

## Cross-Plot Generator Allows Quick A/D Converter Evaluation

### INTRODUCTION

The testing of analog-to-digital converters (ADCs) can be a difficult and time consuming process. The cross-plot generator described here provides a quick, low-cost way to evaluate ADCs.

### ADCs AND THEIR TESTING

Analog-to-digital converters generate a digital code for each discrete value of analog input voltage. The number of codes is a function of resolution. For example, an 8-bit device has 256 codes. The resolution is equal to 1/256 of the full-scale analog voltage. 12-bit converters have 4096 codes and can resolve to 1/4096 of the full-scale voltage. The number of codes can be expressed as  $2^n$  where  $n$  = number of bits.

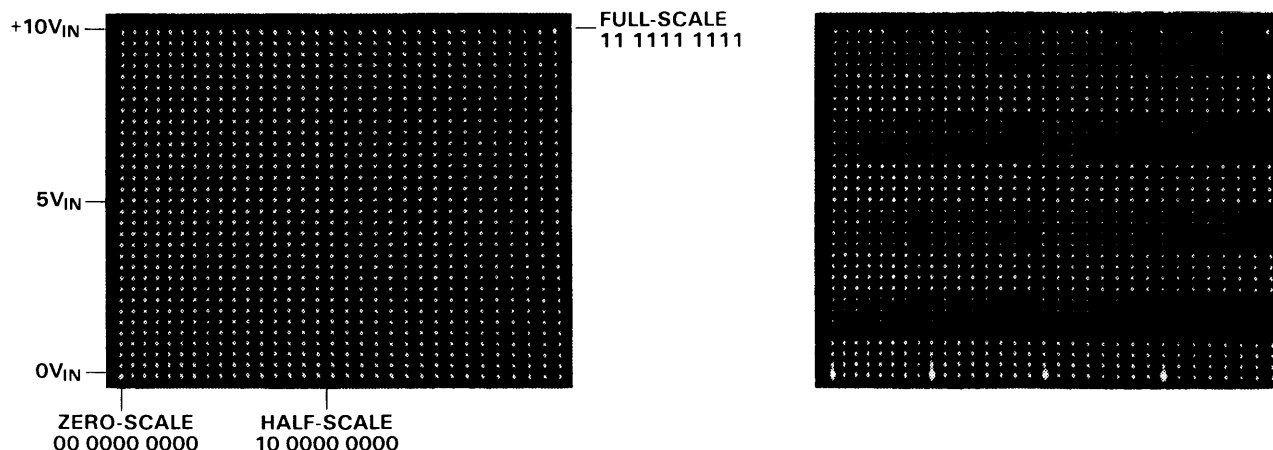
Testing ADCs can be a difficult task. Modern high-resolution devices tax the speed and accuracy of measurement equipment. Linearity tests are highly data-intensive and dynamic measurements require complex and costly test apparatus.

### CROSS-PLOT GENERATOR

The cross-plot generator is a simple approach to ADC evaluation. The system uses basic test equipment, simple logic and timing, and is compatible with converters of any resolution.

The test circuit (see Figure 1) consists of two D/A converters (DACs) which reconstruct the digitized information and display the data in a dot-matrix format (see Matrix Photos). This format allows the user to view the entire transfer function in real time.

### CROSS-PLOT MATRIX



The dot-matrix field for a 10-bit converter is pictured above. The photo illustrates a  $32 \times 32$  dot-matrix or 1024 dots.

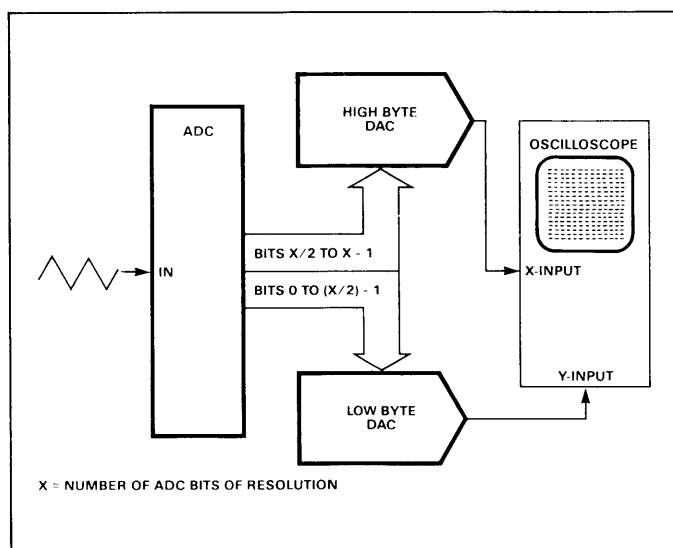
The DUT is an ADC-910 operating with a nominal  $6\mu\text{s}$  conversion time. The inputs are a 10Hz, 0 to 10V triangle wave and a 1MHz clock pulse train. These inputs result in approximately three conversions per code.

