Introduction

The HI5721 is a 10-bit 125MHz Digital to Analog Converter. This current out DAC is designed for low glitch and high Spurious Free Dynamic Range operation. This DAC is ideally suited for Signal Reconstruction and DDS (Direct Digital Synthesis) applications due to it's inherent low noise design.

Architecture

The HI5721 DAC is designed with a split architecture to minimize glitch while maximizing linearity. Figure 1 shows the functional architecture of the device. The 6 least significant bits of the converter are derived by a traditional R/2R network to binaurally weight the 1mA current sources. The upper 4, most significant bits are implemented as segmented or thermometer encoded current sources. The thermometer encoder converts the incoming 4 bits to 15 control lines to enable the most significant current sources.

As shown in Figure 2 the thermometer encoder translates the 4 bit binary input data into a decode that enables individual current sources. For example a binary code of 0110 on the data bits D6 thru D9 will enable current sources I1, I2, I3, I4, I5, and I6. The thermometer encoding architecture ensures good linearity without laser trimming. Also, compared to a straight R/2R design, the worst case glitch is greatly reduced since creating the MSB current is the sum of current sources I1 thru I8. Overall glitch is reduced by a factor of 16. This also reduces the theoretical switching skew from current source to current source by using identically sized switches with identical gain, leakage, and transient responses.

