GAIN FLATNESS control plays an increasingly important role in modern communications systems, notably those that rely on multiple gain stages and high-gain intermediate-frequency (IF) amplifiers. Key receiver components, such as amplifiers and filters, typically exhibit variations in gain or amplitude response, presenting challenges for designers working with modulation schemes such as quadrature amplitude modulation (QAM). However, with the launch of the YSF series of “Flat Gain” amplifiers from Mini-Circuits (www.minicircuits.com), extremely well-controlled amplitude responses are now available in a line of amplifiers spanning a total frequency range of 800 to 3800 MHz with typical gain of 20 dB and typical gain flatness as good as ±0.2 dB across a 400-MHz bandwidth.

Flat gain is hard to come by in any amplifier especially one with even moderate bandwidth. Achieving flat gain requires that the amplifier’s active devices are impedance matched as closely as possible for all of the frequencies within that bandwidth. Since most transistors exhibit extremely low impedances, designing a matching circuit to serve as an interface to the “outside world” at 50 Ω for any appreciable bandwidth requires tradeoffs, such as sacrificing some gain or noise-figure performance in order to achieve flat gain with frequency. For example, developing amplifiers capable of reasonable flat gain and low noise figure usually requires sacrificing output power and dynamic range (as characterized by third-order intercept point). Building an amplifier that has high, flat gain, low noise figure, and even moderate output power at 1-dB compression calls for clever impedance matching across the full operating frequency range.

That is precisely what has been done in the YSF series of Flat Gain amplifiers. They are impedance matched across the frequency range specified for each model and provide a unique combination of high gain, flat response vs. frequency and also relatively low noise figures and output-power levels that are typically in the range of +20 dBm—much higher than other commercial amplifiers that are nominally considered low-noise amplifiers (LNAs).

The YSF amplifiers leverage a mature GaAs enhancement-mode pseudomorphic high-electron-mobility-transistor (E-pHEMT) integrated-circuit (IC) process that has been well characterized to better understand its electrical characteristics over frequency and temperature. This process, and the intelligent design of these two-stage, medium-power amplifiers, contributes greatly to the stable frequency response over temperature (and full characterization data for all of the YSF series amplifiers can be found on the Mini Circuits web site at www.minicircuits.com).

As an example, model YSF-122+ is designed to cover the full cellular communications L-band of 800 to 1200 MHz. As with other members of the YSF Flat Gain amplifier family, it is easy to plug into a design: the amplifier has 50-Ω input and output ports, includes internal feedback and bias circuitry, and operates from a single positive voltage supply. No additional external components are required. As with the other YSF amplifiers, the YSF-122+ is a Mini-Circuits System-In-Pack-
age (MSiP) module that is housed in a 5 x 6 mm plastic package. This is an eight-pad package (Fig. 1), although only three pad connections are needed: for bias, RF input, and RF output. The other five pads are not used. The housing includes input and output DC blocking capacitors.

The YSF-122+ pHEMT amplifier is ideal for applications where a small gain block can be added to overcome the signal losses from passive components in a system, such as filters, cables, or switches. It provides nominal gain of 20 dB with ±0.2 dB gain flatness across its 400-MHz bandwidth. The small-signal gain is typically 20.1 dB at 800 MHz, 20.4 dB at 1000 MHz, and 20.3 dB at 1200 MHz.

The gain remains flat even across its specified operating temperature range of -40 to +85°C (Fig. 2). The amplifier’s gain was characterized at room temperature (+25°C) as well as near the extremes of the operating temperature range (-45 and +85°C). The measurements reveal the expected drop in gain at the high-temperature extreme, and the increase in gain at lower temperatures although, as the plots show, the gain across frequency at all three temperatures tracks closely and remains consistent across frequency and temperature.

The gain-versus-temperature-and-frequency measurements were performed with a bias supply of +5 VDC and input power of -25 dBm (the model YSF-122+ amplifier is rated for maximum input power of +21 dBm). When the YSF-122+ amplifier’s small-signal gain was measured as a function of several different bias voltages above and below the nominal recommended +5-VDC bias level, the gain also remained remarkably flat (Fig. 3), showing the amplifier’s relative insensitivity to variations in supply voltage.

In addition to its extremely flat gain, the YSF-122+ amplifier excels in other parameters not typically associated with high, flat gain, including noise figure, output power, reverse isolation, and output third-order intercept (IP3) performance. The amplifier exhibits noise figure of 3.5 dB at 800 MHz, 3.4 dB at 1000 MHz, and 3.4 dB at 1200 MHz. As with the gain, the noise figure for the YSF-122+ amplifier is very well behaved with bias supply. When characterized at bias settings of +4.75, +5.0, and +5.25 VDC, the noise figure remained close to 3.5 dB across all frequencies of operation. And even across the operating temperature range, where the noise figure of an amplifier is expected to fluctuate, the YSF-122+ shows only about ±0.5 dB variation (Fig. 4).