Each dot in the matrix represents one digital code. Missing or narrow codes are identified as missing or dim dots in the displayed matrix.

This test method yields four types of data:

1. Missing code identification
2. Dynamic response (conversion speed)
3. Converter code-width
4. System noise

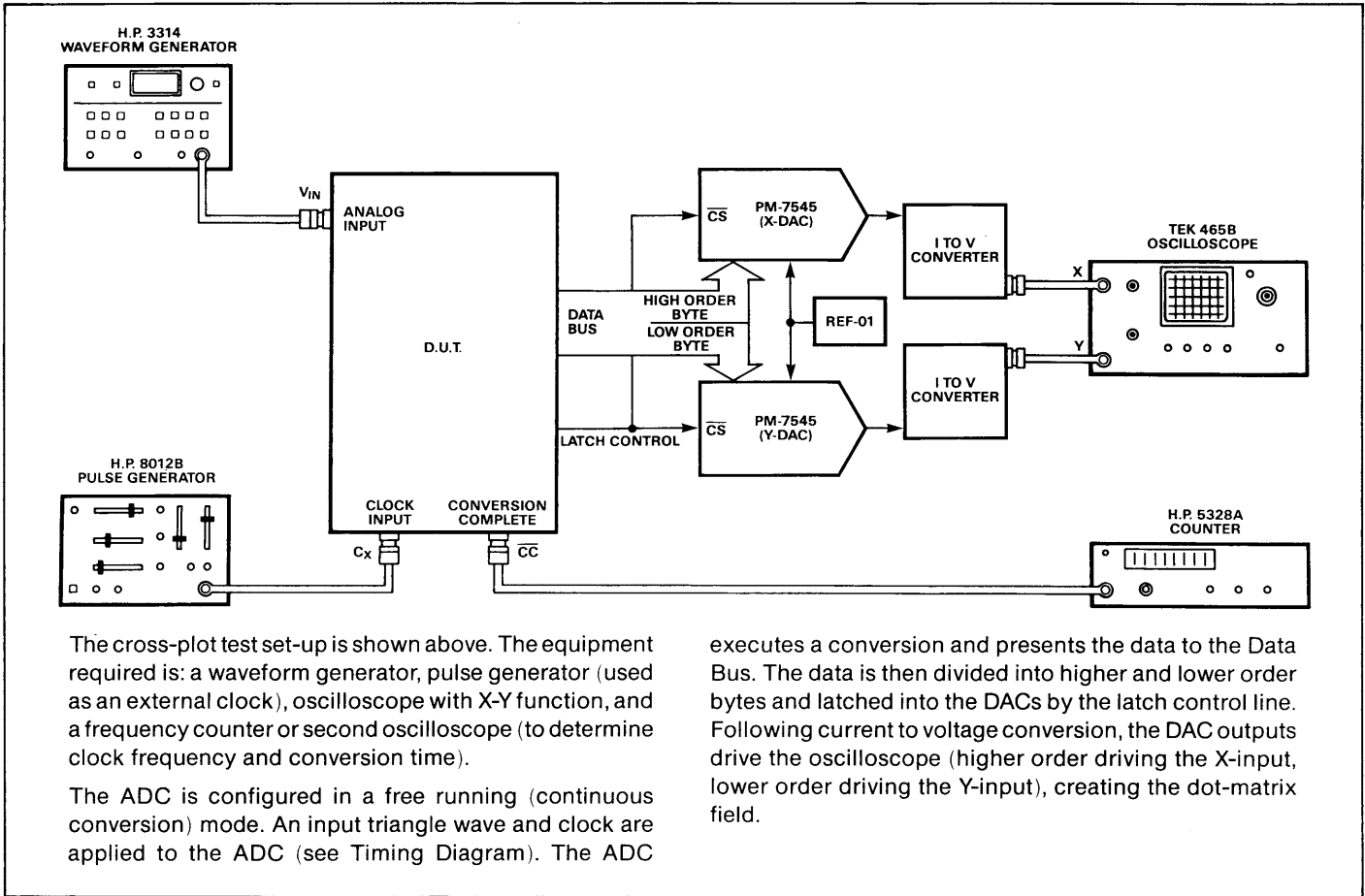
FIGURE 1: Block Diagram



As illustrated in the photo above, missing and narrow codes are clearly visible as weak or absent dots in the array.

