Low-Cost Digital SLMs: Tuner Design Considerations

Overview

The wide variety of low-cost, basic signal level meters (SLM) on the market can make it difficult to differentiate the features and quality of each one. Many of these meters list on their respective data sheets quite comparable specifications. Designing and manufacturing a high-quality, high-performance SLM requires making a few fundamental decisions. As might be expected, the most expeditious design path rarely results in optimal instrument reliability and measurement performance. Despite the apparent similarities of the various meters, full understanding of the more challenging aspects of the design enables us to readily discern which simply provide battery-powered customer premises equipment (CPE) and which provide true test-grade equipment.

Use of a Standardized Tuner Module

One means to quickly bring a low-cost SLM to market is to buy a complete "NIM tuner" module or "tuner network interface module (NIM)" from a third-party manufacturer. Such can tuners are readily available from China at a cost of perhaps $2–3 each and are fully designed by chip vendors such as Thomson, Phillips, NXP, and Mircotune, and then built by high volume original equipment manufacturers (OEMs). These same tuner modules are very often integrated directly into set top boxes and televisions. The primary advantage of using a tuner module inside an SLM, aside from the very low cost, is that the design is highly optimized by the module manufacturer, so very little engineering knowledge or investment is required to power up the tuner and begin performing measurements.

On the other hand, using a can tuner also presents a number of challenges and shortcomings. First, almost all tuner NIMs on the market are currently designed to only operate from 45 to 860 MHz. Only a very small number of commercially available tuner NIMs can operate up to the full 1 GHz of commercially available cable television (CATV) nodes and amplifiers. In some cases, a tuner module can be forced to operate outside its specified frequency range, and perhaps even up to 1 GHz; however, because the manufacturer does not guarantee its module's performance at 1 GHz, the assurances from the instrument manufacturer are unfounded.

Similarly, the performance of standard tuner modules is often designed and specified with the assumption of a residential temperature environment, such as 0°C to 40°C. Performance is not guaranteed outside of this range. Again, if the tuner module vendor does not guarantee its performance, any can tuner-based test equipment that does so is deemed suspect.

Finally, standard tuner modules are not mechanically designed for hostile temperatures, humidity, or sustained vibration as is experienced by test equipment in the course of its lifetime. Often, the tuner NIM will use inexpensive air coil inductors, electrolytic capacitors, and bulky mating connectors, all of which are prone to damage or failure if the instrument is dropped or subjected to sustained vibration over a long period of time, such as in a moving vehicle.

Standard tuner NIMs have non-field replaceable RF connectors are typically very low quality, designed for only a few insertions over their lifetime, and are mechanically integral to the module. As a result, to provide a field-replaceable F connector, instruments using a standard tuner module require an internal "patch" cable between the tuner module and external housing. Connecting the patch cable to the tuner module is either a costly or a highly manual process, the latter option resulting in variation from unit-to-unit in RF level over frequency, vulnerability to off-air ingress signals, and susceptibility to damage or breakage if the instrument is dropped or vibrated.

In addition to the inductor coils and RF connector, the quality of the printed circuit board (PCB) itself can be critical for ensuring reliability. Exposure to humidity and thermal cycling of low-cost boards can lead to dendrite growth or cracking, which in turn can result in measurement inaccuracy or complete instrument failure. While it is often anticipated that CPE will become obsolete within 24–36 months of its deployment, test equipment, including cost-effective instruments, can be expected to last for a minimum of 5 or more years. So an adequate tuner NIM PCB for CPE is typically insufficient for a test-grade SLM.

Alternatively, instead of using standard off-the-shelf tuner modules, JDSU and other test equipment manufacturers will invest in a custom tuner circuit and layout. Choosing this investment over can tuner modules mitigates each of the limitations discussed previously, but requires significant technical investment into engineering design, PCB manufacturing, quality control, and performance characterization tests.

