Design of a Powerful Signal Generator Output Stage

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Signal generators produce defined electrical signals with a characteristic progression over time. If these signals exhibit a simple, periodic waveform, such as with sine, square, or triangular waves, the generators are called function generators. They are often used to check the function of electrical circuits or assemblies. A defined signal is applied to the input and connected at the output to a corresponding measuring device (for example, an oscilloscope). It can then be evaluated by the user. In the past, the challenge usually consisted of designing the output stage. A description of how to design a small and inexpensive output stage with a voltage gain amplifier (VGA) and a current feedback amplifier (CFA) is described in this article.

Typical signal generators offer output voltages in the range of 25 mV to 5 V. To drive loads of 50 Ω and higher, powerful discrete components, multiple components in parallel, or expensive ASICs are typically used on the output side. Internally, there are often relays that allow devices to switch between different amplification or attenuation levels and thus adjust the output level. Through the required switching of the relay for various gains, discontinuous operation arises to a certain extent. A simplified block diagram is shown in Figure 1.
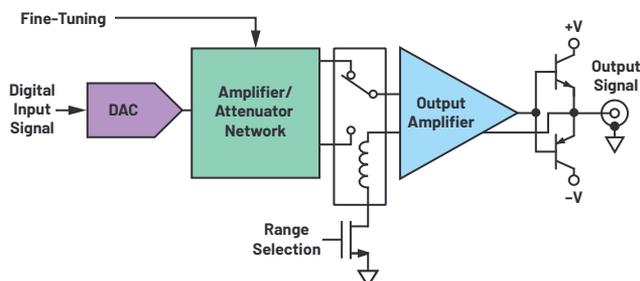

Figure 1. Simplified block diagram of a classic signal generator output stage.

With newer amplifier ICs, loads can also be driven directly without any internal relay. The design of the generator output is thereby simplified and the complexity and costs are lowered. The two main components of such an output are building a powerful output stage, which delivers high speeds, high voltages, high currents, and a variable amplifier with continuous linear fine-tuning capabilities.
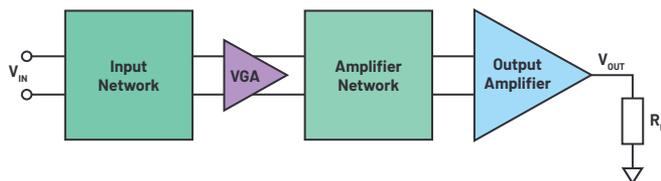

Figure 2. Simplified block diagram of a signal generator output stage with VGA.

First, the original input signal must be amplified or attenuated through a VGA. The VGA's output signal can be set to a desired amplitude independent of its input signal. For an output amplitude, V_{OUT}, of 2 V at a gain of 10, for example, the output amplitude of the VGA must be regulated to 0.2 V. Unfortunately, many VGAs represent the bottleneck due to their limited gain range. Gain ranges greater than 45 dB are quite rare.

With the low power VGA AD8338, Analog Devices enables a programmable gain range from 0 dB to 80 dB. Thus, under ideal conditions, output amplitudes between 0.5 mV and 5 V can be programmed continuously for signal generators without the need for additional relays or switched networks. Through the omission of these mechanical components, discontinuities can be avoided. Because digital-to-analog converters (DACs) and direct digital synthesis (DDS) components often have differential outputs, the AD8338 offers a fully differential interface. In addition, via a flexible input stage, any asymmetries in the input currents can be compensated through an internal feedback loop. At the same time, the internal nodes are kept at 1.5 V. Under normal conditions, the maximum 1.5 V input signal generates a current of 3 mA at input resistances of 500 Ω. With higher input amplitudes—for example, 15 V—a higher resistance would be required directly on the input pins. This resistance is sized in such a way that the same current of 3 mA results.

Many commercial signal generators deliver a maximum effective output power of 250 mW (24 dBm) at a load of 50 Ω (sine wave). However, this is often inadequate for applications with higher output powers, as are required, for example, for testing HF amplifiers or generating ultrasonic pulses. For this reason, current feedback amplifiers are also used. The ADA4870 enables a drive current of 1 A at an amplitude of 17 V on the output side for a supply voltage of ±20 V. Sine waves can be generated under full load up to 23 MHz, which makes them ideal front-end drivers for universal arbitrary waveform generators. To optimize the output signal swing, the ADA4870 is configured with a gain of 10, thus the required input amplitude is 1.6 V. However, because the ADA4870 has a ground-referenced input, but the upstream AD8338 has a differential output, a differential receiver amplifier for differential-to-ground-referenced conversion should be connected between both parts. The AD8130 offers a gain-bandwidth product (GBWP) of 270 MHz and a slew rate of 1090 V/µs, which is a very good fit for this application. The output of the AD8338 is limited to ±1 V, so the intermediate gain of the AD8130 should be designed to be 1.6 V/V. The overall circuit configuration is shown in Figure 3. It offers a bandwidth of 20 MHz at an amplitude of 22.4 V (39 dBm) and a load of 50 Ω.
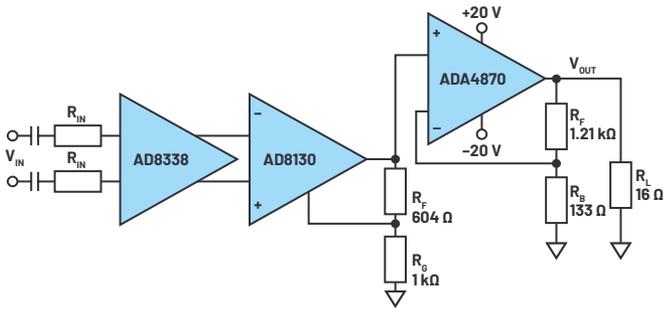
Figure 3. Simplified circuit of a discretely designed signal generator output stage.

Through the combination of a high power VGA (AD8338), a powerful CFA (ADA4870), and a differential receiver amplifier (AD8130), a compact high power signal generator output stage can be built relatively easily. It outshines traditional output stages through its higher system reliability, higher service life, and lower costs.

References

Hunter, David. "Two New Devices Help Reinvent the Signal Generator." *Analog Dialogue*, October 2014.

About the Author

Thomas Brand began his career at Analog Devices in Munich in 2015 as part of his master's thesis. After graduating he was part of a trainee program at Analog Devices. In 2017, he became a field applications engineer. Thomas supports large industrial customers in Central Europe and also specializes in the field of Industrial Ethernet. He studied electrical engineering at the University of Cooperative Education in Mosbach before completing his postgraduate studies in international sales with a master's degree at the University of Applied Sciences in Constance. He can be reached at thomas.brand@analog.com.

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