

DESCRIPTION

This application note describes the setup and test plan implementation for measuring an unknown capacitor using the RI8589 FetPulser's HV1 resource. The solution was optimized for a range of capacitance from ~10nF to 1nF. Methodologies for expanding the test case or targeting other capacitance ranges are also provided.

BACKGROUND

The methodology used is based on fundamental concepts of the time constant derived from the response of a series resistance and capacitance to a step input. As such, this implementation limits the application of this techniques to test cases that involve linear time invariant(LTI) systems. When voltage is applied to the circuit, the current in the capacitor peaks at a maximum current value of the supplied voltage divided by the selected series resistance and then decays to zero asymptotically as the capacitor is fully charged. The observed current over time while the capacitor is charging can be expressed as:

$$i(t) = \frac{V_s}{R} \exp^{-\frac{t}{\tau}} \quad \text{where,}$$

$$V_s = \text{Supply Voltage}$$

$$\tau = RC$$

As the time constant(τ) is a function of the capacitor and resistor in the circuit, if a known resistance is used an unknown capacitor value can be extracted by computing the time interval over which two current values are observed:

$$\text{an initial current, } i(0) = \frac{V_s}{R}$$

and the current occurring at time equal to one time constant:

$$i(\tau) = \frac{V_s}{R} \exp^{-1} \approx 0.368 \frac{V_s}{R}$$

Essentially, after a period of one time constant the observed current is approximately 37% of the peak current value. This can be used to extract the time constant and by extension the unknown capacitance where a known series resistor is used. In practice, this technique can be extended to any initial value within 80% of the peak current value to avoid any possible non-ideal effects of the supply as shown in Figure 1.

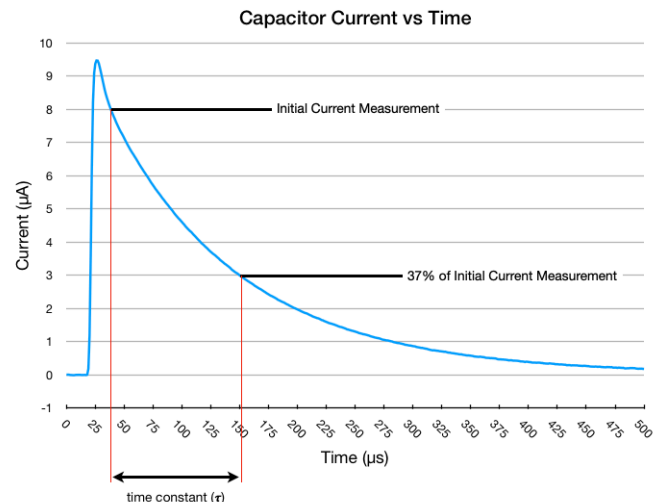


Figure 1: Current Time Response of RC Circuit

IMPLEMENTATION

TEST SETUP

The test circuit setup uses the HV1 resource in the RI8589 FetPulser. HV1_OUT and HV_RTN pins are connected to the unknown capacitance that will be measured with a series resistor as shown in Figure 2. There are four fundamental properties that the user should consider when selecting the series resistance value:

1. The resistance should result in a time constant that can be captured by the FetPulser's 1MSPS digitizer, i.e. — a value that creates at minimum a time constant of >3-4 microseconds.
2. The value should not create a time constant that exceeds the capture buffer of the FetPulser's digitizer, i.e. — the time constant should not exceed ~1ms. A practical capture window would be approximately 4-5 time constants.
3. The resistance in combination with the HV1 voltage sets the max/peak current and as such, should not exceed the current measurement dynamic range set by the 'HV1 Current Range' button.
4. The tolerance of the resistor value should be sufficiently low as to reduce residual error in the time constant calculation. In practice this should be measured directly to insure accuracy.

