a **Technical Note**

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Digital Control of the AD9850/51 DDS Output Amplitude

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In December l996, Analog Devices published application note, AN423, showing a simple analog means of controlling the output amplitude of the AD9850 DDS using an enhancement mode MOSFET. Some users of the AD9850/51 DDS IC's have requested digital control of the output amplitude. The block diagram below shows such a circuit. The high speed AD9731 10-bit DAC is overkill in terms of resolution and speed, but easy access to an evaluation board weighed heavily in its favor. Other DAC's, whether current-out or voltage-out, are adaptable for digital control of the AD9850/51 DDS. I have also provided a small listing of control device alternatives at the end of this article. The DAC input is a 10-bit digital sine wave pattern produced by a Tektronics DG2020 data generator (DC levels or other patterns may be used in place of the sine wave). The DAC output is a 20 mA (maximum) current with an output compliance voltage range from +3 to –1.5 volts. DAC output resistance is 240 Ohms to ground
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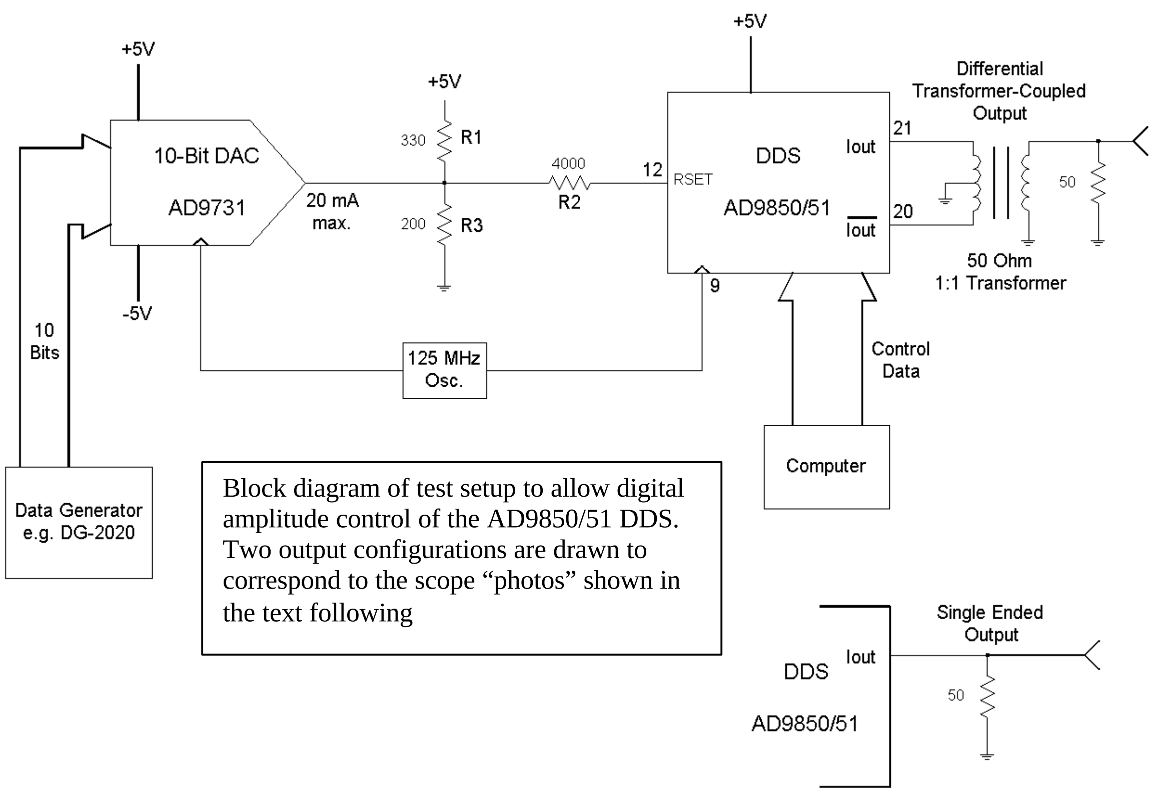


Block diagram of test setup to allow digital amplitude control of the AD9850/51 DDS. Two output configurations are drawn to correspond to the scope "photos" shown in the text following

The voltage at pin 12, R_{set}, of the AD9850/51 is approximately 1.26 volts. This voltage is generated internally and must not be altered. The current that flows through R2 sets the full-scale output of the AD9850/51 output DAC and is equal to $(I_{outB} + I_{out})/32$. R2 is normally connected to ground. By replacing ground with a variable voltage from a DAC , the current through R2 will vary. When the voltage at R1, R2, R3 node is => 1.26 volts, no current or current of the wrong polarity flows through R2 and little DAC output current is seen. When the voltage is < 1.26 volts, then the I_{out}/I_{outB} outputs will become active with a current sum equal to 32 times that flowing in R2.

