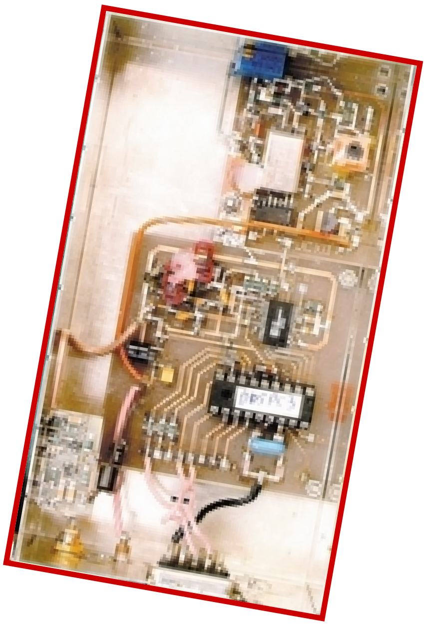
Direct Digital Synthesiser for Radio Projects



By Andy Talbot, G4JNT *

THE PRINCIPLES BEHIND Direct Digital Synthesis (DDS) have been described before in *RadCom* [1] and so will not be described further here. This reference describes a DDS signal source using the same device as employed here, in a self-contained stand-alone unit with LCD display and rotary control for frequency setting. Now, a different approach is adopted, with the DDS chip being included in a small stand-alone module controlled by straightforward text-based messages from a PC. The module has been designed to be used as a drop-in component in larger projects such as receivers or transceivers. An onboard PIC microcontroller allows control of the DDS chip from a standard PC via the serial port, and a straightforward command syntax has been developed so that standard software commands, written in any language, can be used to set the operating parameters. This PIC can easily be reprogrammed to suit any user's requirements in a stand-alone project and enough spare Input / Output lines are provided to allow for this.

This article is intended to provide an overview of the DDS module as a component for larger projects, and only limited details are included. Complete constructional and programming data are available from HF-Instruments [2].

DDS MODULE DESIGN

THE MODULE IS BASED around an Analog Devices AD9850 DDS chip, full details of which are available from Analog Devices [3]. The device will accept a clock signal up to 120MHz, although a suitable source is not provided within the module. This is best left to individual constructors. For most purposes, any low-cost packaged oscillator module will suffice. The DDS can generate an output up to approximately one-third of the clock frequency with a resolution of over 4 billion so, for a 120MHz clock, frequencies from DC to 40MHz can be produced in steps of approximately 28 millihertz (mHz), and so the actual frequency of the clock is unimportant, provided of course it is known with reasonable accuracy. The RF output is at a level of 1V p-p (0.35V RMS) from a source impedance of 100 ohms.

The supplied PIC controller translates text-based messages received from the serial port into command codes for the AD9850, and (optionally) stores these in non-volatile RAM for immediate setting at switch-on. Spare memory in the PIC allows user information, such as the exact clock frequency, to be read out on request, allowing common software to be written that can drive individual modules, each having different clock frequencies. Another option available in the firmware is a 'times-four' output, where the output from the module is designed to drive a quadrature frequency generator which performs the final frequency division.

A single hex-digit module address is included as part of the command syntax, to allow multiple modules to be driven in a multi-drop arrangement from a common controller with one COM port.