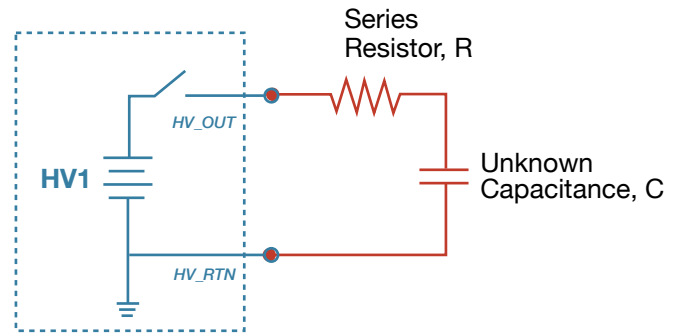
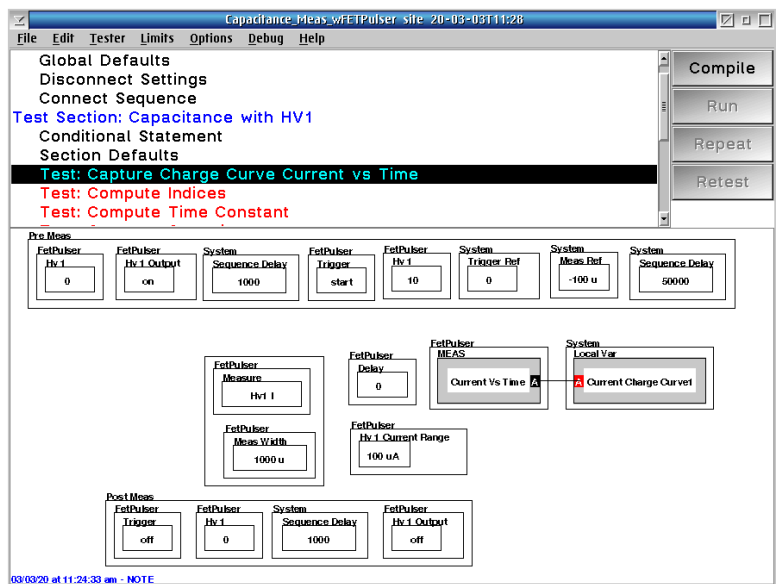


Figure 2: Test Setup

TEST PLAN

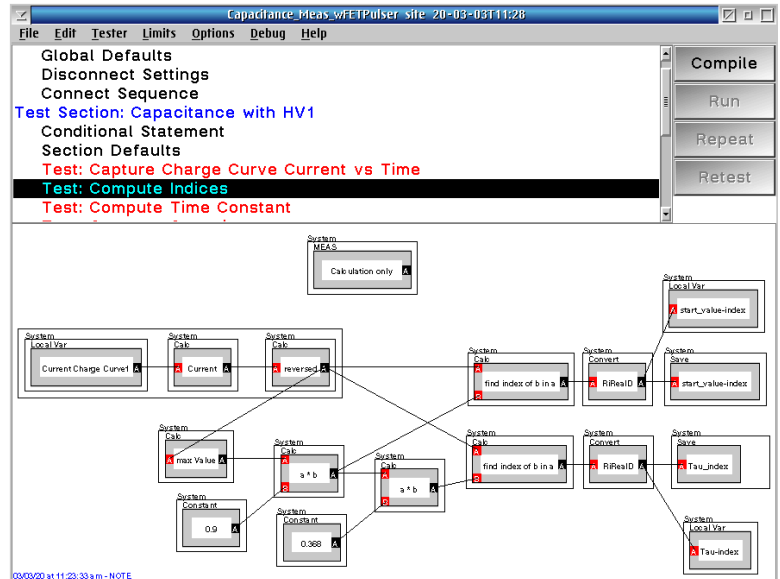
The test plan is divided into four parts:

1. Setup the HV1 supply to deliver 10V and capture the current vs time observed in HV1 during the charging of the capacitor. The sequence IN THE PRE MEASURE is to set HV1 to 0V and connect this to the RC circuit. A sequence delay of 1ms insures that there is no residual voltage on the test circuit, and then HV1 is set to 10V. This is to avoid any transients from HV supply/output connection relay. The capture window is ~1ms which is optimized for capturing the time response of an unknown capacitance in the range of ~1nF to 10nF with a series resistance of ~100kΩ. The 'HV1 Current Range' button is set to 100uA for an expected maximum current of $10V/100k\Omega = 100\mu A$.



