QSpice C-Block Components

Revisiting Trunc()

Document Revisions:

2024.05.27 – Initial published version.

2024.06.08 – Added `*timestep` details and generally reworked.

Caveats & Cautions

First and foremost: Do not assume that anything I say is true until you test it yourself. In particular, I have no insider information about QSpice. I've not seen the source code, don't pretend to understand all of the intricacies of the simulator, or, well, anything. Trust me at your own risk.

If I'm wrong, please let me know. If you think this is valuable information, let me know. (As Dave Plummer, ex-Microsoft developer and YouTube celebrity (Dave's Garage) says, "I'm just in this for the likes and subs.")

Note: This is the fourth document in a clearly unplanned series:

- ***The first C-Block Basics document covered how the QSpice DLL interface works.***
- ***The second C-Block Basics document demonstrated techniques to manage multiple schematic component instances, multi-step simulations, and shared resources.***
- ***The third C-Block Basics document built on the second to demonstrate a technique to execute component code at the beginning and end of simulations.***

This document will hopefully demystify the Trunc() function, what it does, and how to use it. It builds on the first paper so consider that "required reading" for terminology and overview of C-Block components. See my GitHub repository here for the prior documents and code samples for this one.

Overview

The C-Block `Trunc()` function has been the subject of several lengthy discussions on the QSpice forum. The "official example code" (the "ACME Semiconductor" demo program) is complicated and, frankly, doesn't really clearly explain how `Trunc()` works and why/when/how we'd want to use it.

Time has passed, stuff has been learned….

In this paper, I will:

- Demonstrate the problem that the `Trunc()` function is designed to solve.
- Detail the `Trunc()` function parameters.
- Describe the general QSpice simulation cycle as it relates to C-Block components.

- Present sample code for a component using the `Trunc()` function.
- Explain why the `Trunc()` `*timestep` parameter value isn't exactly what one might expect.

Note: *This is a long and tedious paper.* Sorry.

If you're new to writing QSpice C-Block components, I strongly suggest that you start at the beginning of this series for basic concepts and terminology.

The Problem

To understand the problem that `Trunc()` addresses, let's start with the `CblockBasics4.qsch` schematic and `CBlockBasics4.cpp` example code. The component is a simple comparator: `Vout` is set high if `Vin` > `Vref` and set low otherwise. The component's `TTOL` attribute sets the "*time tolerance*" used in the `Trunc()` function. If `TTOL` is zero, the `Trunc()` function is disabled.