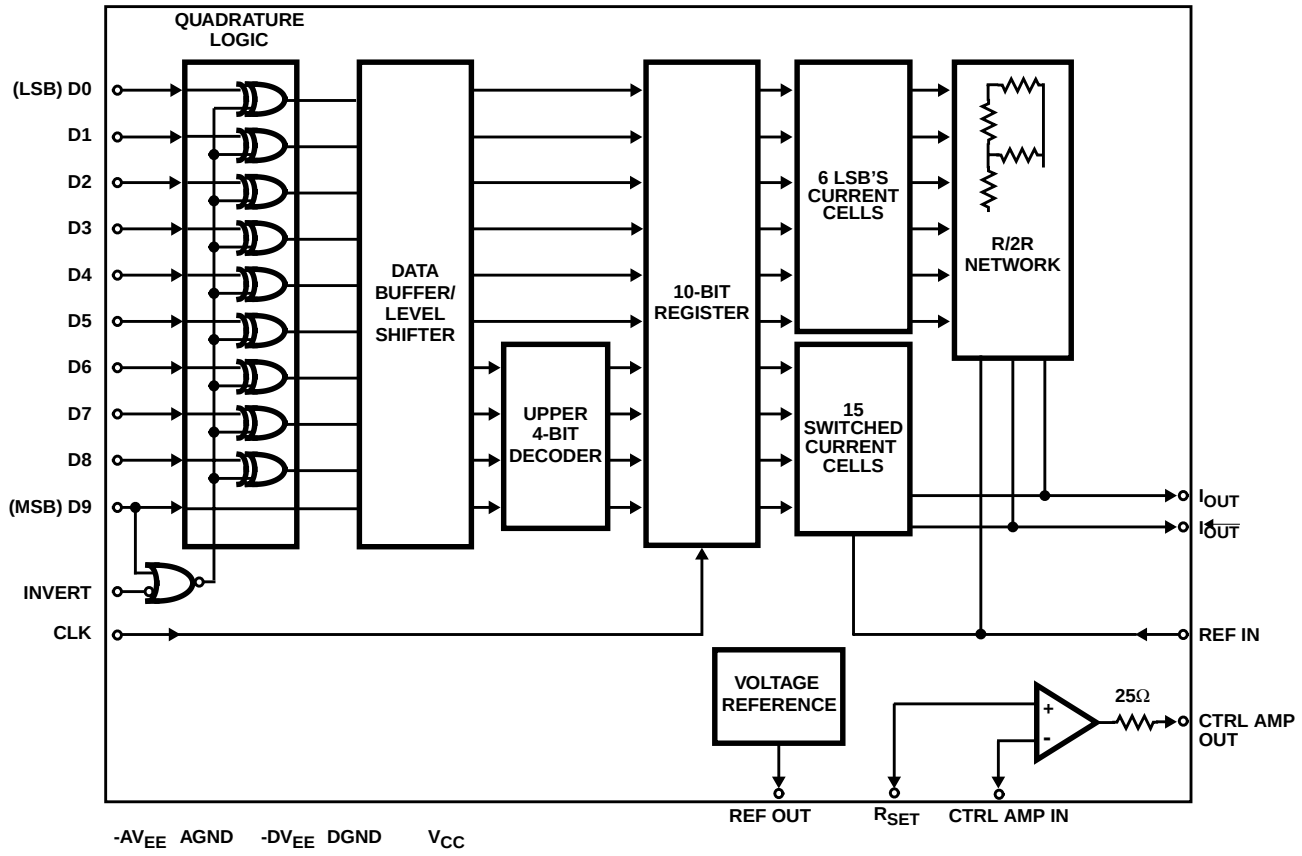


FIGURE 1. BLOCK DIAGRAM

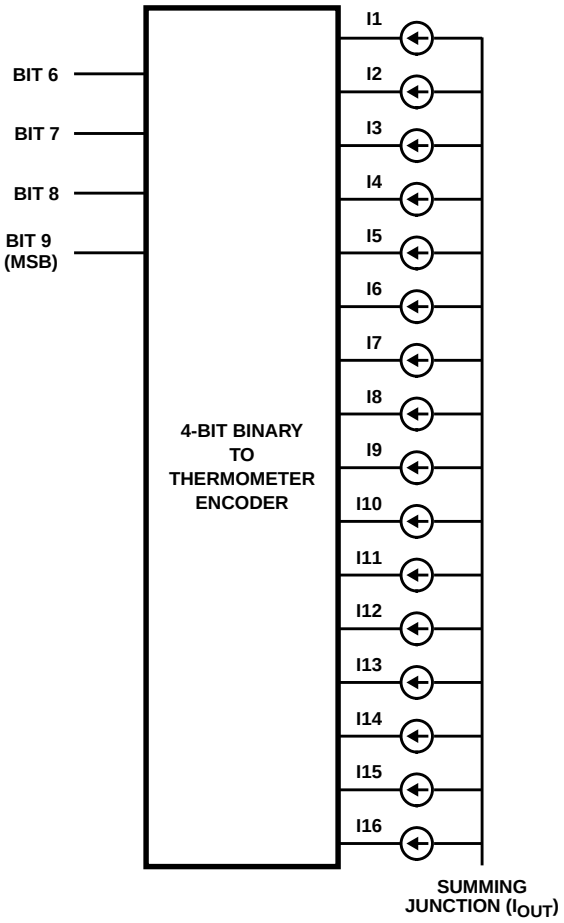


FIGURE 2. THERMOMETER ENCODER

Designing to Minimize Glitch

One cause of Glitch is the time skew between bits of the incoming digital data. Typically the switching time of digital inputs are asymmetrical meaning that the turn off time is faster than the turn on time. Unequal delay paths through the device can cause one current source to change before another. To minimize this, the Intersil HI5721 employes an internal register just prior to the current sources updated on the rising clock edge. In traditional DACs the worst case glitch usually happens at the major transition i.e. 01 1111 1111 to 10 0000 0000. But in the HI5721 the worst case glitch is moved to the 00 0001 1111 to 11 1110 0000 transition. This is achieved by the split R/2R segmented current source architecture. This decreases the amount of current switching at any one time and reduces the glitch by a factor of 16.

Since the glitch is a transient event, this leads designers to believe that a simple low pass filter can be used to eliminate or reduce the size of the glitch. In effect low pass filtering a glitch tends to “smear” the event and does little to remove the energy of the transient.

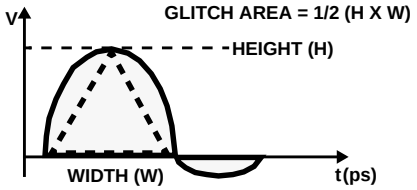


FIGURE 3. GLITCH AREA

Input Timing/Logic Levels

The HI5721 has a maximum clock rate specification of 100MHz. The data setup time before the 50% point of the rising edge of the clock is t_S = 1.2ns (MIN) and the hold time is t_H = 0.5ns (MIN). Logic levels are 0.8V (MAX) for an input low and 2.0V (MIN) for a logic high. The HI5721 is both TTL and CMOS input compatible.

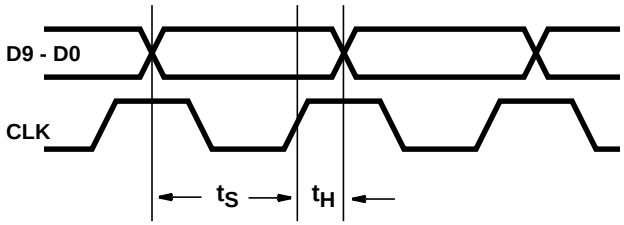


FIGURE 4. HI5721 DATA TIMING

INVERT Control Pin

The INVERT control pin is used to enable the internal quadrature logic on the data bits. The internal quadrature logic feature is used to reduce the amount of memory store in a given Numerically Controlled Oscillator (NCO). The NCO need only store one quadrant of the sine wave data and use the invert pin to create the remaining 3 quadrants of the sine wave.

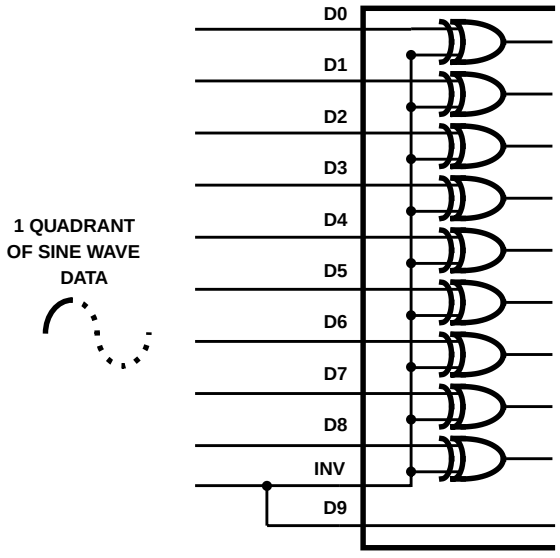


FIGURE 5. USING THE INTERNAL QUADRATURE LOGIC

To use the internal quadrature logic simply connect the INVERT pin to bit D9 of the HI5721 DAC. In normal operation INVERT should be connected to 0V or Digital Ground.

Integral Linearity

The HI5721 has a FSR range of 20.48mA. When driving an equivalent 50Ω load the full scale voltage swing is 0V to +1.024V. Most video and communication applications use a $1V_{P-P}$ voltage swing which yields 20mA full scale current sink capability. With a $1V_{P-P}$ voltage swing on the HI5721 output an LSB is:

$$\text{LSB} = \text{Full Scale Range}/(2^N-1)$$

where N is the number of bits and the Full Scale Range is $1V_{P-P}$.

The LSB size for this application is 977µV. To determine the Integral Linearity of the HI5721 the bit weights of each major transition is taken. The Best Fit Straight Line method is used to calculate the overall INL. Measurements are taken at bits 0 thru 6 at each bit transition. Then all combinations of the upper 4 bits are measured. Finally some worst case codes are measured and the full scale is measured. Once this is completed a best fit straight line is drawn through the data points and the worst case deviation is determined.

The worst case integral linearity of the HI5721 is specified to be less than 1.5 LSBs. The linearity of the HI5721 is worst in the segmented current sources in the thermometer encoded section. This is due to the errors of each current source being biased in one direction and being additive with increasing data values. The R/2R resistor matching need be to a 6-bit level to ensure overall 10-bit linearity. Process control of resistor matching in the BiCMOS process used is easily adequate to do the job. For the overall transfer function the typical INL performance is shown in Figure 6.

