

A Low Cost DDS Function Generator

Build this useful signal source around a dedicated DDS IC and gain a valuable addition to your test bench.

Gary Richardson, AA7VM

I recently began experimenting with narrow-band filters for use in a WWVB receiver and found that my ancient Hewlett Packard 3310A function generator was woefully inadequate as a test signal source—the tuning rate was too high and the frequency stability too low. Rather than spend a lot of money for a new one I decided to try to build one. My first attempt was a Wien Bridge oscillator which was no better. Then I ran across a thread on the **sci.electronics.design** newsgroup discussing an Analog Devices direct digital synthesis (DDS) chip, the AD9833. After studying the data sheet a bit I decided this was just the component I needed.

The AD9833 DDS IC is a low power programmable waveform generator capable of producing sine, triangle and square wave outputs at frequencies from zero to one-half the clock frequency. It can be programmed via a 3-wire serial interface—the parallel port of an IBM compatible PC can easily do the job and the necessary software is readily available. The internal frequency registers are 28 bits, which means that the resolution of the generated signal is the clock frequency divided by 2^{28} —for a 10 MHz clock that is less than 0.04 Hz. It is also inexpensive, less than \$10 in unit quantities, and it provides much of the functionality of a commercial function generator at a fraction of the cost.

Circuit Description

A function generator supplied with power and controlled by your PC can be

The completed function generator is built into an aluminum enclosure. The DDS chip and oscillator are both surface mount devices (SMD) and are soldered to the underside of the board as described in the text.

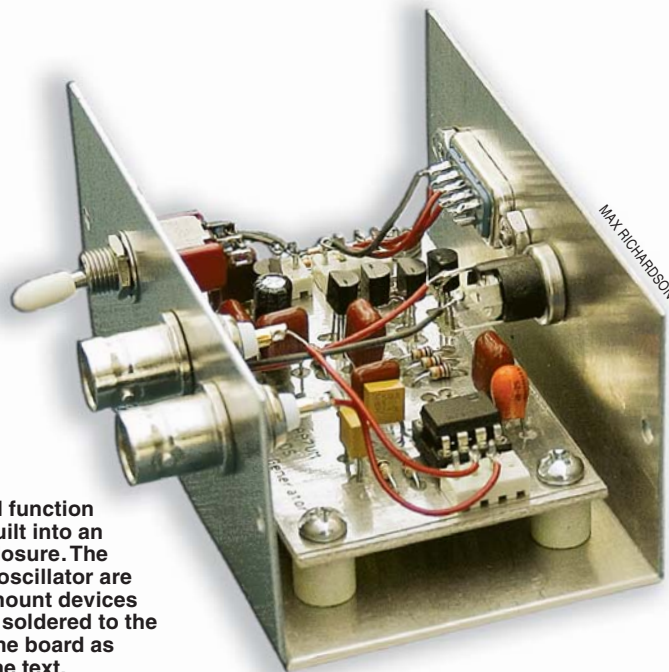
constructed with a minimum of components: DDS chip, clock source, an op-amp, a few resistors, capacitors and diodes and, depending upon your power source, a voltage regulator. Figure 1 is the schematic of my circuit. I used a 10 MHz surface mount oscillator as the clock source because it was convenient and inexpensive—\$3.30. The clock frequency can be as high as 25 MHz (with lower resolution of the output signal). The FET switches provide isolation between the PC and the function generator when the gates are low. Shorting pins 1 and 2 of P4 completes the connection to the PC. My power source is 13.8 V dc, so I used a 78L05 regulator (U3) to obtain the required 5 V dc. The op-amps, U2A and U2B, buffer the AD9833 and provide low impedance outputs.

