Calculating thickness values in the Model 8500

A. THE PHYSICS

The Magna-Mike 8500 measurement system consists of a probe, which contains a permanent magnet and a Hall Cell, and a voltmeter that measures the voltage across the Hall Cell. The Hall voltage is directly proportional to the magnetic flux density at the probe tip. This flux density increases as a steel target ball approaches the tip, and decreases as the ball is taken away. By measuring the Hall voltage and comparing this to a table of thickness values, the gage can estimate the distance to the target ball.

The relationship between the distance to the target ball and probe voltage is shown in Figure 1:

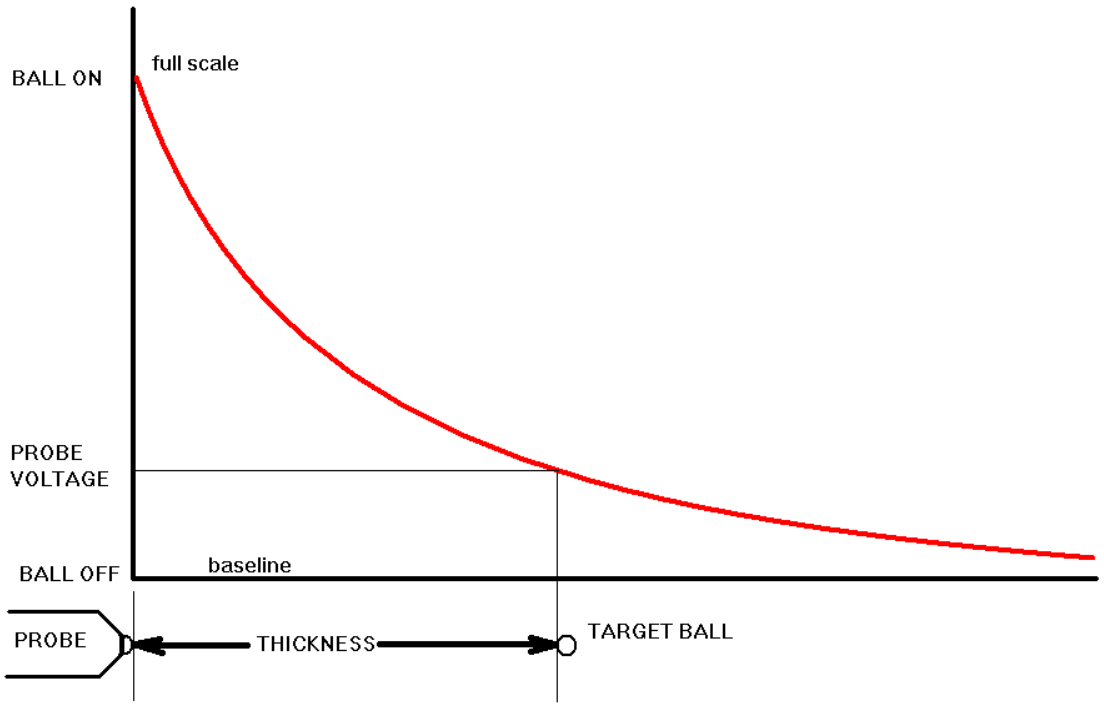

Figure 1

The BALL OFF and BALL ON voltages are captured and stored by a gage calibration procedure. The typical “baseline” or BALL OFF voltage of a probe is approximately 120 millivolts. (This will vary from probe to probe.) The voltage increase (to full scale or BALL ON level) caused by the presence of a target ball resting on the tip will vary according to the size of target ball employed. It may be as small as +6 millivolts in the case of the smallest (0.0625 inch diameter) target ball or as large as +100 millivolts in the case of the largest (0.25 inch diameter) target ball. The largest possible probe signal is no greater than 250 millivolts.

B. THE ELECTRONICS

The differential probe voltage is amplified by 14 at U602 (an INA128 instrumentation amplifier) and referenced to ground. The INA128 has a maximum guaranteed output swing of +3.6 to –3.6 volts, so at this gain will handle all expected input signals without hitting its output rail.