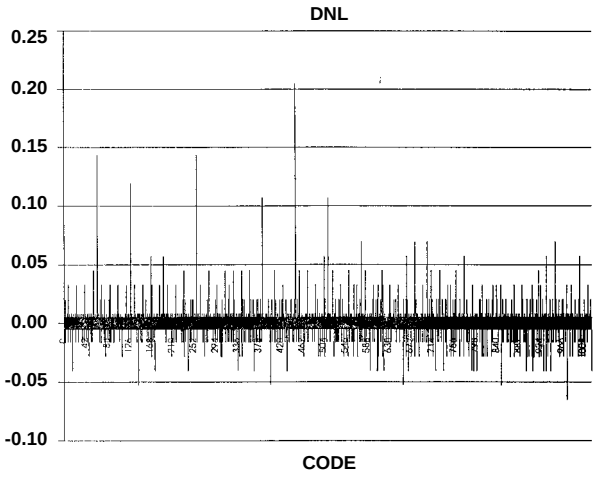


FIGURE 6A. INL TYPICAL PERFORMANCE CURVE

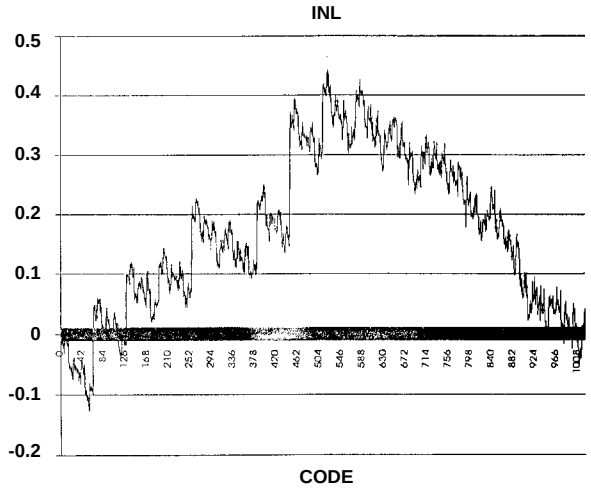


FIGURE 6B. TYPICAL PERFORMANCE CURVE

FIGURE 6.

Differential Linearity and Missing Codes

For a D/A Converter the differential linearity is the step size difference throughout the entire code range. For the HI5721 the step to step maximum difference is 1.0 LSBs. For any given D/A converter, to guarantee no missing codes the converter must be monotonic.

The definition of monotonicity is; as the input code is increased the output should increase. When an input code is increased and the output of the DAC does not increase or reverses direction, then this converter is assumed to be missing codes.

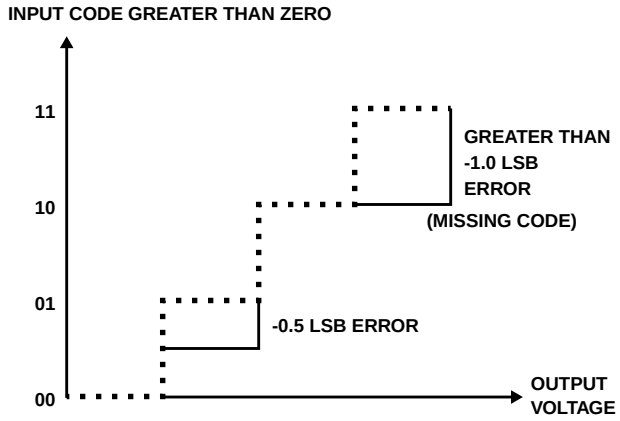


FIGURE 7. DNL EXAMPLE

Shown in Figure 7, as the input code increases the output voltage should increase. When an error of greater than 1.0 LSB is incurred, that bit can be assumed to be a missing code since the output did not increase but rather remained the same.

Adjusting Full Scale

The R_{SET} pin is used to set the Full Scale Output Current. The output current is a function of the reference voltage applied to the CONTROL AMP IN pin and the value of the R_{SET} resistor. To calculate the I_{OUT} Full Scale Current use the following formula:

I_{OUT} Full Scale = 32 x (CONTROL AMP IN/R_{SET})

So where CONTROL AMP IN = 1.25V

and R_{SET} = 1960Ω

I_{OUT} = 20.4mA

To adjust the output full scale current, use a potentiometer in rheostat mode as shown in Figure 8.

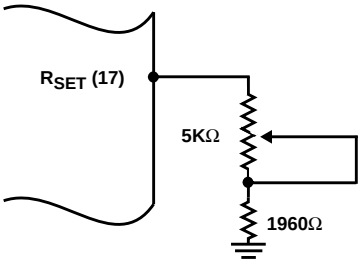


FIGURE 8. FULL SCALE OUTPUT APPLICATION CIRCUIT

The Control Amplifier

The internal Control Amplifier is used to buffer the internal or an external reference. The precision current cells require an adequate amount of drive to bias. The Control Amplifier frees the user from having to provide an external amplifier.

The Evaluation Board

The HI5721 Evaluation board is a 1/2 size daughter board designed to interface to the HSP-EVAL board. When used together these boards create a flexible and powerful DDS system. The HSP45116 board is used to generate the high speed digital sine wave patterns for the D/A module. The HI5721 board reconstructs the incoming digital data to an analog representation that can be analyzed on a spectrum analyzer or oscilloscope.

Plugging In

After setting-up the HSP45116 board and the HI5721 board; power should be applied to the banana jacks. A +5V, and a -5.2V supply will be needed. To reduce noise the power supply leads should be twisted pairs.

Connect the interface cable to an IBM PC or compatible's parallel port. Power should be applied to the board and then run the software directly from floppy disk. To run the software place the floppy disk into drive A: and type:

A: NCOMCTRL

the HSP45116 Control Panel will be loaded. To exercise the board the following parameters should be set:

BINFMT# = 0

and then set the Center Frequency to:

CENTER FREQUENCY = 01000000_{HEX}

where the center frequency is in hex. At this point the output of the HI5721 DAC module should be converting a sine wave at 48KHz. Connect the output of the HI5721 module to an oscilloscope.

The HI5721 module has Jumper plug for selecting the INVERT feature of the HI5721. When J2 is installed, the quadrature logic is disabled. When J2 is removed, the quadrature logic is enabled and the DAC data will be 1's complemented.

DDS Interface

The HSP45116 board is a TTL/CMOS compatible logic board. The HI5721 is a TTL/CMOS compatible logic D/A converter. The design of the DAC module is to interface to the 10 Most Significant Bits of the NCO. The HI5721 module should be plugged into P2 of the HSP-EVAL board.