The output signal amplitude of the AD9833 is typically $0.6 V_{p-p}$ at low frequencies. R4 and R5 can be selected to provide some additional gain if desired, or R5 can be omitted for unity gain. With $R4=294 \Omega$ and $R5=1 k\Omega$, the gain will be 1.294 and the low frequency output will be $0.775 V_{p-p}$ or 0 dBm into 600Ω . R8,

R9, C6 and C7 form a second-order low pass filter with a break frequency of 1 MHz.¹ This may be used to attenuate the spurious components in the sine wave output. The choice of op-amp is somewhat critical; it should have a gain-bandwidth product of at least a few MHz, be stable in a unity-gain configuration, operate with a single supply of 5 V dc and have rail-to-rail output.² The 3 MHz TLV2472 works reasonably well and total current consumption of the board is 12.5 mA.

Construction

Construction of the function generator PC board is relatively straightforward. The most difficult component to install is the DDS chip, which is only available in a surface-mount MSOP-10 package.³ The oscillator is also a surface-mount device, but it is very large, and easy to solder in place. A two-layer PC board is used, with a top-side ground plane and bottom-side circuit traces.⁴ The surface-mount components are placed on the bottom side. The AD9833 has separate analog and digital grounds, and the data sheet recommends that these be connected at only one place. This is done at C6. If your PC board does not have



¹Notes appear on page 42.