In this case, as conversion speed is increased beyond the ADC's capability, missing codes are observed.

**FIGURE 2: Block Diagram**



**MISSING CODES**

One form of converter malfunction occurs when some digital codes are absent or missing. Missing codes can cause serious problems in systems level applications. These missing codes can be identified as holes in the dot-matrix field.

**DYNAMIC TESTING**

Conversion speeds can be measured with the cross-plot generator. A slow triangle wave is applied to the ADC's input. The waveform's voltage is adjusted to sweep from just below zero-scale to just above full-scale. The triangle-wave test frequency should be chosen so that the analog input remains within 1/2 LSB during the converter's conversion time. The conversion clock frequency is then increased until conversion codes (dots in the array) first begin dropping out. A frequency counter is used to determine the clock frequency and conversion time.

Alternately, a second oscilloscope may be used, monitoring the ADC's Conversion Complete line, to determine directly the minimum conversion time.

**CODE WIDTH**

Code-width, or differential nonlinearity, is a measure of the width of the converter's quantizing bands. Each band or code-step has a finite value. As the input voltage is slowly swept, several conversions take place for each code value. Since the number of conversions is dependent upon code-width, shorter codes produce fewer conversions. The intensity of each dot displayed in the matrix is a direct function of the number of conversions and hence the code-width. Dimmer dots, therefore, denote narrower codes and higher differential nonlinearities. Narrow code-widths are depicted in the dot-matrix photograph.