Spurious Free Dynamic Range

The Spurious Free Dynamic Range of the HI5721 DACs is the most important specification for communication applications. This specification shows how Integral Linearity, Glitch, and Switching noise affect the spectral purity of the output signal. Several important things must be noted first.

When a quantized signal is reconstructed, certain artifacts are created. Let's take the example of trying to recreate a 1MHz sine wave with a $1V_{P-P}$ output. In the frequency domain the fundamental should appear at 1MHz as shown in Figure 9.

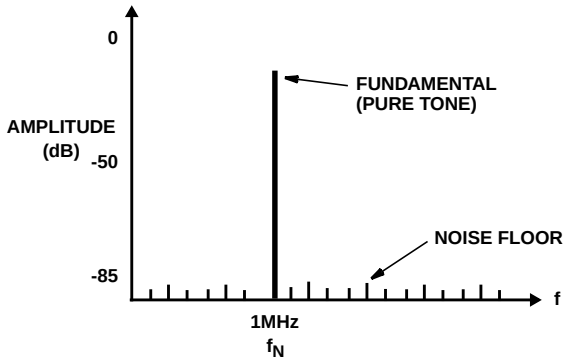


FIGURE 9. FREQUENCY PLOT OF 1MHz TONE

The fundamental of a pure 1MHz tone should appear as an impulse in the frequency domain at 1MHz. In a sampled system noise terms are produced near the sampling frequencies called aliases. These aliases are related to the fundamental in that they are located at $\pm f_N$ around the sampling frequency as shown in Figure 10.

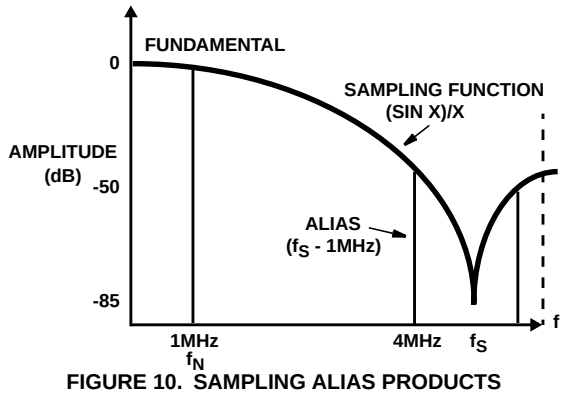


FIGURE 10. SAMPLING ALIAS PRODUCTS

So for a 1MHz fundamental and a 5MHz sampling rate an alias term is created at 4MHz and 6MHz. A (SIN)/X function shaping is also induced by sampling a signal. Aliases continue up through the frequency spectrum repeating around the sampling frequency and its harmonics (i.e. $2f_S$, $3f_S$, $4f_S$).

A reconstructed sine wave out of the HI5721 is not ideal and as such has harmonics of the fundamental. The difference between the magnitude of the fundamental and the highest noise spur whether it is harmonically related to the fundamental or not, is the definition of Spurious Free Dynamic Range. Figures 11, through 16 are sample plots taken of the HI5721 at various frequencies. Included are the oscilloscope plots.