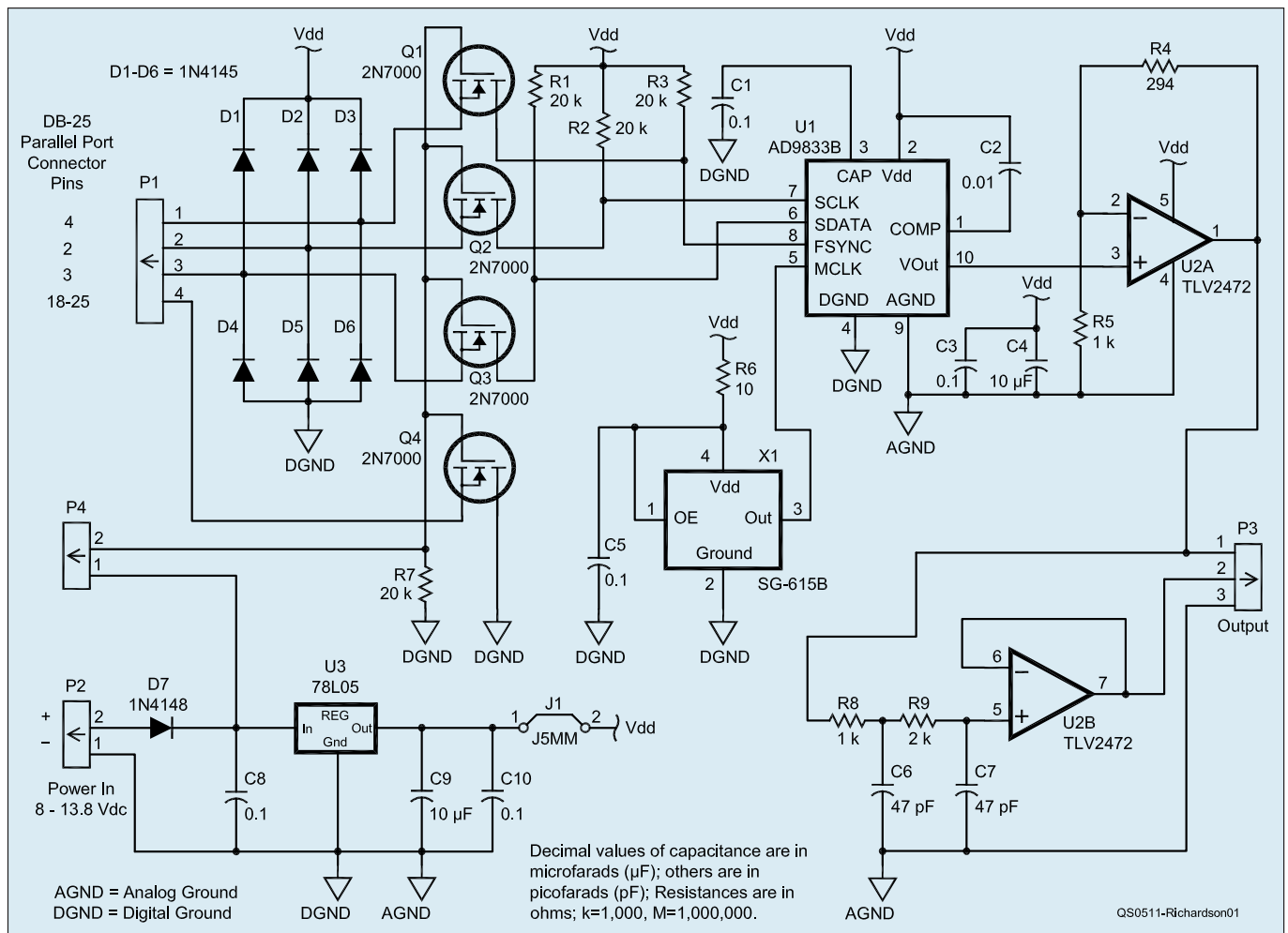


Figure 1—Schematic of the DDS function generator. All resistors are $\frac{1}{8}$ or $\frac{1}{4}$ W. All capacitors are rated at 16 V dc or greater. All ND part numbers are Digi-Key (701 Brooks Ave South, Thief River Falls, MN 56701; 800-344-4539; www.digikey.com).

C1, C3, C5, C8, C10—0.1 μF , P4593-ND.
C2—0.01 μF , P4582-ND.
C6, C7—47 μF , PCE3181CT-ND.
C9—10 μF , PCE3061CT-ND.
D1-D7—1N4148, 1N4148DICT-ND.
P1—36-pin connector, NorComp, 1036-ND.
Q1, Q2, Q3, Q4—2N7000, 2N7000FS-ND.

R1, R2, R3, R7—20 k Ω .
R4—294 Ω , 294XBK-ND.
R5, R8—1 k Ω , 1.00KXBK-ND.
R6—10 Ω , 10.0XBK-ND.
R9—2 k Ω , 2.00KXBK-ND.
U1—AD9833B DDS waveform generator, Analog Devices, AD9833BRM-ND.

U2—TLV2472IP operational amplifier, Texas Instruments, 296-10617-5-ND.
U3—UA78L05ACL voltage regulator, Texas Instruments, 296-1365-ND.
X1—SG-615B 10.000 MHz oscillator, ECS-8FM-100-TR, XC639CT-ND.

plated-through holes it will be necessary to solder the ground side of C6 at both the top and bottom sides of the PC board to complete this connection. Similarly, the ground ends of D6, C5 and C8 should also be soldered at both the top and bottom to complete the digital ground circuit and tie it to the ground plane. Do not forget to install jumper J1.

The lead photo shows the completed board mounted in a small aluminum enclosure. I made a cable from some 4-conductor wire and DB-9 and DB-25 connectors. Figure 1 indicates pin assignments for both.

Figure 2 shows the layout of the pc board and the bottom-side circuit trace. The AD9833 is located in the center of

the board and is dwarfed by the much larger through-hole components that surround it. There is room at the corners of the board for 6-32 mounting screws.

Software Support

This circuit is modeled after the AD9833 evaluation board and the evaluation board software can be used to control it. This is a Windows program and it can be downloaded from the Analog Devices Web site.⁵ It provides control of all of the device features such as setting the frequency registers, selecting the waveform, etc. It also can generate a sweep frequency output.

I have written driver software in Python that can be used to control the

AD9833 with a Python program.⁶ Contact me by e-mail if you would like a copy.

