Application Note: Measuring Steady-state "on" resistance (R_{on})

Applications

- The purpose of this application note is to standardize measurement techniques for Steady State "on" resistance.
- To give some background on why this value is important.

Description

For any device, R_{on} of its output driver has direct effect on what load it can drive in regular operation. In a voltage mode driver like that used for the 882, the value of the Ron determines how many DRAMs it can drive while still maintaining the optimal signal integrity. If the value for R_{on} is too high, the driver is considers being weak, it will not make proper Voh/Vol level if too many devices are connected at its output. On the other hand if the R_{on} value is small, the rising edge becomes too sharp when few devices are connected at its output creating excess noise in the system.

There are two R_{on} number in any driver, the Resistance of the pull up transistor and the pull down transistor.

Steady-state "on" resistance (R_{on})
R_{on},*up* = pull-up resistance
R_{on},*down* = pull-down resistance

$$Ron\_up = \left(\frac{VDD - VOH}{VOH - VTT}\right) \cdot RTT$$

$$Ron\_down = \left(\frac{VOL - VSS}{VTT - VOL}\right) \cdot RTT$$

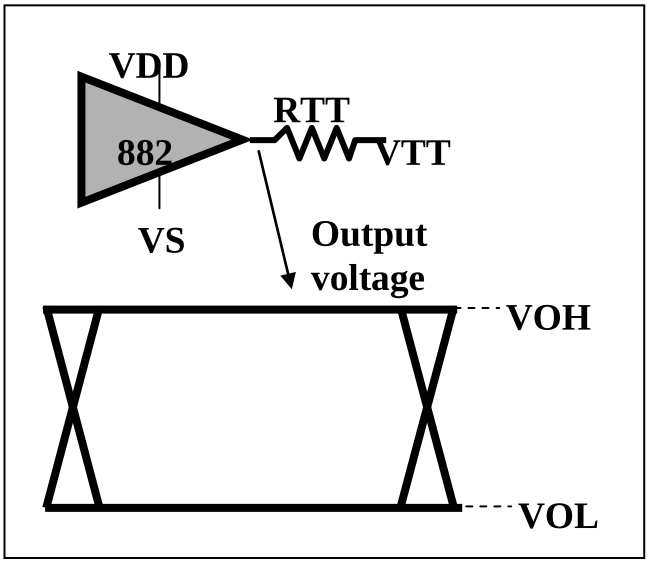


Figure 1. Output Driver and waveforms.

Procedure

This measurement is done using the 882 Clock Reference Board. Connect a scope probe to the output driver under test on the Intel Reference Raw Card. Make sure you have calibrated the probe and have proper Gnd reference. Turning on averaging on the scope channel to reduce noise is also recommended.

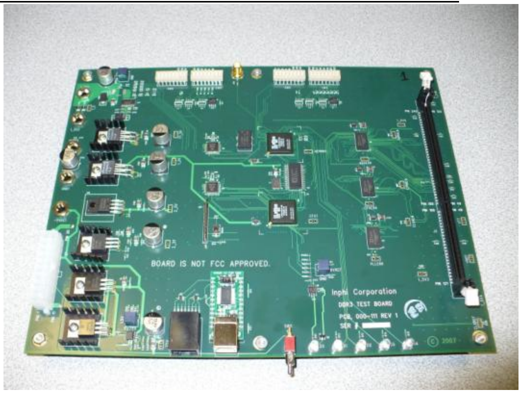


Figure 2. Clock Reference Board

Step 1. Load output pattern with long train of 0's and 1's in to the CRB.
Step 2. Measure and record the value of Vtt using a calibrated DMM or scope channel.
Step 3. Measure and record the value of driving a 1 and 0.
Step 4. Using the formula below to calculate the R_{on} up and R_{on} Down.

$$Ron\_up = \left(\frac{VDD - Vm\_drive1}{Vm\_drive1 - VTT} \right) \cdot RTT$$

$$Ron\_down = \left(\frac{Vm\_drive0 - VSS}{VTT - Vm\_drive0} \right) \cdot RTT$$