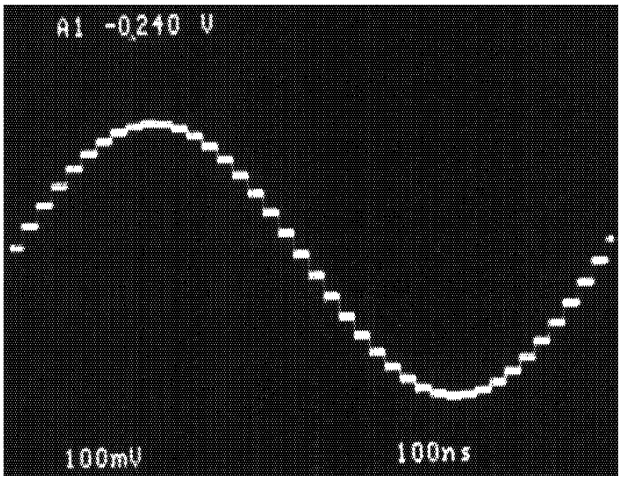


FIGURE 11A. OSCILLOSCOPE PLOT

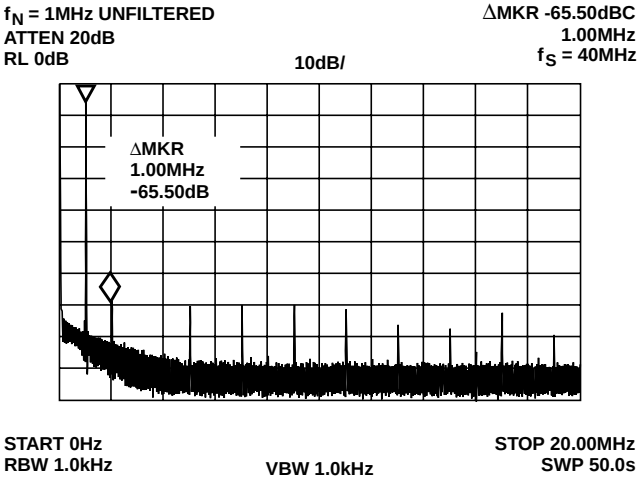


FIGURE 11B. SAMPLE PLOT

FIGURE 11. A 1MHz FUNDAMENTAL TO f_S UNFILTERED

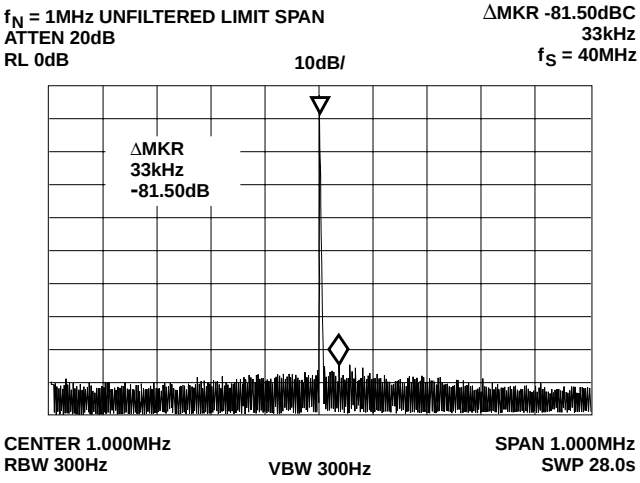


FIGURE 12. A 1MHz FUNDAMENTAL ON A 1MHz SPAN UNFILTERED

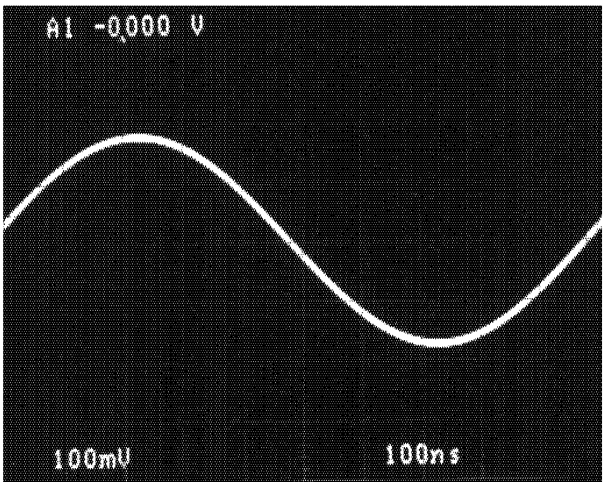


FIGURE 13A. OSCILLOSCOPE PLOT

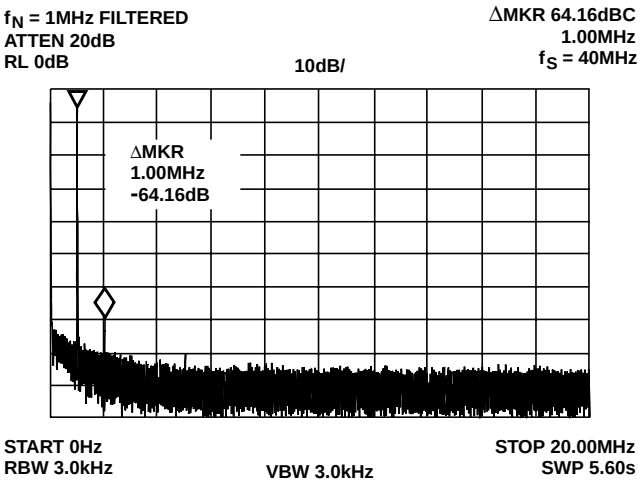


FIGURE 13B. A 1MHz FUNDAMENTAL TO NIQUIST WITH A 20MHz BANDPASS FILTER

FIGURE 13. A 1MHz FUNDAMENTAL TO NYQUIST WITH A 20MHz BANDPASS FILTER

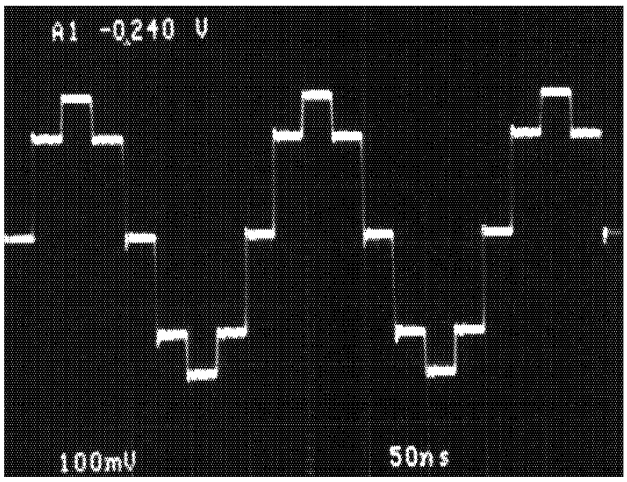


FIGURE 14A. OSCILLOSCOPE PLOT

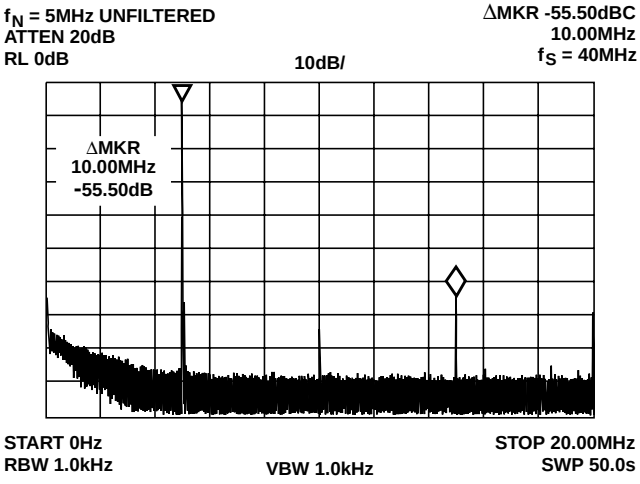


FIGURE 14B. SAMPLE PLOT

FIGURE 14. A 5MHz FUNDAMENTAL TO f_S UNFILTERED

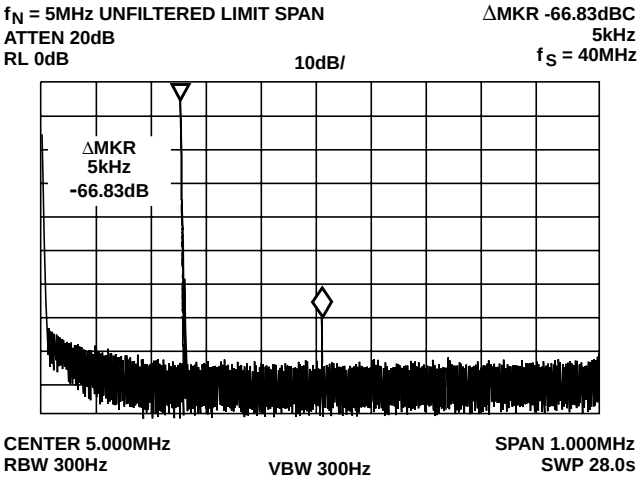
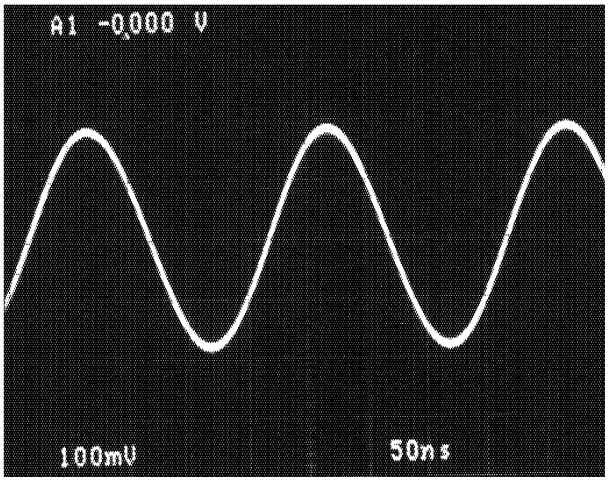