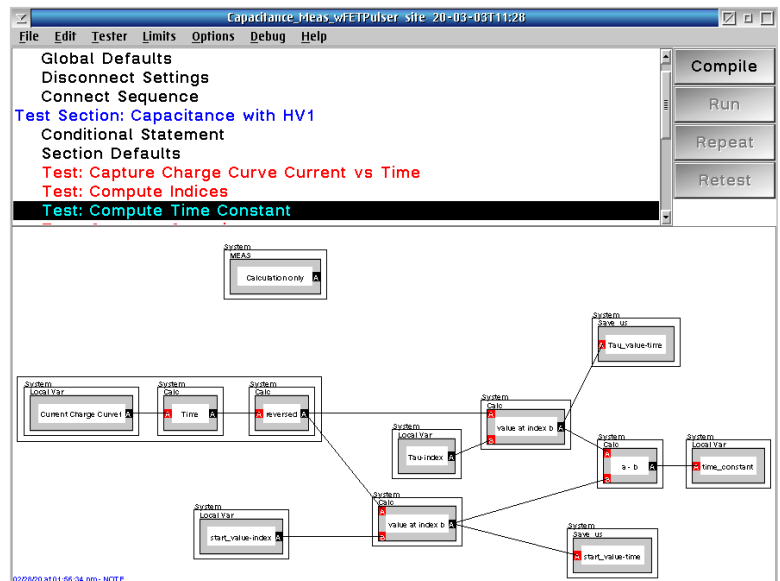
2. Compute the index of an initial current value(90% of maximum) during charging and the index where 37% of the initial current value occurs. The maximum observed current is dependent on the selected series resistor. As this could be clipped by the selected 'HV1 Current Range' button, the first index extracted is 90% of the maximum observed value to avoid this scenario. The second index is 37% of the first index representing one time constant based on the equation:

$$\tau(\text{time constant})=R*C=\text{Current}*(1-0.37).$$



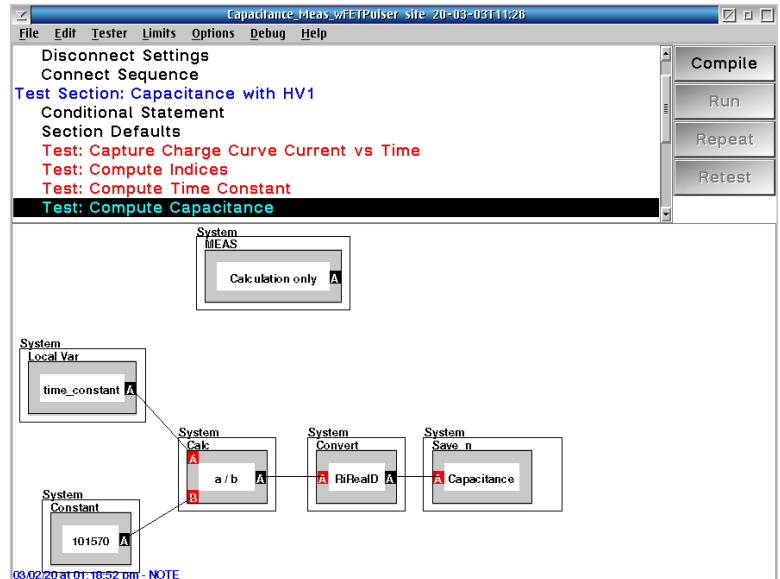
NOTE: The 'Calc:reversed' block is to flip the order of measured data. This lets the 'Calc:find index of b in a' interpolation functions ignore the in-rush event of the supply so that the index extraction functions occur along the time response as the current asymptotically approaches zero.

3. This panel uses the indices extracted from the current curve in the previous panel to extract the time values where both events occur: 90% of max of current and 37% of the 90% value. It then computes the difference between these two times which represents one time constant.



4. The time constant is then divided by the known/supplied series resistance to calculate the unknown capacitance:

$$\text{Capacitor} = \tau(\text{time constant}) / \text{Resistor}$$
 In the example test plan, a 100 kΩ resistor with 5% tolerance (which was measured to be 101570 Ω) was used.



NOTE: The Capacitance data save uses a 'Units Scale' format of "n" for nano from the right click options, but there is no option for Farads as a measurement unit. The 'Data Format' is overwritten by a custom unit of 'nF' inserted using the custom units parameter. The custom units parameter can be accessed by right clicking on the data save and selecting 'Parameters...' from the pop-up menu. An entry of 'units' with a value of 'nF' is used to display the correct units in the worksheet. Divide the time constant by the known series resistor value to compute the observed capacitance/capacitor.