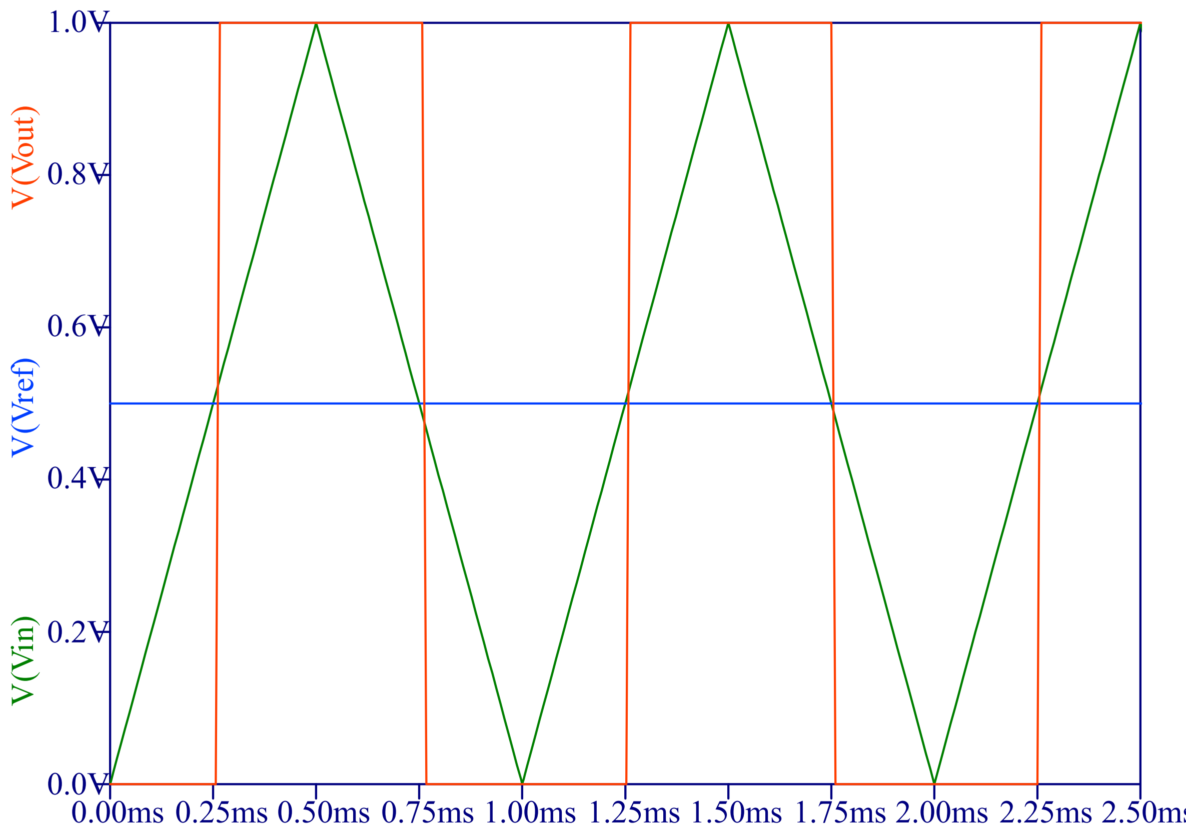


Figure 1 – MAXSTEP=10µS (Trunc() disabled)

We expect a comparator to produce something like Figure 1. Here, `Trunc()` is disabled and I've set the `MAXSTEP` option to 10µs in the schematic. (Only the first 2.5ms of simulation is shown.)

Setting `MAXSTEP` to a small value gives us a nice result but forces QSpice to take far more samples than are really needed. Presumably, there are some 250 sample points in the 2.5ms shown above. And, of course, more sample points produces longer simulation run times.

Figure 2 shows the result without using `MAXSTEP` and with `Trunc()` disabled.