FIGURE 15. A 5MHz FUNDAMENTAL ON A 1MHz SPAN UNFILTERED



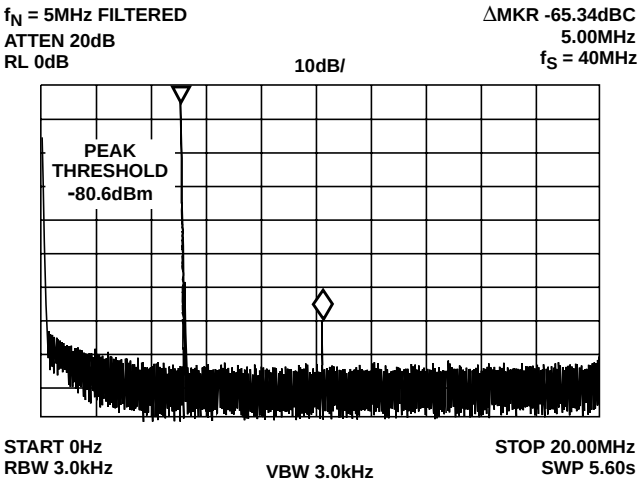


FIGURE 16A. OSCILLOSCOPE PLOT **FIGURE 16B. SAMPLE PLOT**

FIGURE 16. A 5MHz FUNDAMENTAL TO f_S WITH A BANDPASS FILTER

Using the HSP-EVAL Test Platform

The HSP-EVAL DDS platform allows quick testing of spectral properties of a given DAC. The Numerically Controlled Oscillator/Modulator (NCOM) generates digital sinewave patterns that are loaded into the DAC. The analog output of the DAC is the reconstructed sinewave pattern. The program NCOMCTRL allows downloading of the desired center frequency. The clock or sampling frequency is 25MHz. To determine the center frequency codeword the following formula is used:

$$\text{Center Frequency}_{HEX} = (\text{Desired Frequency}/25\text{MHZ}) \times 2^{32}$$

This 32-bit hexadecimal word will create the fundamental. In order to ensure zero phase offset the cursor should be moved to the LOAD select. Pressing the spacebar the value should be toggled from 1 to 0 and back to 1 again. This will ensure that any previous values in the phase register are cleared and the sinewave pattern is started at zero phase.

The HSP-EVAL setup is powered from the DAC module power-supply banana jacks. The output of the setup can be observed on an oscilloscope or a spectrum analyzer.

