual TruPwr™ detector to measure forward- and reverse power. The AD8364 two-channel, true-rms-responding RF power-measurement subsystem precisely measures and controls the signal power. Its flexibility allows easy monitoring and control of RF power amplifiers, radio transceiver AGC circuits, and other communications systems. The AD8364 output can be used to calculate VSWR and monitor the match on the transmission line. A large VSWR indicates a problem with the antenna, so the operator should protect the system by adjusting the PA gain or the power supply voltage.

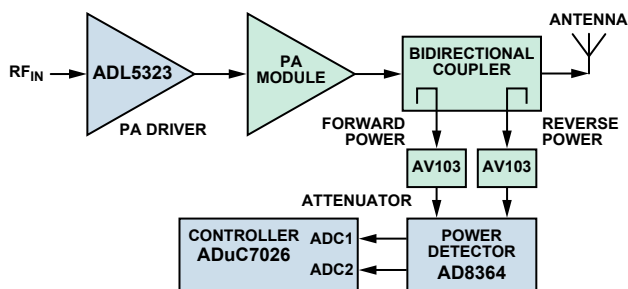


Figure 5. VSWR monitor functional block diagram.

Autopower Control: The transmitter must ensure that the power amplifier can satisfy the system requirements and hold the output power at the desired value—high enough to cover the expected area but low enough to keep from influencing another base station. It should provide overpower protection to ensure that the power amplifier does not operate in an overpower condition, which can cause the power amplifier to saturate and the signal to have nonlinear distortion. For these reasons, the output power must be tested and controlled to make sure it remains steady.

Figure 6 shows the functional block diagram of the autopower control loop, which comprises the bidirectional coupler, TruPwr detector, microcontroller, and voltage-variable attenuator. The bidirectional coupler transfers the forward power to the TruPwr detector, which tracks the change in signal amplitude. The ADuC7026's on-chip ADC samples the output. The microcontroller compares the actual output power with the expected power and uses a proportional-integral-derivative (PID) algorithm to adjust the control voltage error, making the power amplifier operate at the point of best performance.

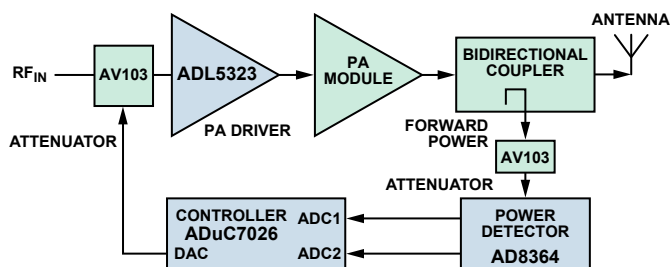


Figure 6. Autopower control functional block diagram.

Figure 7 shows a flow chart for the PID algorithm. First, the program initializes the control parameter K_p , K_i , and K_d and sets the expected output power. Next, the ADC samples the output of the AD8364. The sampled data is then filtered and converted to power. Then, the difference between the expected output power and the actual output power, the next expected sample value, and the control voltage are calculated according to the system transfer function, and the DAC registers are configured. This completes one cycle of the sample and control process, which then continues in a circular manner.

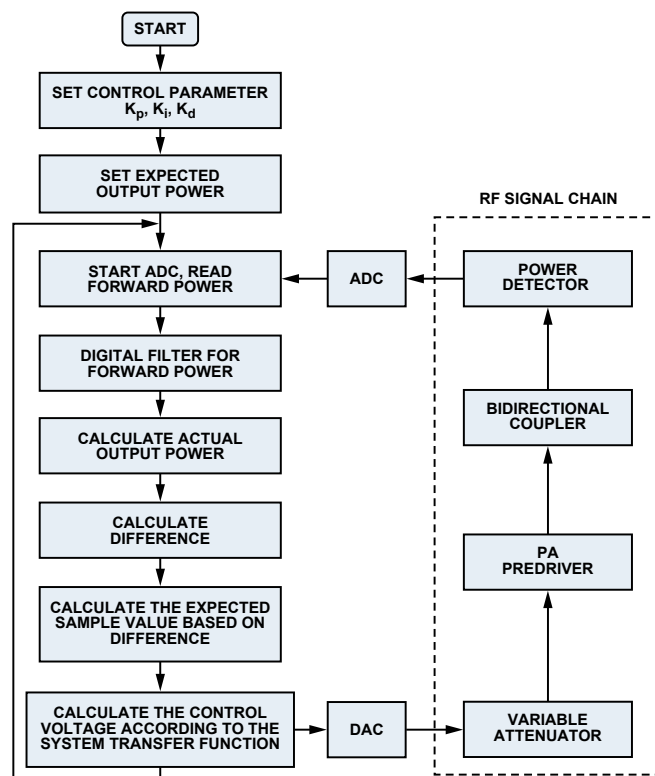


Figure 7. Flow chart for PID algorithm.

User Interface

The user interface (UI) displays the detected data and responds to commands from the operator. Figure 8 shows the flow chart for the UI. The serial port should be opened and communication links should be started after the UI is running. A different module can then be selected for detection and control.