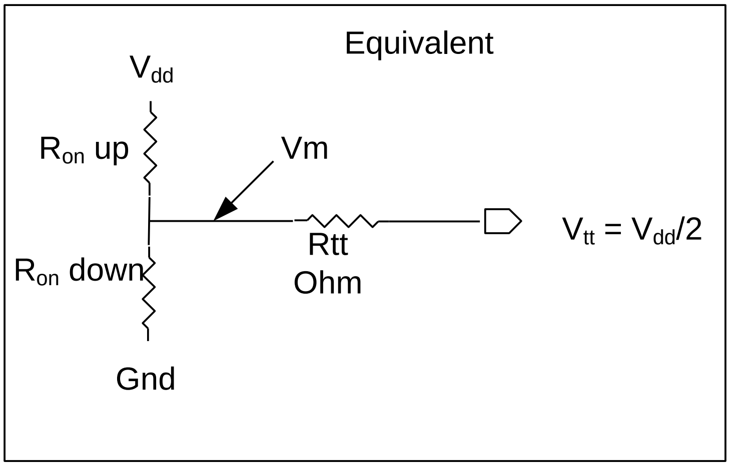


Figure 3. Equivalent Model

Example

In this example, we are using Inphi's INSSTE32882 register. We have measure the driver in Weak, Medium, and Strong mode. The Rtt in this case is 50ohm, Vdd at 1.4V and Vtt is at .7V.