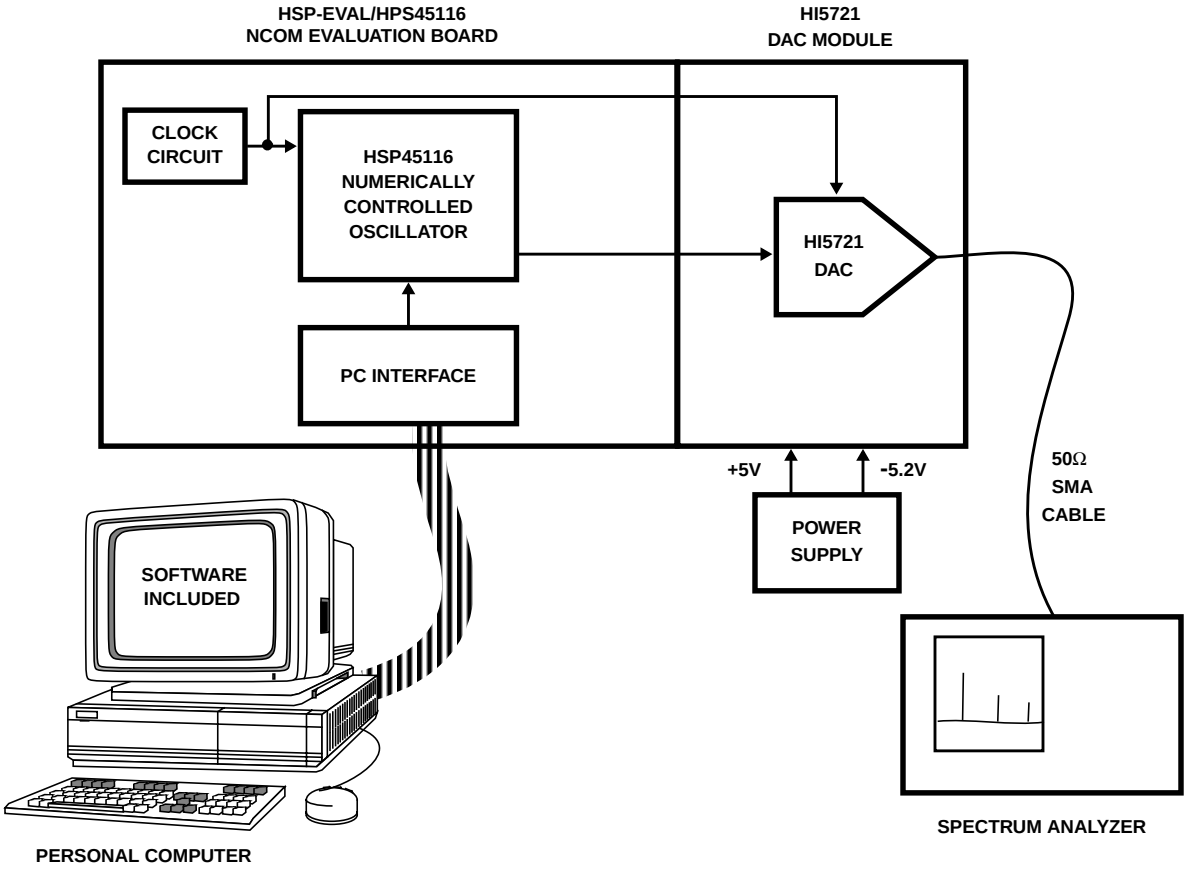
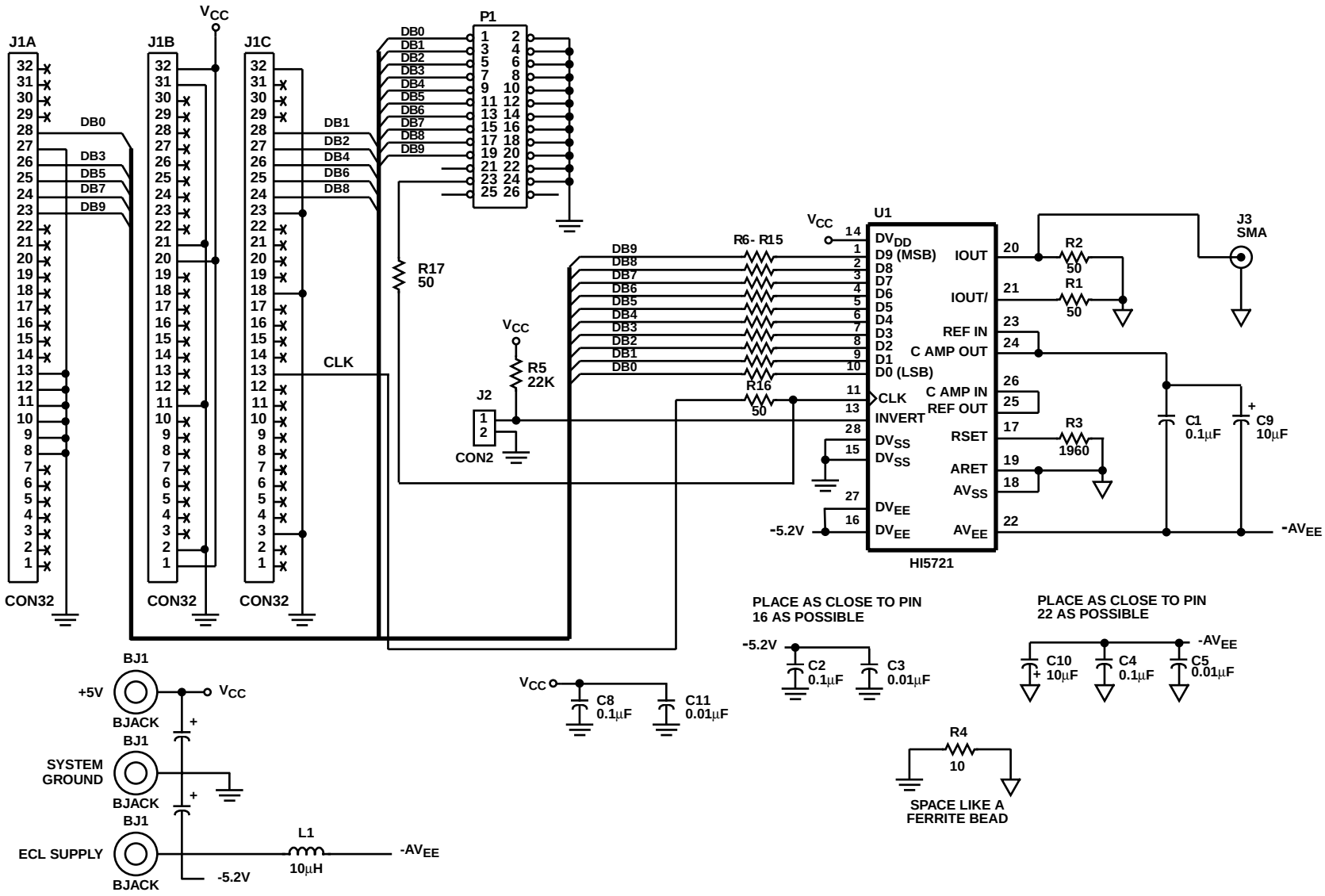


FIGURE 17. INTERSIL HI5721/DDS EVALUATION SYSTEM SETUP BLOCK DIAGRAM

Schematic Diagram



NOTES:

1. All passive components are SMT devices, except polarized capacitors and ferrite beads.
2. HI5721 is a 28 lead DIP.

FIGURE 18.