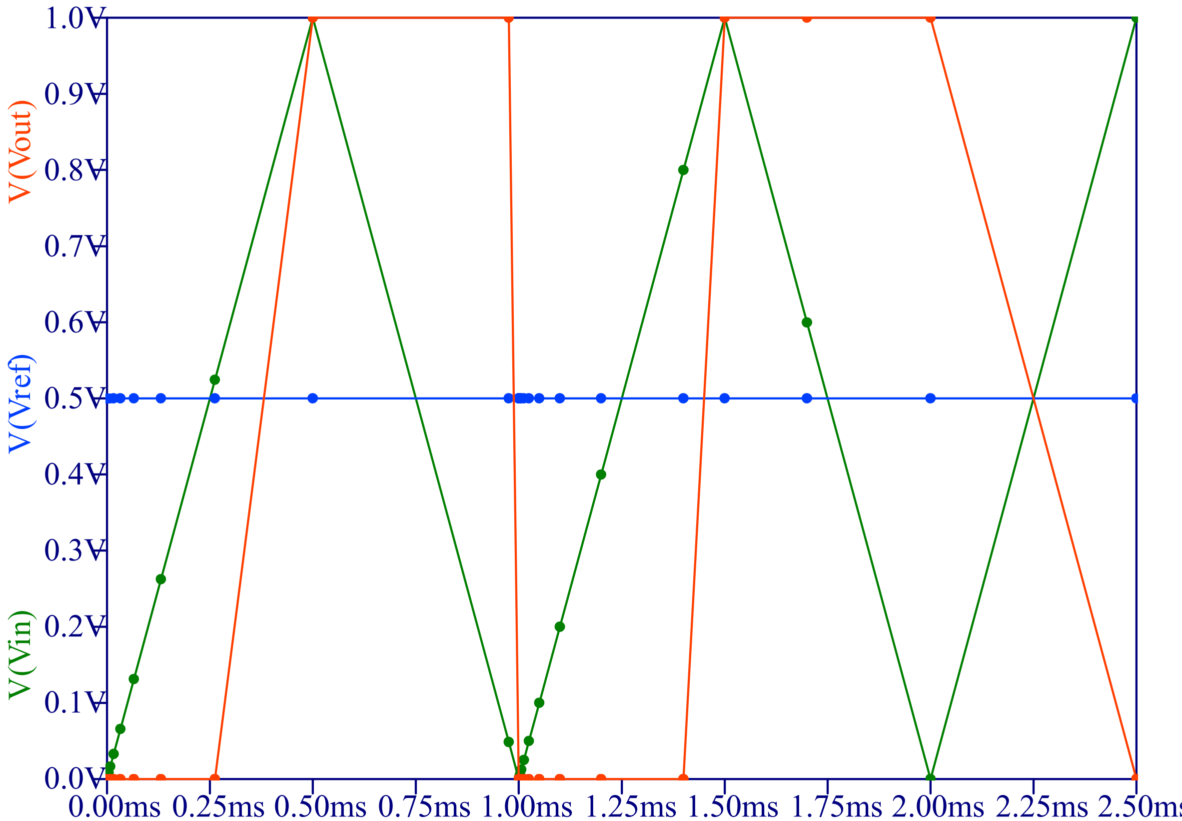


Figure 2 – Trunc() Disabled (TTOL=0)

Clearly, the result looks not at all like a proper comparator output. Rising/falling edges are not sharp. The edges don't fall on the actual triggering event. It's bad. Very bad.

The problem is this: QSpice uses a predictive/adaptive algorithm to select simulation time-steps. It attempts to increase the simulation sample point density around time-points where circuit values are changing rapidly.[1]

Because QSpice knows nothing about the internals of our component, the simulation points were selected based on only the schematic voltage sources. Above, we get only a couple of dozen sample points; clearly more are needed. (If we had a more complex schematic, QSpice would almost certainly generate many more samples.)

To help QSpice do its predictive/adaptive time-stepping/sampling magic, we can use `Trunc()` to give QSpice some insight into our component.

Figure 3 shows a simulation using `Trunc()` with a `TTOL` of 10µs. This is a definite improvement. Now we get nice sharp edge transitions. While there are still many "extra" sample points, it's not as bad as setting MAXSTEP to 10µs.

1 See QSpice forum member @KSKelvin's excellent documentation for more details about QSpice's adaptive time-step algorithm: QSpice - How Time Step Works.pdf.