$$Ron\_up = \left(\frac{1.4 - 1.251}{1.251 - .7}\right) \cdot 50 = 13.52$$

$$Ron\_down = \left(\frac{.154 - 0}{.7 - .154}\right) \cdot 50 = 14.10$$

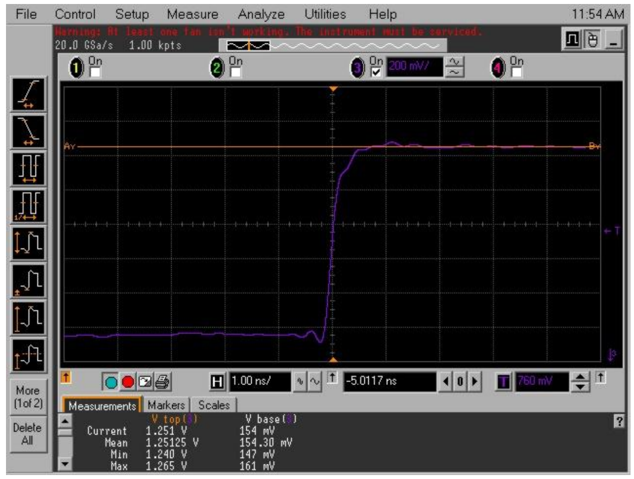


Figure 4. Strong Driver

$$Ron\_up = \left(\frac{1.4 - 1.21}{1.21 - .7}\right) \cdot 50 = 18.63$$

$$Ron\_down = \left(\frac{.193 - 0}{.7 - .193}\right) \cdot 50 = 19.04$$

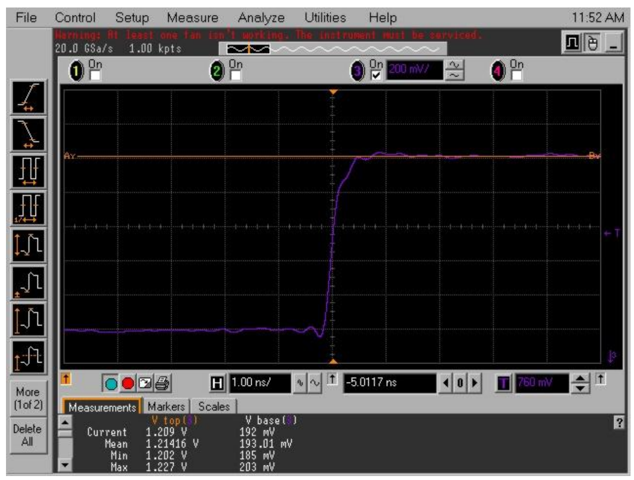


Figure 5. Medium Driver

$$Ron\_up = \left(\frac{1.4 - 1.181}{1.181 - .7}\right) \cdot 50 = 22.77$$

$$Ron\_down = \left(\frac{.237 - 0}{.7 - .237}\right) \cdot 50 = 25.59$$

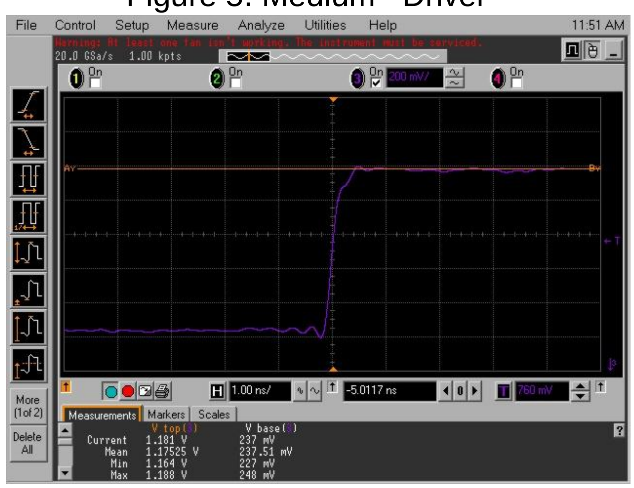
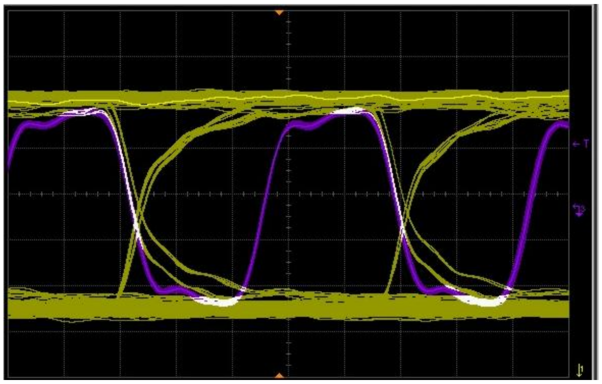


Figure 6. Weak Driver

Measurement



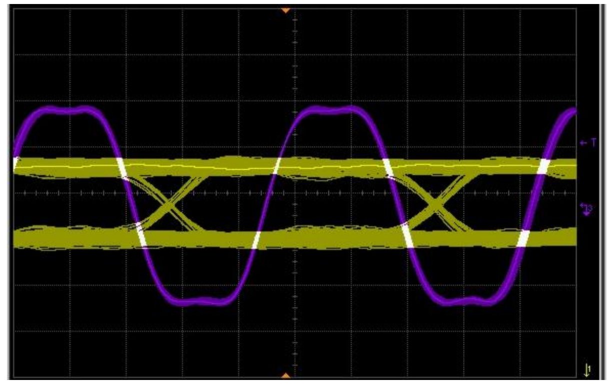


Figure 7. Driver with R_{on} at 20 Ohm

Figure 8. Driver with R_{on} at 75 Ohm

Here we are showing actual measurement of driver with different R_{on} value. The voltage and time scale in this case are same. You can see the in Figure 7, the lower R_{on} driver can achieve a higher VOH/VOL compare with the Higher R_{on} Driver in Figure 8 with the same load.

Conclusion

The concept of R_{on} is not very difficult. Yet it is a very important figure of merit on how good a driver is and defines its performance limits. A driver with high R_{on} value is called a weak driver and if load down by large number of devices will not be able to reach the proper VOH/VOL level. But higher R_{on} will reduce total current out of the driver which leads to lower total power for the modules. A driver with low R_{on} value is called a strong driver and if load down by small numbers of device will burn excess static current and increase overall power of a system. This can be especially tricky in DDR3 Register DRAM module where programmable R_{on} on the 882 register allows memory manufactures to optimize R_{on} for different memory configuration and performance while reduce overall power usage.

For Further Information

There are many other application notes and documents located on Inphi's website.

- Clock reference board (CRB Product Brief)

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