Evaluation Board Layers

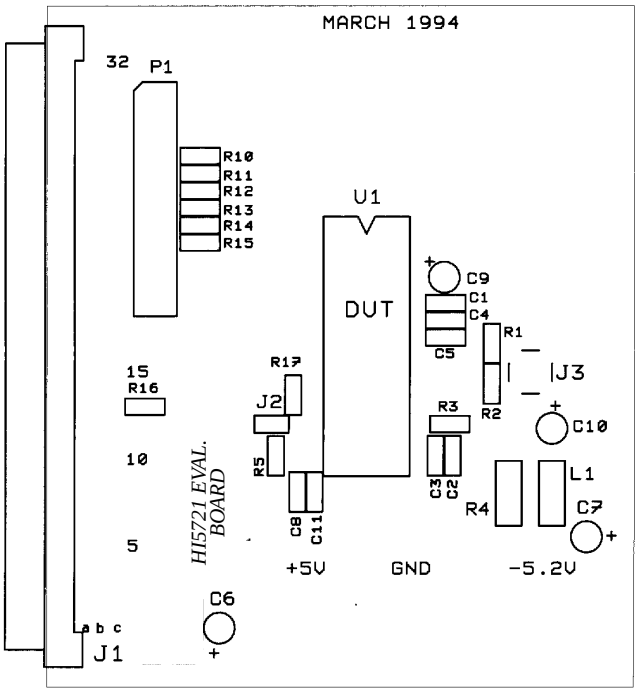


FIGURE 19A. HI5721 SILKSCREEN

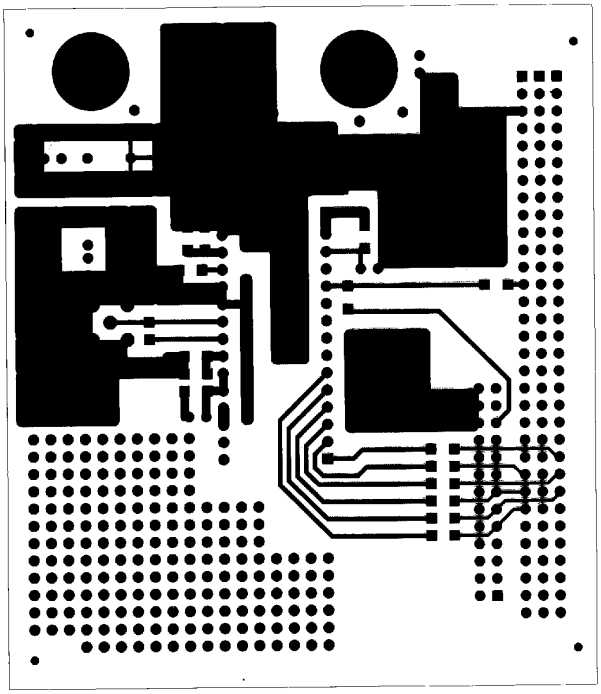


FIGURE 19B. HI5721 LAYER 1

Evaluation Board Layers (Continued)

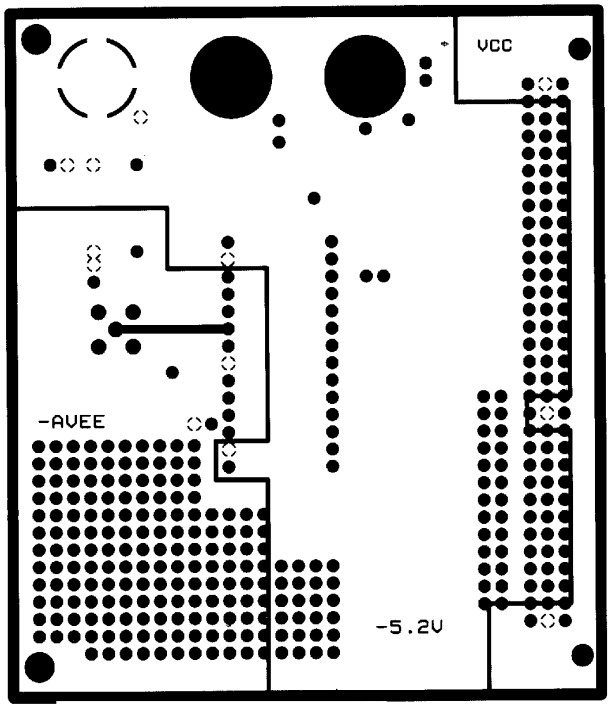


FIGURE 19C. HI5721 LAYER 2

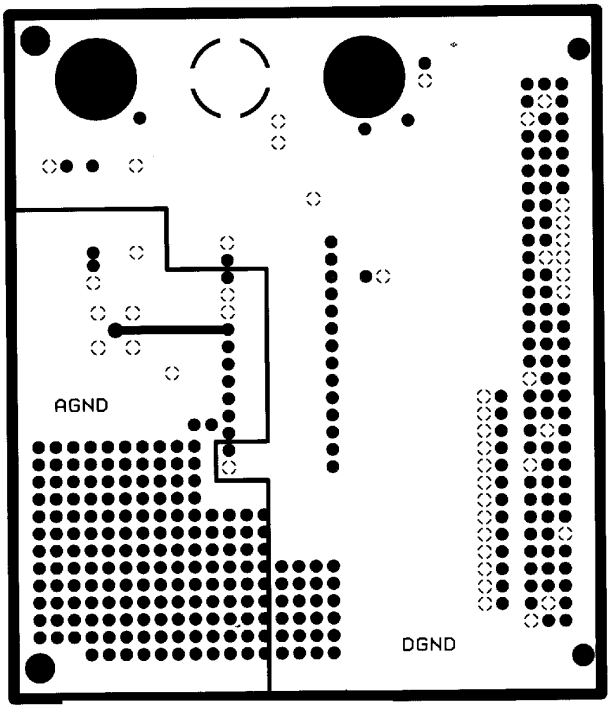


FIGURE 19D. HI5721 LAYER 3

Evaluation Board Layers (Continued)

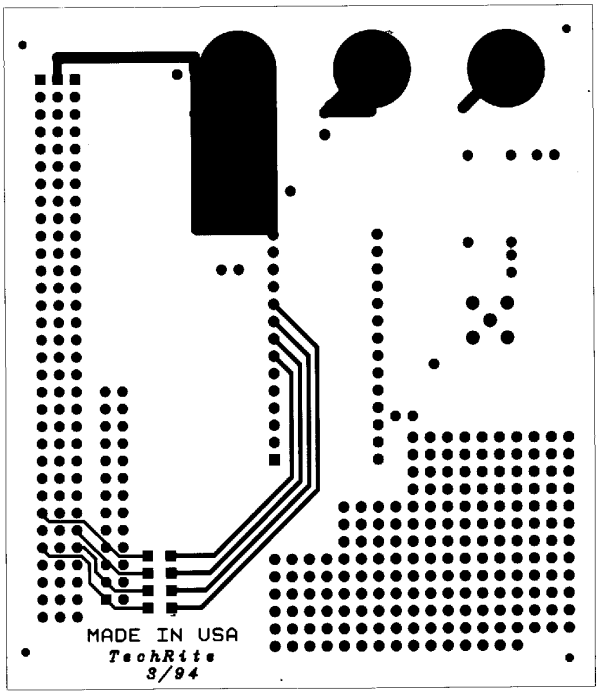


FIGURE 19E. HI5721 LAYER 4

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