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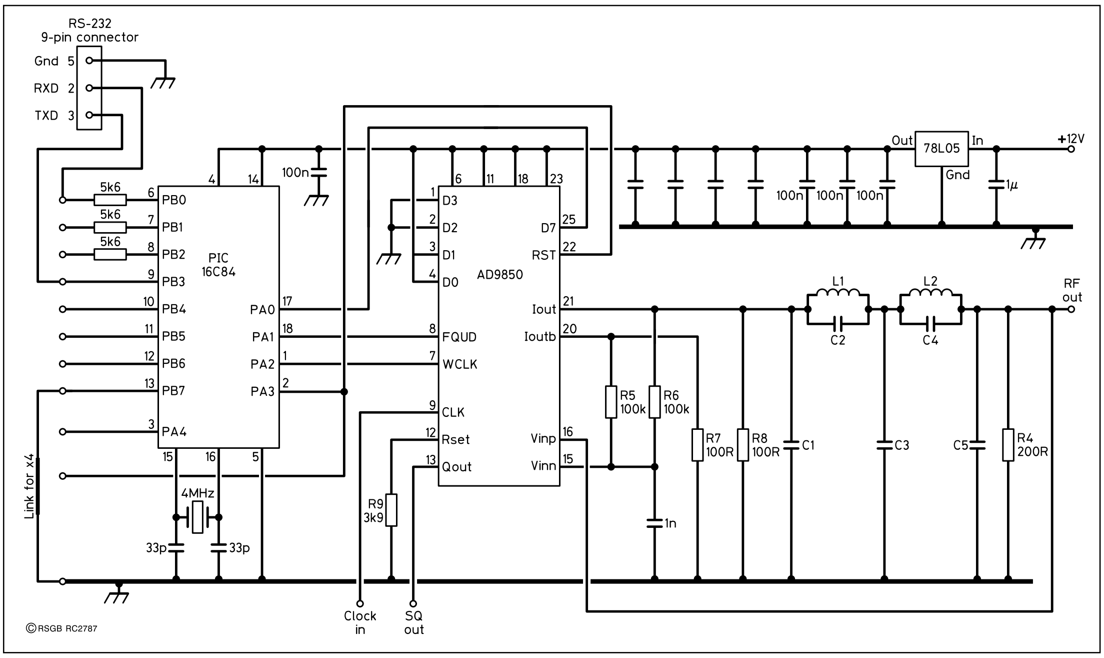

Fig 1: Circuit diagram of the AD9850 DDS module. Filter components and some decoupling components are dependent upon clock frequency.

OUTPUT SPURII

SPURIOUS output signals from a DDS are complex in their nature and are not harmonically related – the device data sheet gives more details. All spurii from the design here are at levels of –60dB or better. This figure is obtained from the manufacturer's specification and is affected by the design of the output filter. One useful facet about DDS circuitry is that the spurious levels below the output filter cutoff are inherently dependent on the circuits internal to the DDS chip, and are not affected by poor circuit layout; this aspect is often troublesome in other synthesiser designs, as filtering cannot remove close-in products.

60dBc spurious levels may be considered a bit excessive if this module were to be used alone as the local oscillator of a high-performance wide-band receiver, but there are additional techniques such as Phase Locked Loops that can clean up this signal which will not be covered here. An example is given in Reference [4]. For narrow-band receivers, such as are used for LF, the filtering needed for other purposes should be sufficient to eliminate the effects of most of the DDS-generated spurii.

CONSTRUCTION

THE CIRCUIT DIAGRAM is shown in **Fig 1**, from which it can be seen that the module actually has very few components, most of them being for decoupling and output filtering. A ready-made PCB with plated-through holes is available from HF-Instruments [2]. This can be supplied with the tiny surface-mount AD9850 device already soldered on and removes the biggest hurdle for most constructors - soldering the tiny chip with its 0.6mm pin spacing. All other components are of the larger size 1206 or 0805 surface-mount style; for the output filter, wire ended components are used. The PIC controller is mounted in a socket for easy re-programming.

The photograph shows a prototype version of the DDS board, together with a high-stability 94MHz source on the PCB top right and an output buffer amplifier bottom left.

Values of components for the output filter depend on the clock frequency chosen, as do the values of decoupling capacitors. With a clock input that can range from a few kHz up to 120MHz, the optimum values of these can vary over a wide range. Guidelines for selecting appropriate values are given in the constructional and programming data available from [2].

SOFTWARE CONTROL

COMMANDS ARE SENT using ASCII / Hex characters over a bi-directional RS-232 link with no handshaking. Parameters are 19,200 baud, 8 data bits, no parity, 1 stop bit. A simple terminal programme such as HYPERTRM (Windows®) or PROCOMM (DOS) can be used to command the frequency source. Set this to 19200 N 8 1, full-duplex, no flow control and all start up and modem commands set to null. Alternatively, custom software can be written to drive the COM port with the commands.