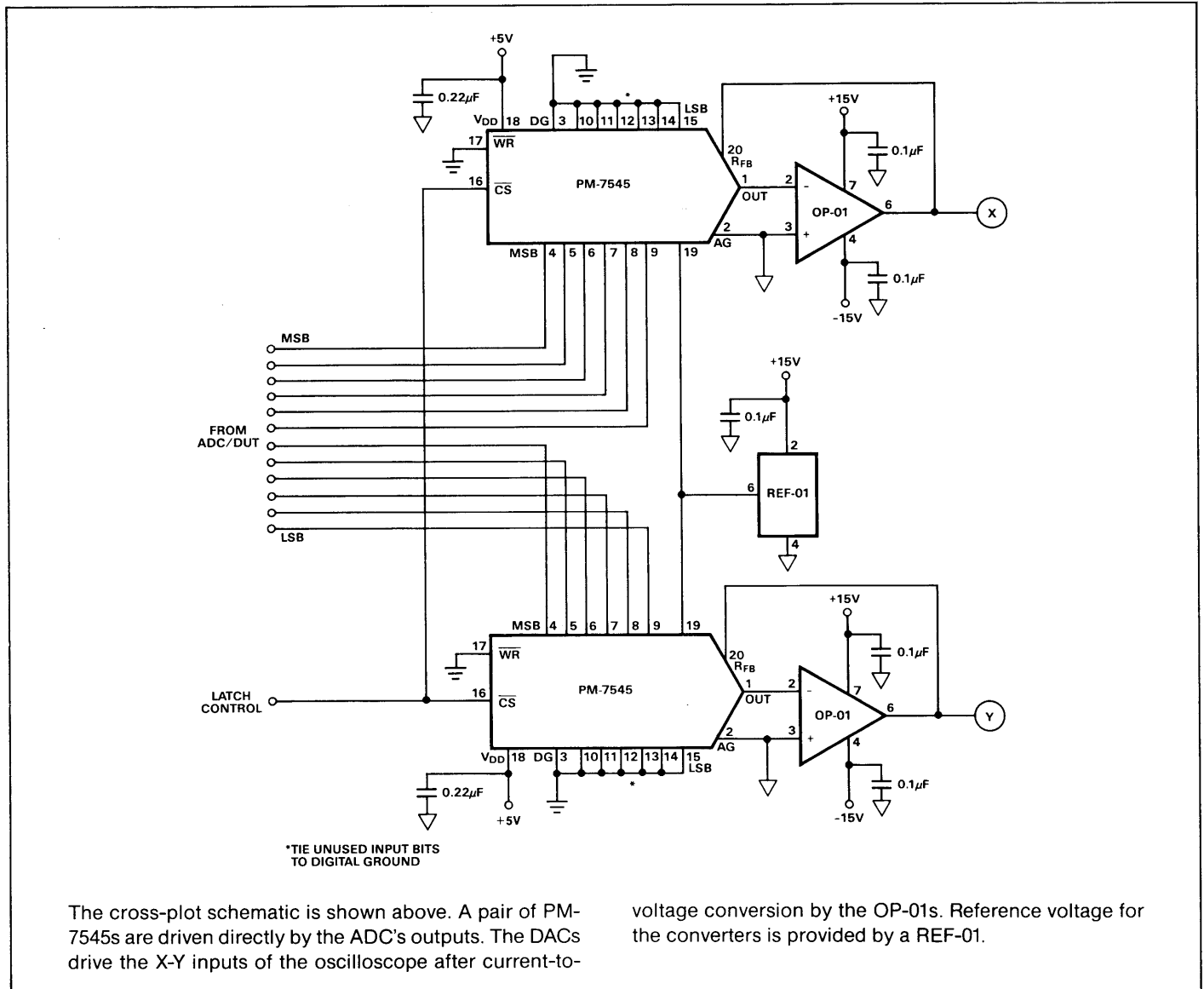
## SYSTEM NOISE

The cross-plot generator can be used to determine the repeatability of ADCs. By slowing down the input triangle wave frequency to 0.1Hz, the oscilloscope should ideally display one dot at a time when the input voltage is between code transitions. As the input voltage approaches a code transition, two dots will appear on the oscilloscope screen. Once the input voltage moves to the next code, a single dot will again appear on the oscilloscope screen. If the ADC system has noise problems,

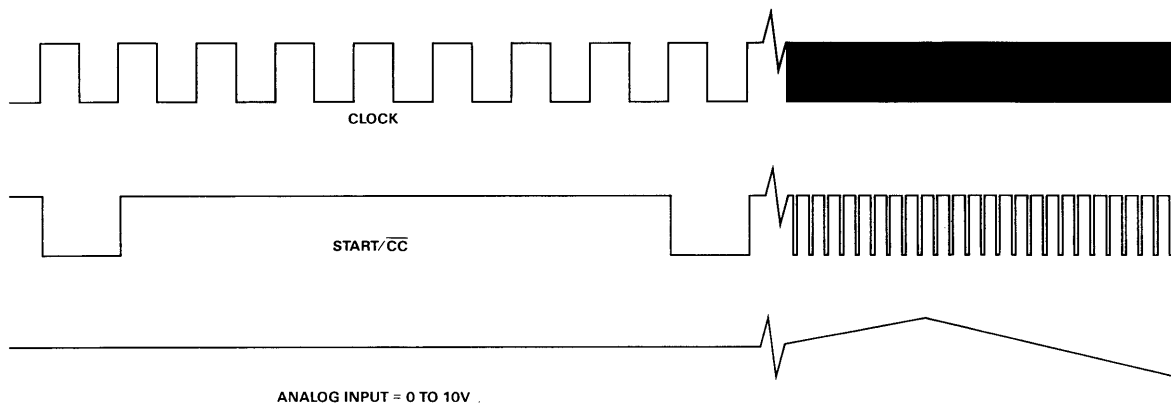
either due to layout or the ADC itself, the oscilloscope display will show two, three, or more dots simultaneously. This is an indication of undesirable noise in the system causing multiple output codes for a single analog input voltage.

Checking prototype circuits with this test can help quickly identify the noise level and source. Proper location of bypass capacitors, central analog ground, and digital signal lines can be easily determined, speeding the system debugging process.

**FIGURE 3:** Schematic



**FIGURE 4:** Timing Diagram



A typical timing diagram for a 10-bit successive approximation conversion system (ADC-910) is shown above. The analog input is a slow triangle wave sweeping the full input range of the converter (shown here as a unipolar 10V range).

The clock provides a time base for the converter and is several orders of magnitude faster than the input fre-

quency. This high clock frequency, relative to the analog input, insures that the analog voltage changes less than 1/2 LSB during the conversion time.

The  $\overline{\text{START/CC}}$  signal (sometimes termed  $\overline{\text{BUSY}}$ ) is generated by the ADC and can function as a data-load pulse for the DACs.