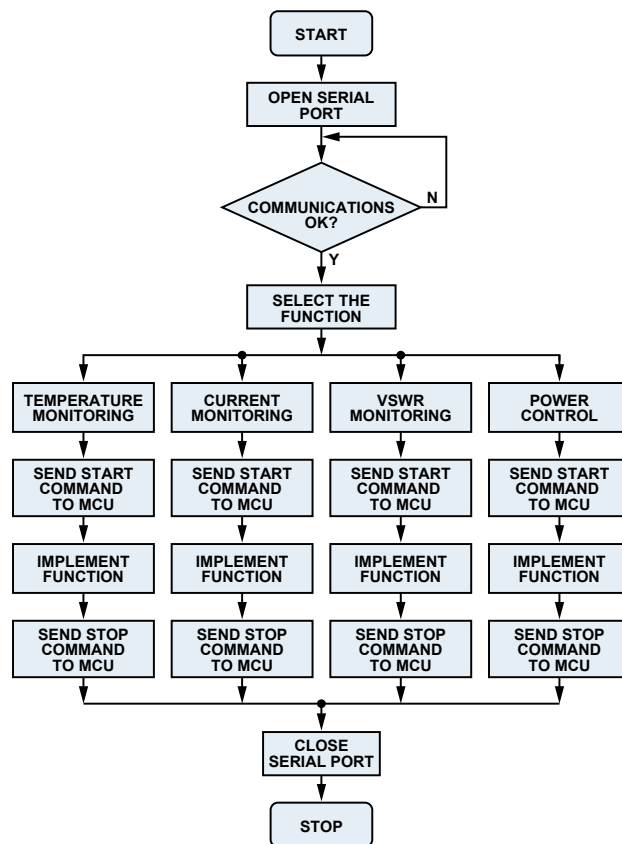


Figure 8. Flow chart for controlling the UI.

Figure 9 shows the temperature test result. A user can change the high- and low-temperature thresholds at any time. In the example, the high threshold is changed from 35°C to 31°C. When the ambient temperature rises above the new threshold, the overtemperature alarm light turns red and the PC sounds a continuous alarm.

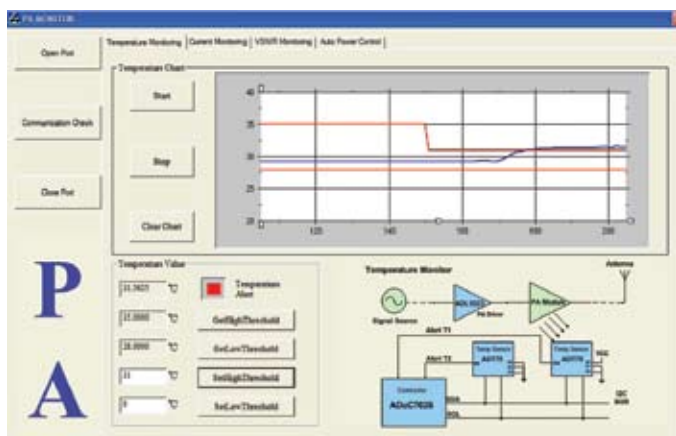


Figure 9. Interface for showing temperature test result.

Hardware Connection

Figure 10 shows the connection of the PA monitor demo. The main board is powered by a 6-V adapter. It connects to the PC with a serial cable so that the lower-end ADuC7026 MCU can communicate with the upper-end PC. The RF signal, generated by the ADF4252 fractional-N PLL synthesizer evaluation board (EVB), is connected with the RF input of the main board. The RF signal proceeds through the signal chain as follows: RF Input→Variable Attenuator→PA Predriver→Bidirectional Coupler→RF Output→Spectrum Analyzer. The output frequency of the ADF4252 EVB is controlled by the PC through a parallel to serial cable.

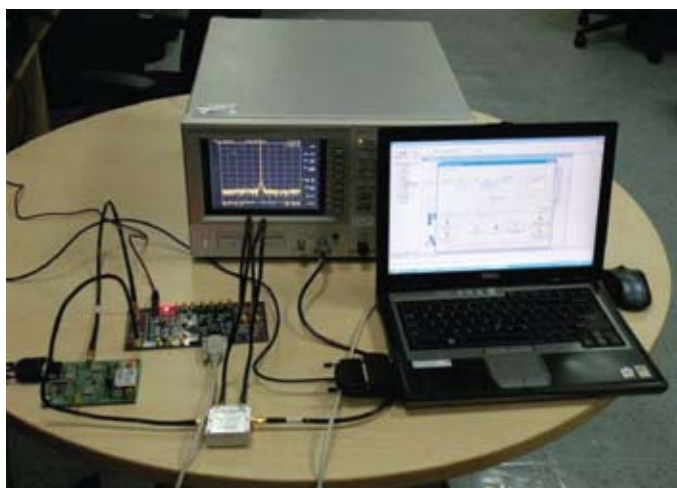


Figure 10. Hardware connection for PA monitor demo.

Conclusion

This reference design provides an integrated solution for monitoring and controlling the PA in cellular base station (GSM, EDGE, UMTS, CDMA, TD-SCDMA), point-to-multipoint, and other RF transmission systems. Using ADI's ADuC7026 precision analog microcontroller to implement the PA monitor application can add flexibility with its multichannel, high-performance 12-bit ADC and DAC, as well as its on-chip programmable logic array (PLA). Conversions can be initiated by the external conversion input or the PLA conversion output. This is helpful for TD-SCDMA applications, which need synchronized signals to sample forward power. The advantage of the integrated PLA is obvious: users can easily and compactly implement logic according to their requirements. Moreover, all kinds of algorithms, such as PID control, VSWR monitor, temperature monitor, and current monitor, can be realized by the ADuC7026, so no other controllers are required. From a system design perspective, this integrated solution can save PCB area, ease PCB layout, decrease system cost, and improve reliability.

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References

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