The first character sent is a board address which precedes all commands. This is a single Hex character sent as ASCII 0 – F and potentially allows up to 16 modules to be driven from the same COM port.

The next character is a command which may have hex data following it.

- Q followed by eight hex digits for the frequency command word terminated by a carriage return [CR]
- P followed by two hex digits for phase word and [CR]
- U writes the data sent above to the AD9850 DDS chip
- W as for U, and also stores all data in the PIC's non-volatile EEPROM memory for switch-on next time
- Y followed by one Hex digit, changes the board address and stores in EEPROM. No [CR] needed
- K followed by 10 hex digits and [CR]. User data, not used for driving the DDS. (In practice, read as decimal number for user data, typically clock frequency)
- R read back current data values – not necessarily those in EEPROM

The 32 bit or 8 hexadecimal character, value N (required for frequency-setting), can be derived from:

$$N = F_{out} / F_{clock} \times 2^{32}$$

Phase can be set to any one of 32 values in increments of 11.25 degrees. These form the five highest significant bits of the phase word Pxx. The lowest three bits are ignored.

Data is sent back from the DDS in text strings which can be read directly by application software.

An example of a command to set the output frequency is:

5Q03D70A3D [CR]	Board address 5, set frequency word N = hex 03D70A3D
5U	Programme the DDS to this value (with a 120 MHz clock, this gives an output at 1.8MHz)

APPLICATIONS

ANY EXPERIMENTS or testing that needs an agile frequency source is a candidate. Just about any programming language that includes commands to drive the serial port can be employed, and does not even have to be PC-based. The only requirement is that you can actually write suitable software!

One application written to demonstrate the functionality of the module is for generating a narrow-band Multi-Tone Hellschreiber signal for LF use. SMT-Hell transmits visible text as an image, and can be received on a frequency / time plot, commonly known as a spectrogram or waterfall display, using public domain commonly-available audio analysis software. The software generates SMT-Hell signals by directly commanding the DDS module (in real time) to set the frequencies that make up the vertical elements of each character sent. The horizontal components are made up by appropriately setting software delays. Transmissions as narrow as 2.5Hz bandwidth have been sent on 137kHz and successfully decoded as visible letters even where the signal is completely inaudible below the noise.

The ability to set the output signal phase to one of 32 values means that slow Phase Shift Keying is also possible by direct command. An additional command code (T) allows frequency and phase updates to be synchronised to an external trigger input on port B1 such as that from a GPS receiver. The DDS chip is updated within 3µs of the trigger signal rising edge and will allow, for example, precisely-timed low data rate signalling experiments.

By using the DDS output to drive the reference input to a conventional Phase Locked Loop synthesiser, the best of both worlds becomes possible. The high-frequency capability of PLL synthesisers, up to many GHz, can be coupled with the tiny step size of the DDS. For example, a PLL operating with an output at 2.4GHz could be made with a step size of 0.55Hz.

DDS frequency resolution is considerably better than the stability of most crystals will allow. In fact, the actual crystal frequency can be measured, stored in the user data area of memory and then used in subsequent high-accuracy output frequency calculations.

REFERENCES

[1] 'PIC 'n' Mix Direct Digital Synthesiser' Peter Rhodes, G3XJP, *RadCom* January 1999.

[2] The Printed Circuit Board is available from HF-Instruments who can supply a bare version for users who wish to obtain their own AD9850 devices, and also a PCB with the DDS chip ready-mounted. Phone 01420 590 000. Costs are £8.00 and £40.00 respectively. Discounts are available for purchases of two or more. Full constructional details are available from their website at www.hf-inst.co.uk.

For anyone without web access, HF-Instruments will provide printed copies of the documentation on request.

[3] Analog Devices' web site: www.analog.com

[4] 'A PLL Spur Eliminator for DDS VFOs', Rick Peterson, WA6NUT, *QEX* July/August 2000. ♦