Validation of Measurement Performance

Regardless of the measurement system architecture chosen, extensive design validation is necessary to ensure its suitability as commercial-grade test equipment for the end user. In particular, RF measurement accuracy must be validated over the full specified temperature range and measurement accuracy range of the device and beyond. Testing beyond the specified range is necessary to ensure adequate design margin for the device. For example, if measurement accuracy is specified from −10°C to +50°C ambient, it may be necessary to test the device accuracy from −30°C to +70°C.

In addition, testing the PCB assembly quality and robustness through rapid thermal cycling with simultaneous vibration is a well-known means for predicting field life and identifying design weaknesses. For example, using special thermal chambers to ramp the ambient device temperature from −70°C to +100°C at ramp rates up to 10°C/minute, while at the same time subjecting the device to an extreme vibration profile, determine how to strengthen future designs. Such test facilities require a great deal of expertise to operate and can be costly to obtain, but fault-prone PCBs will usually fail under such a test.

Besides testing for measurement accuracy over temperature, properly qualified test equipment will also be characterized with respect to performance with a fully loaded channel plan and adjacent channel levels. When multiple strong channels are present at the device input, intermodulation products often limit the measurement accuracy at some particular frequencies. Identifying the vulnerabilities of a particular design to such issues requires performing extensive, time-consuming testing over frequency, level, and temperature. Furthermore, it is necessary to test not only a single device to this degree, but a sufficiently large number of devices so that the designer can be confident that all devices manufactured according to the design will meet the specification.

JDSU meters are always designed and tested to the most vigorous specifications.

Measurement Performance

Nearly all commercially available tuners and tuner modules available on the market will measure and report a signal level parameter by default. However, the purpose of such measurements is not for troubleshooting services, but simply to provide some means for a host set top box or television to determine whether any signals are being received by the tuner.

Therefore, such standard signal level measurements are very often inaccurate over temperature or over the full range of input levels that may be encountered on the CATV network. Predictably, tuner manufacturers almost never guarantee the accuracy of built-in signal level measurements, if they are specified at all.

Similarly, tuner modules that incorporate a quadrature amplitude modulation (QAM) demodulator can perform modulation error rate (MER) and bit error rate (BER) tests without any development effort required by the test equipment manufacturer. Such results are typically representative of the signal quality but do not serve to provide the highly accurate measurements required by test equipment. In particular, measuring the BER by testing all or nearly all of the bits received is very challenging and requires implementation of sophisticated software algorithms. Unfortunately, it is all too easy to merely simulate high BER coverage, which is the route that some test equipment employs.

Percentage of coverage aside, when a test device uses a standard tuner module in lieu of a custom, optimized tuner design, the receiver MER and BER performance is fixed and cannot be improved upon. If the design exhibits significant BER problems with one particular channel at an extreme temperature, for example, the only means to mitigate this is ignoring those BER results that are presumed the result of the receiver itself. Other challenging input signal situations that can result in erroneous BER include strong adjacent channel levels and performance with a full channel plan present, including tilt. Detecting the use of such BER compensation or correction is difficult without highly specialized signal generation equipment.

JDSU customers can always be assured that the BER measurement inside JDSU test equipment counts *all* the errors that occur and maintains them on the display until 1,000,000,000 bits have been tested.

Summary

Many low-cost SLMs appear similar based on feature set and product performance specifications. However, meters that incorporate a standard low-cost “can” or NIM-based tuner module will exhibit significant design weaknesses. In fact, some such products use the MER and BER measurements of the module itself and incorporate compensation algorithms to mask the limitations of the mass-produced tuner module.

The alternative, however, is not without cost. Developing and qualifying a proper, custom RF tuner circuit with the performance needed for test equipment is expensive, time-consuming, and requires a significant technical expertise. However, vendors who are willing to invest in such a design can avoid the limitations of accuracy over temperature, mechanical durability, and measurement performance inherent in mass-produced receiver modules. This investment is exactly what makes JDSU meters superior and the best performing testers on the market today.

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