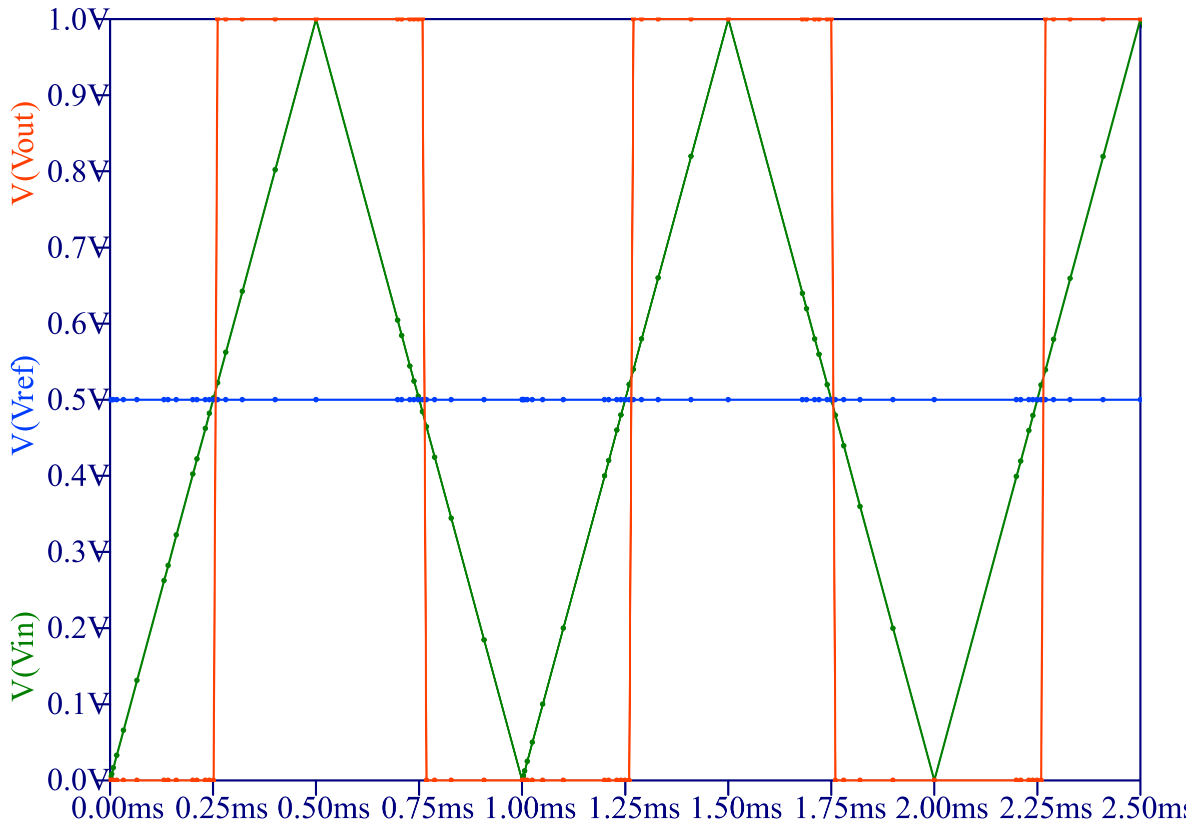


Figure 3 – TTOL=10µs

To sum it up: `Trunc()` provides a way to tighten up the simulation samples around our component's output state transitions. It forces a TTOL-sized sample window around the state changes.

Trunc() – Parameter Overview

If you compare the evaluation function and `Trunc()` function signatures in `CBlockBasics4`, they are quite similar:

```
void cblockbasics4(InstData **opaque, double t, uData *data)
void Trunc(InstData *inst, double t, uData *data, double *timestep)
```

In the evaluation function, the parameters are:

`opaque`	A pointer to a location to save a pointer to the per-instance data that we allocate.
`t`	The QSpice simulation clock time for the current simulation datapoint.
`data`	A pointer to the `uData` array of input port, output port, and component attribute values.

`Trunc()` is similar but adds a parameter:

`inst`	A pointer to the per-instance data that we allocated in the evaluation function. That is, it's equivalent to *opaque.
`t`	The *proposed next* simulation clock time for the next evaluation function call.
`data`	A pointer to the `uData` array of port and attribute values *that would be present* in the next evaluation function call if `Trunc()` returns *without* changing the value in `*timestep`.
`timestep`	A pointer to a time-step value.

The `timestep` parameter is a bit more complicated. I'll cover it in more detail later. For now, just think of it as a place to return a value to force QSpice to reduce the simulation time-step.

OK, that's probably confusing. Pushing on….

The QSpice Simulation Cycle

We'll need to understand the basic QSpice simulation cycle. During initialization, the evaluation function, `MaxExtStepSize()` (if present), and `Trunc()` (if present) are called a few times. After initialization, the simulation cycle is something like this:

1. QSpice calls the evaluation function for some simulation time-point (the evaluation function "`t`" parameter). A simulation sample is recorded.
2. QSpice selects a "*proposed* next time-step/sample time-point." It then calls `MaxExtStepSize()` (if present) which may reduce the proposed time-step/time-point.
3. QSpice calculates circuit values for the *proposed* time-step. This includes all of the input data values for the component at the proposed time-step.
4. QSpice calls `Trunc()` (if present) with the calculated circuit values. The "`t`" parameter passed to `Trunc()` is the *proposed* simulation time-point. The `data` parameter array contains the calculated input values for time = `t`.
5. If `Trunc()` returns a value in `*timestep` that is smaller than the *proposed* time-step, QSpice reduces the *proposed* time-point and returns to step #3 to recalculate inputs and call `Trunc()` again.
6. Otherwise, QSpice returns to #1 to process and commit the simulation sample for the proposed time-step.

If you prefer a flowchart, see Appendix A.