Operation

There are a few facts that should be kept in mind when using this function generator. The most obvious is that the output signal is quantized. The AD9833 generates the sine and triangle outputs digitally by updating a 10-bit digital-to-analog converter (DAC) with the appropriate values at the clock rate. With a 10 MHz clock, this quantization begins to become apparent in the unfiltered output at frequencies as low as 80 kHz. Also, the signal amplitude varies with frequency. This variation can be expressed mathematically as $[\sin(x)]/x$ with

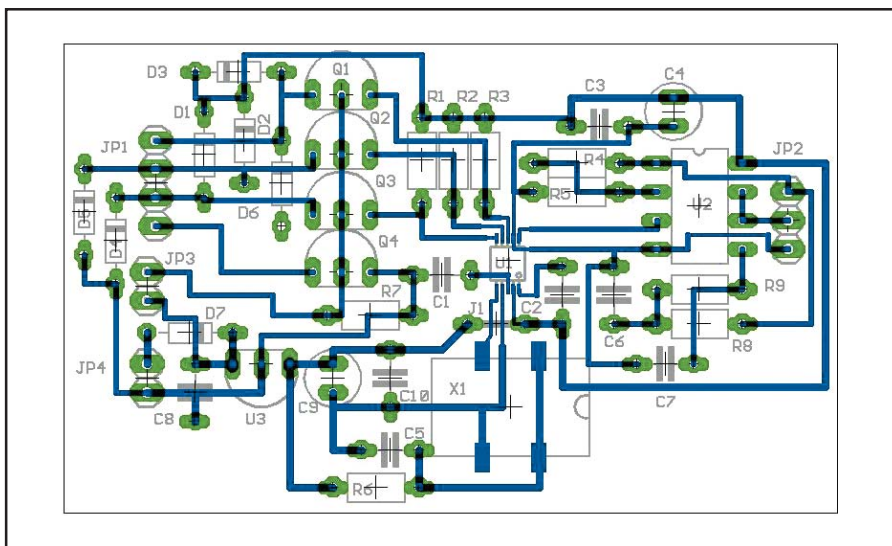


Figure 2—The layout of the function generator PC board showing the bottom-side circuit trace and the placement of the components.

$x = (2 \pi f) / f_c$, where f is the desired frequency and f_c is the clock frequency. This might be of concern when making measurements at widely spaced frequencies. Lastly, the sine wave output is not a pure sine wave; it contains spectral components at other (image) frequencies. These image components appear at multiples of the clock frequency plus and minus the fundamental.

There is a great deal of information

about the AD9833 and direct digital synthesis techniques available on the Analog Devices Web site.

Notes

¹The poles of this network are at 0.99 MHz and 5.8 MHz. To select another break frequency, compute $R7$ as $0.293/2\pi f C8$ and set $C9 = C8$ and $R8 = 2 R7$.

²If a non rail-to-rail output amplifier is used, the signal may be clipped at the lower limit (near

zero). A voltage divider (eg, 1 k Ω , 51 k Ω) between the output of $Q1$ and V_{DD} could be used to bias the input to $Q2$ slightly positive to overcome this problem.

³For a few tips on working with SMT parts see A. Davis, "SMT Soldering," *QST*, Feb 2000, p 70. You may find some useful information on the Web but it seems mostly to be for commercial applications. This site was interesting: www.geocities.com/vk3em/smtguide/websmt.html. Also, check out the electronics newsgroups such as sci.electronics.design, sci.electronics.basic, comp.arch.embedded.piclist, comp.robotics.misc, etc for discussions of SMT problems.

⁴A drilled and etched PC board is available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118; tel 847-836-9148 (voice and fax); farcir@ais.net; www.farcircuits.net.

⁵www.analog.com/en/content/0,2886,770%255F843%255F29173,00.html.

⁶*Python* is a very elegant, high level, open source programming language. See www.python.org.

*Gary Richardson, AA7VM, has been interested in things electrical and mechanical since an early age. He received a Novice license and the call KN5WHO in 1957. Gary earned an MSEE degree from Michigan State University in 1967 and spent much of his career designing software for embedded microprocessors in medical systems. He received the Amateur Extra class license in 1994. You can reach Gary at PO Box 228, Marblemount, WA 98267; garyr@fidalgo.net. **QST***

Feedback

◇ In "A LowCost DDS Function Generator" [November 2005, p 40], the maximum supply voltage should be 20 V, not 30 V as indicated.