
Firmware Design for Wide-Bandwidth IF Support and Improved Measurement Speed

The addition of a wideband linear IF module to a Modular Measurement System (MMS) spectrum analyzer presented two main challenges to the firmware: providing sufficient operational speed and adding new features and operations. The concern over operational speed was heightened by the fact that many of the applications targeted by this product required speed similar to that obtained by instruments that did not have to account for either software calibration or modularity.

Operational Speed

The challenges associated with operational speed involved finding a way to apply calibration in near real time and efficient handling of incoming data and temporary variables.

Calibrated Operation. To obtain calibrated data from an MMS spectrum analyzer, every trace data point obtained from the ADC must be corrected using the appropriate calibration data. This needs to be done as close to real time as possible or the lag between the incoming raw data and the completion of the correction processing will quickly become the dominant factor in the retrace dead time.

The particular calibration data that must be applied and the algorithms that must be used to apply it are dependent upon the currently active signal path of the instrument. This can change as the user selects different IF bandwidths, different ADCs, and so on. This situation is complicated further by the desire to be able to do trace math (such as calculating the difference of the active trace and a baseline trace) as the data is received. Finally, the trace data needs to be sent to the remote display (if one is active) as the processing is completed. All of these complications exist even without a linear IF module.

If a conventional program is used to apply the per-point calibration, the time to perform the necessary number of conditional tests would overwhelm the actual calculation times. An alternative approach has been used since the beginning by the MMS spectrum analyzers. Instead of performing the conditional tests for each data point, an efficient state machine constructs a program to perform the necessary calculations for the current instrument state. This is done by properly combining machine code program fragments. The construction of this program (known as the RAM program) is properly synchronized with the appropriate state changes and trace operations.

During the execution of the RAM program, calibration and interpolation table addresses and calibration constants are stored in the CPU registers whenever possible. A preloaded register set is prepared at the same time that the RAM program is constructed. If the RAM program catches up with the incoming data stream, the process running the RAM program can swap out to allow other operations to occur. By keeping all the necessary data in the CPU registers, this swapping occurs quickly.

To account for a linear IF module, various additions to the RAM program were required. Previously, all IF modules supported by the system were log IF modules. Since all data calibration occurs after the signal has traversed the IF section, it made sense to keep almost all of the correction factors in dB. This has the additional advantage of allowing simple addition and subtraction to be used to apply the calibration data. Further simplification is achieved by storing the correction factors as 16-bit, fixed-point values. A scaling factor of 100 is used. For example, a value of 10.34 dB would be stored as 1034.

With the addition of a linear IF module, the assumption of logged incoming data was no longer valid. The main alternatives were either to rework the RAM program to be able to handle linear data (including the need to do multiplication and division instead of simply addition and subtraction) or to translate the incoming linear data to log data (preinterpolation). The latter approach is much quicker at performing the calculations, but it also has the potential for a loss of accuracy. However, with the ADCs currently supported by the MMS spectrum analyzer, both the accuracy and the range are limited by the ADC, not by an initial interpolation. Thus, the preinterpolation approach was taken.

Later experimentation showed that, with the reference level set properly, a 38.5-dB range could be achieved with the required accuracy. This was sufficient for the intended use of the product. When a display of linear voltage or power is desired, a table lookup and postinterpolation is performed toward the end of the RAM program.

Hardware Caches. At fast (short) sweep times, even the RAM program, running on a 20-MHz MC68020, is not fast enough to keep up with the incoming data stream. At this point, the data is buffered for the RAM program to process when it can. At the fastest sweep times, the data acquisition loop is actually locked in

the MC68020 instruction cache to minimize memory accesses for this time-critical operation.

Software Caches. In addition to the hardware cache built into the MC68020, the MMS spectrum analyzer firmware makes use of software caches as appropriate. Because of the modular nature of the instrument, a change of state can impose a heavy calculation burden. This burden must be borne by an affordable CPU.

Detailed timing and analysis of the operation of the instrument revealed several intensive calculations that could be identified by a minimal number of internal state variables. These variables are used as tags for software caches. This approach saves 60 ms or more for some common state change operations. Use of these caches was integrated with the RAM program so that a register could access the cache data directly, avoiding costly data copying.

Further performance improvements were realized by recognizing situations in which a calculation might need to be redone because of further user inputs before a data acquisition is performed. In such cases, if it is possible, calculation is delayed.

Additional Adaptations for a Wideband Linear IF

Adding more features and operations to the MMS spectrum analyzer involved advertising the capabilities of the IF module to the analyzer and preselector centering.

Configuration Support. In addition to the changes to the RAM program, the main signal routing algorithms had to be enhanced to account for the linear IF module. In the MMS spectrum analyzer, all modules advertise their capabilities to the control module via an ASCII capability string. This machine readable string is effectively a logical block diagram of the module, including all inputs, outputs, and switching capabilities. Some of the elements of this model are named so that the control module can properly manipulate the hardware via a standardized command language.

The addition of support for a linear IF module required minimal additions to the capability string language. Most of the components of the module had already been modeled. Support for an additional value to an existing option flag was the only thing required.

Preselector Centering. The wideband IF module presented an additional difficulty with preselected systems. With a narrowband IF, the tuning of the preselector is done via peaking. In peaking a test signal is injected into the system and the preselector hardware is tuned to provide a maximum response. This approach does not work for a wideband IF module, since the peak of the passband may not be near the center. Hence, using preselector peaking with a wideband IF module could easily result in a substantially reduced available signal bandwidth.

The proper approach for adjusting a preselector to work with a wideband IF module is to center the filter based upon a user-configurable signal delta value (typically 6 dB). Centering occurs in three main stages. First, a coarse search sketches the shape of the curve and identifies where to search for the peak value. Next, a fine search identifies the actual peak. Both of these steps are similar to what occurs for preselector peaking, except that coarse values are saved. The final step involves fine searches in the areas of the curve that correspond to the user-specified delta from the peak value. In all searches, an appropriate amount of overlap is used since the curve might not be locally monotonic.

The initial implementation worked correctly, but test users sometimes complained that the preselector still wasn't being centered correctly. The typical situation was that a user had a band-limited signal path that had not been previously connected to a narrowband spectrum analyzer. Thus, the user was not aware that the signal path was the problem.

The solution to this situation is to display the centering graphically as it occurs. All of the coarse and fine points are plotted so that the user can see what is happening. In addition, the user can examine and change the selected centering setting.

Conclusion

By using the techniques described above, we were able to add support for a wideband linear IF module into the MMS spectrum analyzer family and achieve speed that matches or even exceeds that of instruments with less functionality and configurability.

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