The above is somewhat simplified. The key takeaway is this: Each time that `Trunc()` is called, the circuit state (including the `data` array input values) is pre-calculated for a proposed next sample time-point. This is as computationally expensive as taking a simulation sample.

Yeah, probably as clear as mud. Sorry. Hopefully, the code will bring all of the above together.

CBlockBasics4 Code – Trunc()

The evaluation function is straight-forward: It allocates a per-instance structure and saves the `TTOL` parameter in the structure.

Here is the `Trunc()` function implementation for reference:

```
 1.extern "C" __declspec(dllexport) void Trunc(
 2.    InstData *inst, double t, uData *data, double *timestep) {
 3.
 4.  if (!inst->ttol) return;   // do nothing if disabled
 5.
 6.  if (*timestep > inst->ttol) {
 7.    // Save a copy of the output vector
 8.    double      &Vout  = data[4].d;
 9.    const double _Vout = Vout;
10.
11.    // create temporary copy of instance data
12.    InstData  tmp  = *inst;
13.    InstData *pTmp = &tmp;
14.
15.    // call the evaluation function with the temporary instance data
16.    cblockbasics4(&pTmp, t, data);
17.
18.    // implement a meaningful way to detect if the state has changed...
19.    if (Vout != _Vout) { *timestep = inst->ttol; }
20.
21.    // Restore output vector
22.    Vout = _Vout;
23.  }
24.}
```

Line #4 is there only to make it easy to disable `Trunc()` in this demonstration code. It wouldn't usually be present in production code.

The important code is in lines #6 to #23. If `TTOL` is less than `*timestep`, it:

- Creates a temporary copy of the per-instance data.
- Saves a copy of the `Vout` state in `_Vout`.
- Calls the evaluation function with the temporary per-instance data, the proposed `t` time-point, and the pre-calculated `data` array values.
- If the evaluation function changes the `Vout` state, sets `*timestep` to return our desired TTOL.
- Finally, restores the `data` array `Vout` value from the saved `_Vout` value.

This is the basic technique for using `Trunc()` – call the evaluation function to determine if the state would change at time `t` and, if so, force QSpice to choose a smaller time-step by returning a small value (TTOL) in `*timestep`. We could do other things but we'll save that for another day.

Note that the evaluation function "doesn't know" whether it's being called directly by QSpice (when a simulation sample would be recorded/committed) or by `Trunc()` (when a simulation sample is not being recorded/committed). That's why we must preserve/restore the `data` array contents in the `Trunc()` call to the evaluation function.

About *timestep

The `*timestep` value isn't exactly what I initially expected. I assumed – incorrectly – that QSpice would pre-load `*timestep` with the actual time increment between the last sample time and the proposed next sample time. That would make sense; the evaluation function doesn't need to be called if the proposed time-step is less than the target TTOL.

To my surprise, the value passed in `*timestep` is *always* `INF` (floating point infinity) in our sample schematic. Therefore, the conditional in line #6 above is *always* true and the evaluation function is *always* called.

Turns out that the `*timestep` value is shared between multiple schematic instances of the component. So, if a component reduces `*timestep`, then the next instance called will receive that reduced value. Assuming that the second instance uses the same or larger `TTOL`, the call to the evaluation function will be bypassed.

Keep the following in mind:

- QSpice calls multiple component instances' `Trunc()` functions in an "arbitrary order." More accurately, the order is determined by the netlist but the netlist order changes as components are added/deleted. If we want our components to operate correctly with multiple instances, we should make no assumptions about the order of instance calls.
- Assume that we have two instances, `Inst1` and `Inst2,` and that QSpice calls them in that order. If `Inst1` sets `*timestep` to, say, 1ms and `Inst2` changes `*timestep` to 2ms, I presume QSpice will use the last value set. I've not tested this. Anyway, just make sure that a component never increases `*timestep` and you won't have unexpected problems.
- If the evaluation function is computationally expensive, you might consider computing the time-step yourself. That is, save the time parameter to the per-instance structure in the evaluation function and calculate the time-step in `Trunc().` Then call the evaluation function only if the calculated increment is greater than `TTOL`.

For what it's worth, I've asked the QSpice author to pre-load `*timestep` with the actual time-step. Maybe he will change it, maybe not.