Without R1, the voltage developed across R3 can be from 0 to some negative voltage. This is because the DAC is sinking current from ground through R3. R1 is added to dc offset the voltage in a positive direction at the junction of R1 and R3. The component values were chosen to accommodate the built-in 240 Ohm output resistance of the AD9731 DAC. Adjusting the value of R1 gives more or less positive dc offset voltage, but will also cause the voltage swing of the DAC to vary somewhat. The goal in this example was to set the maximum positive peak of the AD9731 DAC output to approximately 1.1 volts, so that the DDS output was fairly close to minimum output and to provide a 1.5 volt swing. This produces approximately 12 mA output maximum and 1.2 mA minimum (20 dB dynamic range) from the DDS. As the voltage at the R1/R3 node decreases below 1.26V, the DDS output current increases. The maximum output current of the AD9850/51 is 20 mA for proper DDS DAC performance. The value of R2 is the nominal value used on the AD9850/51 evaluation boards. The parallel combination of R1, R3 and the internal DAC output resistance of 240 Ohms will yield the resistive load that the 20 mA output of the AD9731 DAC sees.

If a single-ended output configuration (see bottom of block diagram) of the AD9850/51 DDS is used, you will get a pulsed output that looks like Figure 1. Figure 2 shows the effect of combining the I_{out} and I_{outB} of the DDS in a broadband, center-tapped RF transformer (for example, Mini-Circuits T1-1T). Use of a transformer adds symmetry to the output envelope but also eliminates or limits the low frequency (dc to 50 kHz) output capability of the DDS. An op amp can be used in place of a transformer to retain DDS operation down to dc.

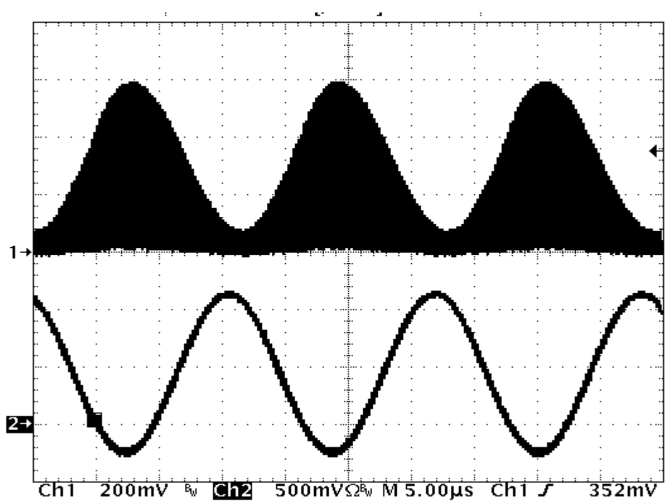


Figure 1

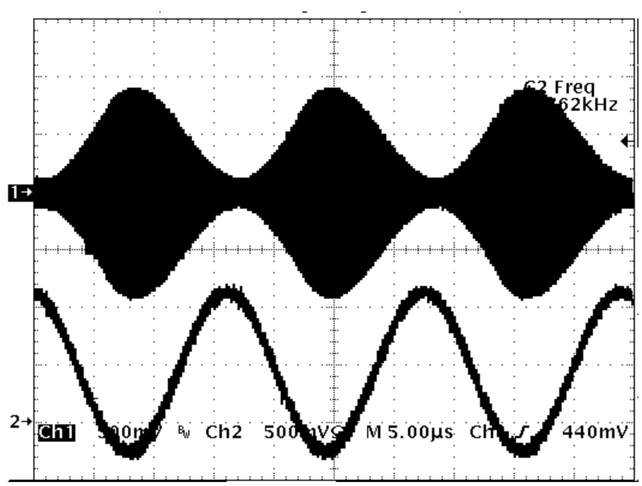
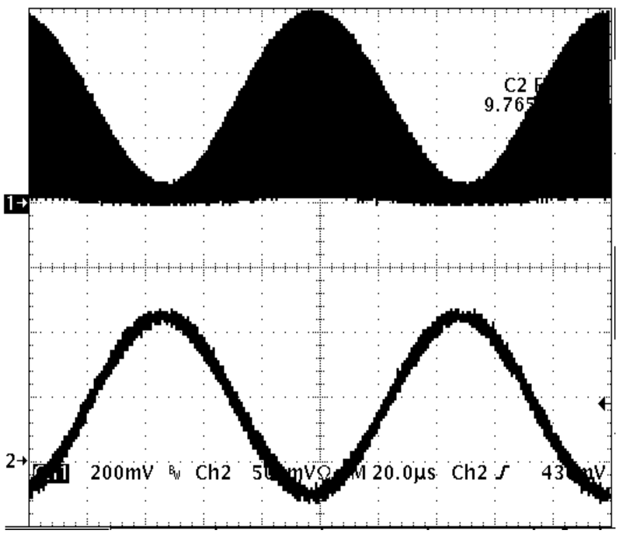


