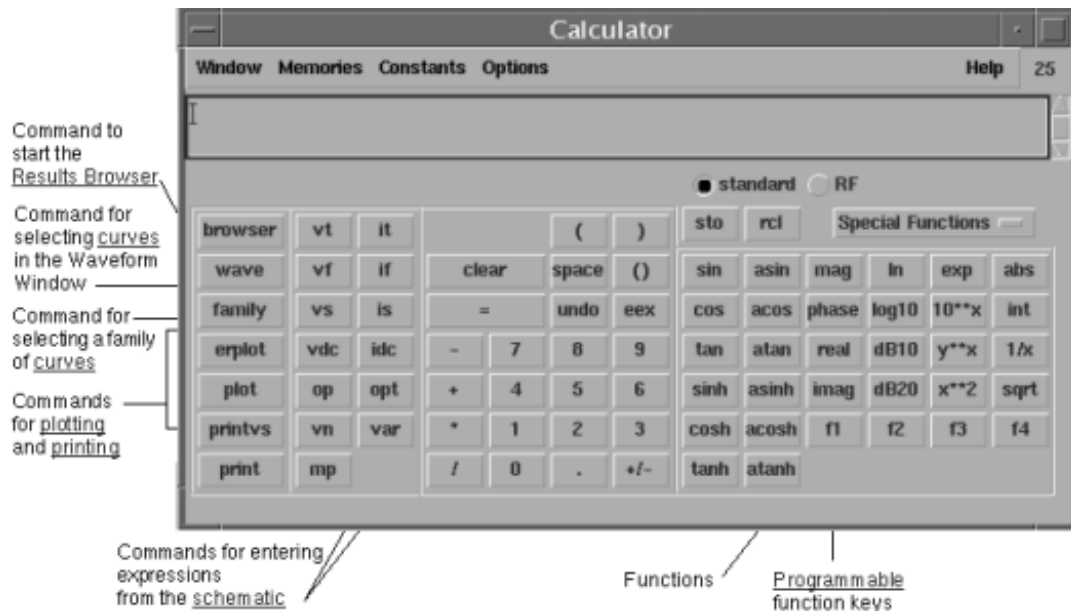
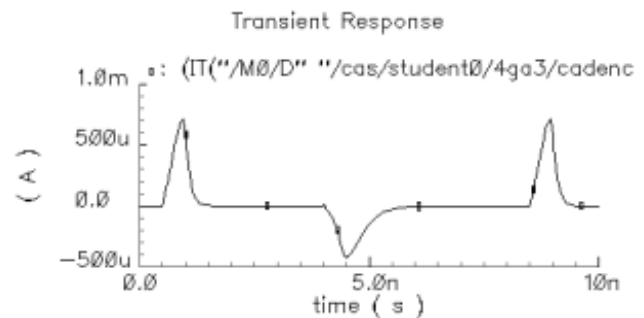


6.0 The Waveform Calculator

To analyze resulting waveforms we have an immensely powerful tool in the Waveform Calculator. From a waveform window, select **Tools | Calculator**. As you might imagine, the most straightforward use of the waveform calculator is to add/subtract/multiply/divide one waveform by another and plot the result. It will perform functions in either the time or frequency domain, operating in either Algebraic mode (Normal), or RPN (Reverse Polish Notation - a la HP calculators). To keep things simple we'll use the Algebraic mode (**Options | Algebraic**), and only perform calculations based on transient (time-domain) simulations.



From the schematic of the inverter and the resulting drain currents (plotted on the previous page), note that the sum of the two currents goes to charge the load. Lets plot the sum of M0/D and M1/D. We have three ways to enter results: from the schematic, from the waveform plots, or from the stored result files deep in the unix hierarchy (we're going to avoid this). First, save the waveform in the window using '**Window | Save**' and call it '**inv**'. On the calculator, **click 'wave'**, **select the M0/D waveform** from the plot window, **click '+'** on the calculator, **select the M1/D waveform**. Selecting **erplot** from the calculator will reset the screen and plot the resulting expression.

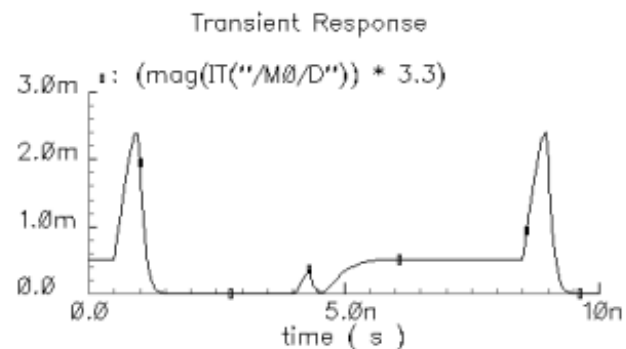
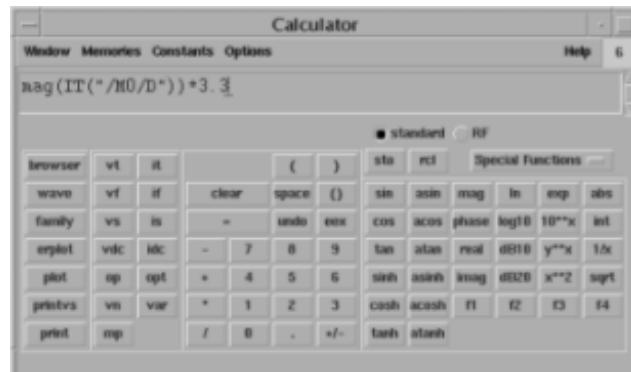


Alternatively, instead of selecting the waveforms, we could have selected **it** (current-transient), and selected the M0 and M1 drain terminals from the schematic. If we wanted Voltage expressions the nets would be selected after clicking **vt**.

Like any other calculator, we can store this result in memory. Select store (**sto** or **Memory | Store**), and save the expression as **i_load**. **Clear** the calculator.

Finally, we want to determine the power consumption of the inverter. **Instantaneous Power = mag(current) * voltage**. There are a few places in the circuit where we can measure the dissipation. For example, we could measure the power dissipation across each transistor and add them, or more easily, we can simply measure the current out of the source, and multiply that by the source voltage. From the schematic, it is apparent that the current out of the source is equal to the drain current through the PMOS transistor. (You can plot it to convince yourself) We have to build this power expression in the calculator.

Building the expression is exactly like using a standard calculator. Either **type 'mag('** or **click the mag** button to start. Then select the 'it' button and select the M0/Drain terminal from the schematic. (Alternatively you could use the wave button and select the current waveform from the plot window.) **Type in a closing bracket** for the magnitude expression. Now we need to multiply this by the output voltage (~3.3V). **Type or click '*'** for multiply and a **constant of 3.3**. If we wanted to however, we could multiply the expression by the source voltage waveform (in case the source voltage fluctuated with the drawn current as in a low-battery.) **Clicking erplot** on the calculator should now erase the current plot and plot the power consumption, in Watts, as shown below. **Leave the window open.**



Similar to any digital scope on a lab bench, the calculator can also do such things as calculate delay between two waveforms, find min, max, integrate a waveform, differentiate, calculate overshoot etc. More details about these **'Special Functions'** are available in the on-line help. We'll use it to determine the average power. **Clear** any current expression in the calculator, **select 'Special Functions | rms'** or **type 'rms('**. **Click wave**, and **select** the instantaneous **power waveform** just created. **Close the bracket** and **click '='** to get the final average power result. (NB: This is not really accurate because we should only do it over one period or 8ns, not 10ns) My result was an average power of 689uW.