The voltmeter employed in the 8500 is a Burr-Brown ADS1211U A/D converter. This is a Delta-Sigma converter, which publishes a 24-bit value covering a theoretical range from –5 to +5 volts. The effective resolution and range depend upon the programming and circuit design. In the 8500, the A/D converter is employed single-ended, at 60 Hz, set to an internal gain of 1, and has no VBIAS circuit. This gives the A/D converter a nominal input range of 0 to 5 volts and a resolution of 2^{23} (or about 8 million) bits over that range, of which perhaps 2^{19} (or 512K) bits are well determined.

The output range of the INA128 amplifier limits the top end to about +3.6 volts, and the A/D converter will actually resolve negative inputs down to about –0.5 volts. The output is "twos complement" so a zero input voltage nominally corresponds to a zero output value, and negative input values will appear as counting down from 2^{24}. Taken together, the front end of the 8500 appears as shown in Figure 2:

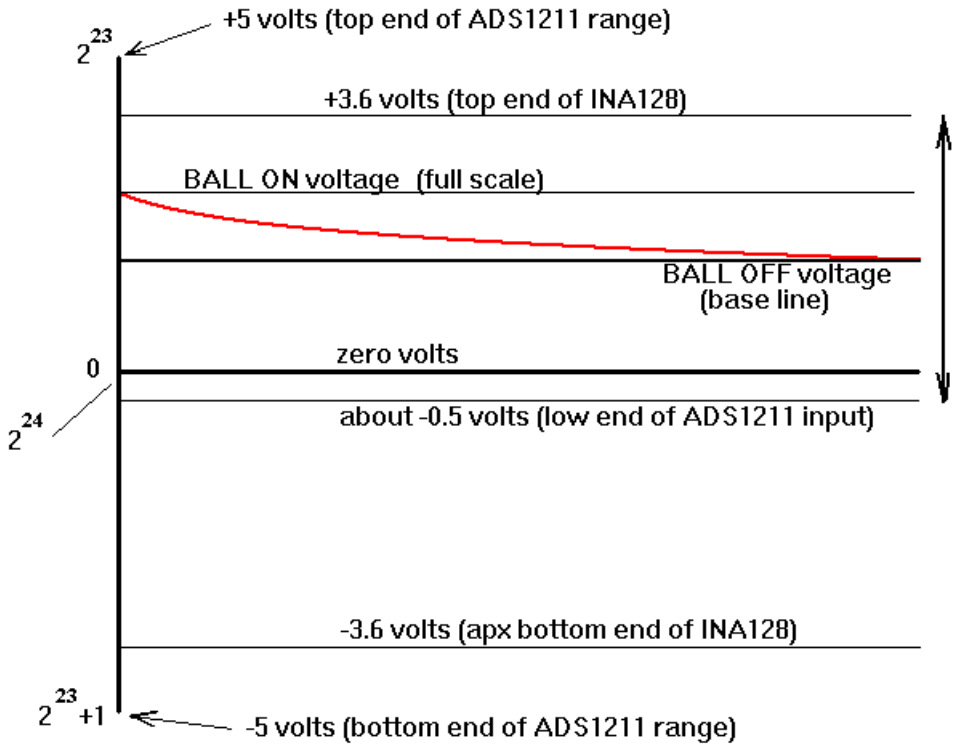

Figure 2

An example of values for a standard probe and 0.125 inch diameter target ball are shown in the table below:

	Probe Voltage	INA128 Output	Nominal A/D value
BALL ON or full scale	140 mV	1.96 V	3288334
BALL OFF or baseline	120 mV	1.68 V	2818572
Delta	20 mV	0.28 V	469762

This gives the system a theoretical resolution of more than 400K bits between BALL ON and BALL OFF. The last few bits, however, (as stated earlier) are noise. To obtain superior resolution, several results are averaged to produce a new published result every 4, 8, or 16 Hz (depending upon the display update rate chosen by the operator).

C. THE CALCULATIONS

The Magna-Mike program contains, for each possible probe and target ball combination, a 4096 point table which relates each signal level between a baseline and full scale to a theoretical distances from probe tip to target ball. (Over short spans of several indexes, the table is completely or nearly linear, so 4096 points are actually more than are required to characterize the curve.) The shape of these tables matches the curve shown in the first diagram of this document. Each of the 4096 points is called an INDEX point. Index 0 is assigned to the BALL OFF end of the table and Index 4095 is assigned to the BALL on end. Once the BALL OFF and BALL ON voltages have been measured, the span of A/D counts between BALL OFF and BALL ON can be calculated and divided by 4096 to provide a ratio of A/D points per index.