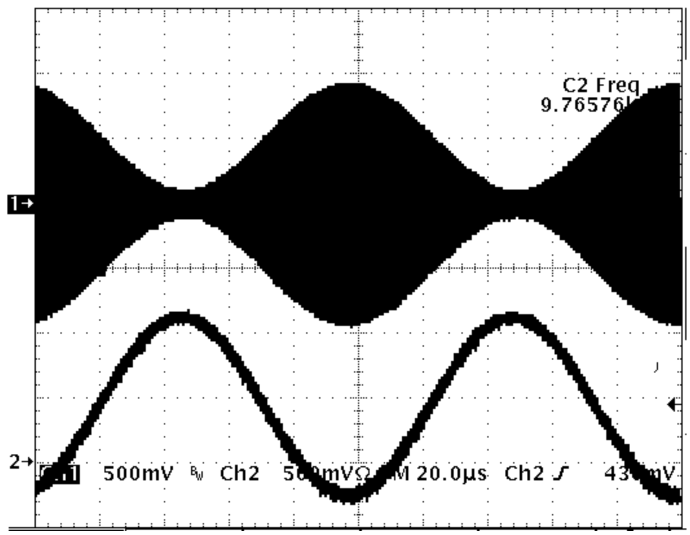
Figure 2

Above, two scope views were captured using an “envelope” function instead of “trace”. These show the AD9850 DDS output sine wave being amplitude modulated with a 61 kHz sine wave from an AD9731 10-bit DAC. The top trace of the left image is the amplitude envelope of the 10 MHz DDS single-ended output signal. The bottom trace of the left image shows the modulating signal produced by the AD9731 10-bit DAC. Both signals are dc coupled to the scope. Ground for each channel is indicated by the arrow to the right of the trace number located at the left edge of the “screen”.

Voltage levels for each trace are seen at the bottom of the screen. To the right, a similar scope view showing the same conditions above except the DDS output is differentially coupled using a center-tapped transformer. This allows the I_{out} and I_{outB} signals of the DDS to be combined to form a symmetrical amplitude modulated envelope. Note that the dc offset of the amplitude envelope (top trace, right image) is symmetrical about ground and some distortion is evident. This distortion is due to the limited frequency response of the R_{set} input of the AD9850/51.

Below are captured scope views under similar conditions as figures 1 and 2 except that the modulating frequency has been decreased from 61 kHz to 10 kHz. Note that the modulation envelope at right is noticeably less distorted than that of figure 2. This is due to the modulation frequency being more compatible with the R_{set} input bandwidth limitation. If you look closely at figure 2, you will see a slight phase misalignment between the DDS output envelope and the modulating signal peaks and valleys. This phase shift and consequent signal distortion are indicative of "running out of bandwidth".





The information presented here and in AN423 is meant to give you an idea of what you can do with the R_{set} input of the AD9850 and AD9851 DDS to achieve output amplitude control. Important things to remember are:

- the voltage at the R_{set} input pin (1.26 volts) must not be modified
- R_{set} modulating bandwidth is about 100 kHz maximum
- changes in R_{set} current are multiplied by 32 at the DDS output
- maximum R_{set} current is 625 microamps
- R_{set} current is "sourcing" not "sinking"

If your control of R_{set} stays within these constraints then you can safely and effectively control the AD9850/51 output current using any means at your disposal…digital pots, DAC's, FET's, manual pots, analog voltage or current sources, transistors, photoresistor, thermister, etc.

If you have an interesting circuit to suggest for a particular DDS application, please feel free to fax me at 336 605 4187. I'm interested in what you are doing with DDS devices