The YSF-122+ also delivers typical output power at 1-dB compression of +20.5 dBm at midband, with levels of +20.5 dBm at 800 MHz, +20.5 dBm at 1000 MHz, and +20.4 dBm at 1200 MHz. The output IP3 performance is typically +37 dBm at 800 MHz, +36 dBm at 1000 MHz, and +36 dBm at 1200 MHz. The reverse isolation is typically 32 dB, while the midband input return loss is typically 11 dB and the midband output return loss is typically 15 dB. The amplifier typically draws 118 mA from a +5-VDC supply.
The YSF-122+ is just one example of the Flat Gain amplifier product line, with additional models providing various bands of coverage through 3.8 GHz (see table), including model YSF-232+ with a bandwidth of 1700 to 2300 MHz that is well suited to many cellular communications applications and two relatively broadband models, the 900-to-2150-MHz model YSF-2151+ and the 900-to-3200-MHz model YSF-322+.

The YSF-232+ maintains impressive ±0.2 dB gain flatness for typical gain of 20 dB across the 600-MHz bandwidth from 1700 to 2300 MHz. At room temperature, the gain is typically 19.8 dB at 1700 MHz, 20.0 dB at 2000 MHz, and 19.5 dB at 2300 MHz. The output power at 1-dB compression is typically +20 dBm at all three test frequencies, with IP3 of typically +35 dBm at all three test frequencies. As with the lower-frequency YSF-122+, the YSF-232+ maintains remarkably flat gain across the frequency range even with fluctuations in the supply voltage (Fig. 5). The YSF-232+ amplifier has typical midband noise figure of 2.8 dB and typical reverse isolation of 30 dB.

For general-purpose, broadband satcom applications, the YSF-2151+ amplifier has typical specified gain flatness of ±0.4 dB from 900 to 2150 MHz (Fig. 6). It supplies typical gain of 20.2 dB at 900 MHz, 20.0 at 1600 MHz, and 19.8 dB at 2150 MHz. The output power is +20 dBm at all three test frequencies, and the noise figure remarkably drops with increasing frequency, registering 3.5 dB at 900 MHz, 3.1 dB at 1600 MHz, and 2.6 dB at 2150 MHz. The YSF-2151+ has high reverse isolation of 30.5 dB with typical current draw of 118 mA at +5 VDC.

The broadest-bandwidth YSF amplifier is model YSF-322+, with 20 dB typical gain at 2000 MHz and a usable bandwidth of 900 to 3200 MHz, although gain does drop off to typically 16 dB at the upper-frequency limit. As a result of the wide bandwidth covered, this is the YSF amplifier with the poorest gain flatness, at ±2.2 dB, although still competitive performance for such a wide bandwidth. In spite of the broad bandwidth, the YSF-322+ achieves low noise figure, with typically 3.5 dB at 900 MHz, 3.0 dB at 1700 MHz, 2.5 dB at 2500 MHz, and 2.5 dB at 3200 MHz. The output power at 1-dB gain compression is +20 dBm at all four test frequencies, while the typical reverse isolation is a robust 30 dB.

The highest-frequency YSF amplifier is model YSF-382+, which covers 3300 to 3800 MHz. The gain drops off somewhat compared to the other members of the Flat Gain family, 16.0 dB at 3300 MHz, 14.5 dB at 3600 MHz, and 14.0 dB at 3800 MHz, but the gain response is still a respectable ±0.9 dB in terms of flatness with frequency (Fig. 6). The noise figure is typically 2.5 dB at 3300 MHz, 2.5 dB at 3600 MHz, and 2.6 dB at 3800 MHz, while the output power at 1-dB compression is typically +20 dBm at all three test frequencies, and the output IP3 is typically +36 dBm at all three test frequencies. The YSF-382+ exhibits 28 dB typical reverse isolation for good immunity from signal reflections in the signal-processing chain, such as from reflective filters.

The YSF Flat Gain amplifiers are designed to handle maximum input-power levels to +21 dBm and are supplied in eight-lead 5 x 6 mm plastic surface-mount packages with a conductive metal paddle for dissipating excess heat. All of the E-pHEMT amplifiers are two-stage designs that operate from a single +5-VDC voltage supply and all feature input and output ports matched to 50 Ω for ease of use. Full data sheets, performance curves, and raw data are available on the Mini-Circuits web site. —JB Mini-Circuits, P. O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500, FAX: (718) 332-4661, www.minicircuits.com.