Conclusion

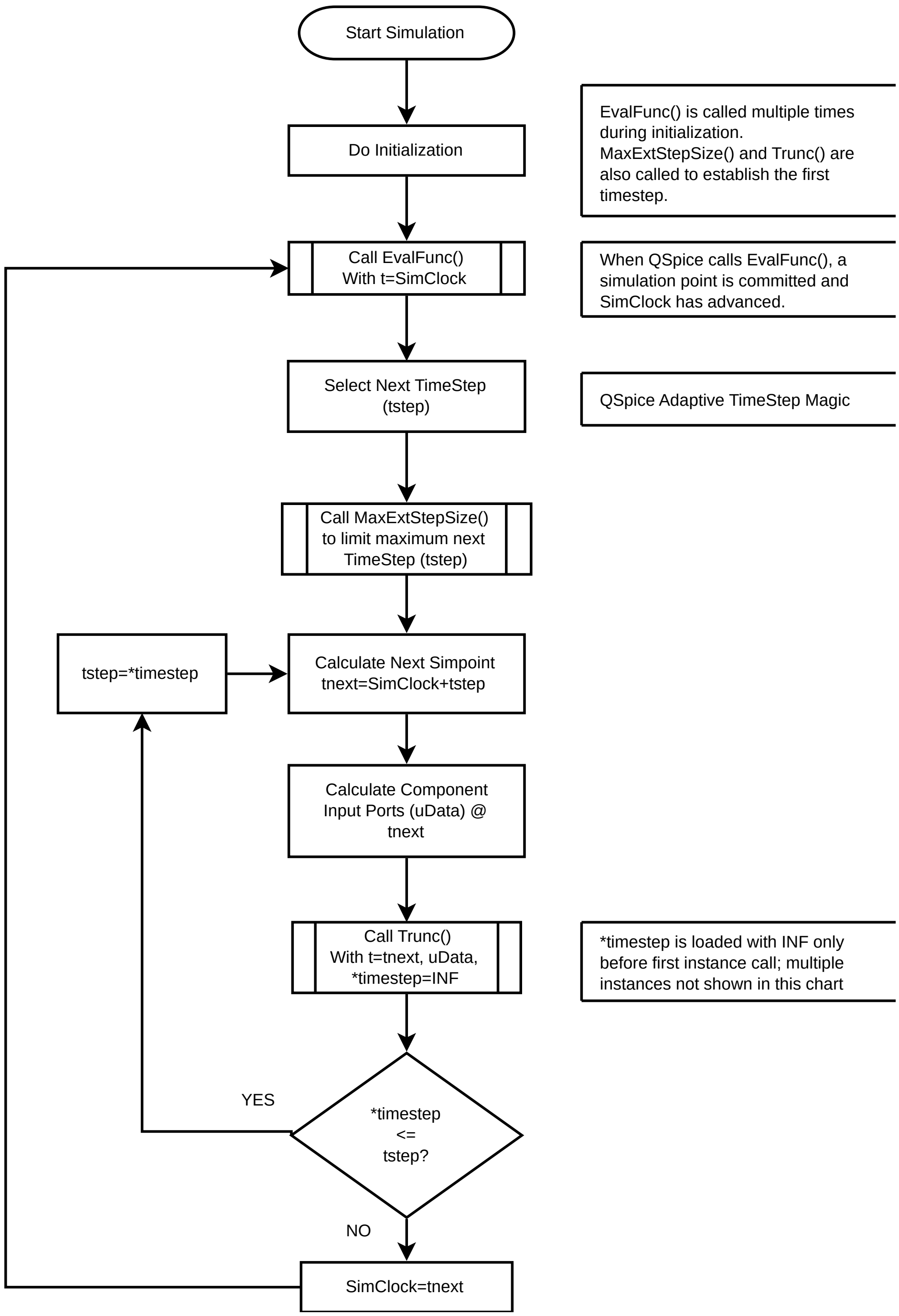
We've covered how `Trunc()` works in painful detail. I hope that you find the information useful.

Please let me know if you find problems or have suggestions for improving this documentation.

--robert

Appendix A

The QSpice Simulation Cycle*



* This is a conceptual overview of the simulation cycle for explanatory purposes only.