ATX LABS TECH BRIEF

ATX Labs has Devloped a Computer Driven Algorithm for the Fully Automated Calibration of Type IIb Presettable Torque Wrenches used at the Microwave Test Bench

This Technique Results in an Automated Calibration Procedure that Converges Reliably to a Preset Torque Value with added Uncertainties

One of the more ubiquitous tools at the microwave test bench is the presettable “break-away” torque wrench that is used to apply a known rotational force across the flats of a microwave connector. A presettable wrench by definition is one that has been set by the manufacturer to a certain value and tolerance. Typically torque values for microwave applications range from about 5 to 20 in-lbs for common connectors including though not limited to 1.85mm, 2.4mm, 2.93mm, 3.5mm and Type N. Given the cost of microwave test instruments and components, as well as the investment with regard to time and labor, the use of a torque wrench is a prudent and cost effective way to ensure the proper seating of opposing mating planes of male and female connectors.

The common pro forma approach for torque wrench calibration is to use a torque transducer that has itself been traceably calibrated by using the known standards of force and length that flow from the definition of torque. This is done because there is no primary torque standard in the U.S. If one examines the Scope of Accreditation for calibration labs operating in the U.S. it is found that the best cal procedures that cover the common torque ranges used in the microwave disciplines will have an expanded uncertainty of about +/- 0.02 in-lbs at a 95% confidence level (k=2). This value then carries forward to the calibration of the torque tool itself and adds to the final uncertainty of the tool after deployment.

Most commonly, torque wrench calibration relies on identifying an “as found” condition based on ten torque readings with a stated uncertainty, also expressed at a confidence level of 95%, and this process (though not the uncertainty analysis) is covered by ISO 6789:2003. For uncertainty analysis *The Guide to Uncertainty in Measurement,* JCGM 100:2008 (popularly referred to as GUM) is relied upon by most in the engineering community as the basic guide. The tolerance for the class of wrench under discussion is +/- 6% of the preset value per ISO 6789, though +/- 10% is not an uncommon specification among manufacturers.

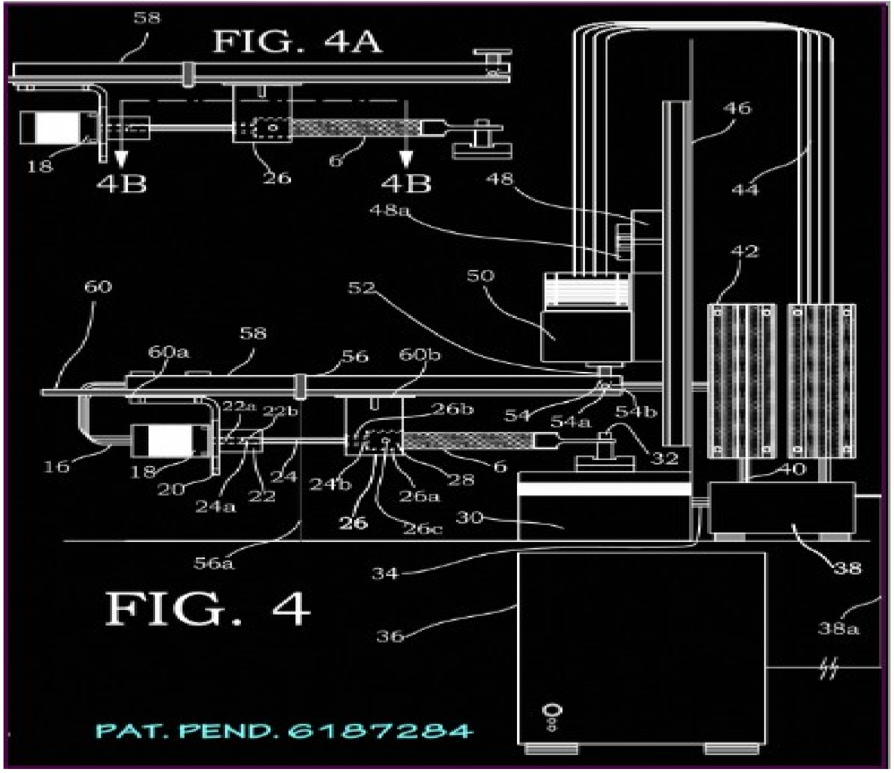

FIG. 4A

FIG. 4

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If the as found condition is not satisfactory, there is a separate charge and labor component associated with making an adjustment to return the wrench to its nominal value. The human element in both of these exercises with regard to both as found readings and adjusted readings is considerable, and final values may vary as a function of whether the tools were exercised prior to use per section 6.3d of ISO 6789. They may also vary as a function of the angle or position in which the technician held the wrench during testing. Patience and skill are needed since the resetting of the tool requires an internal spring adjustment while alternately turning the wrench and recording the measurement; this implies a series of iterative measurements and wrench arm movements until a sequence of readings converges to the nominal value of the tool. Therefore another degree of uncertainty is introduced by the final requirement of judging when convergence is achieved in the presence of noise which is inherent in this kind of measurement. Time and the cost of bench labor can support only so much care with regard to the determination of convergence.

Per ISO6789, there are several mechanical constraints that need to be observed in order to get a reliable calibration for Class IIC wrenches (sec. 4B) as defined in the Standard: **[1] Sec. 5.1.5.2** – a tolerance threshold of 6%; **[2] Sec. 6.1** – an uncertainty calculation

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with a confidence level of k=2; **[3] Sec. 6.2** – a temperature arc of no greater than +/- 5 degrees centered at 23C; **[4] Sec. 6.3.1D** – the use of a pre-loading regimen consisting of no less that five releases prior to calibration; [**5**] **Sec. 6.3.1E** – the application of a force simulating the holding force of the human hand such that the force is constrained to be centrally located in a specified holding region; **[6] Sec. 6.3.2** – the application of a force in the region defined above that is no greater than +/- 3% off the horizontal axis of the wrench (side planar view) that shall be constrained to run in a level line through the point of contact at the testing socket of the torque measuring instrument; **[7] Sec. 6.4.2 –** the application of force in the region defined above that shall be no greater than +/- 10% off a line that is normal to the wrench axis when viewed from above (top planar view).

The bulk of the mechanical constraints defined above by ISO6789 make manual testing and calibration extremely challenging and time consuming. If a 6% tolerance per Sec. 5.1.5.2, as calibrated, is to be achieved, not just in the lab under well defined conditions, but in the field where several of the constraints above may not be realized – like the wrench handle pitch or the angle at which force is applied relative to normal, or even the holding point – then it would be desirable in the lab to achieve a far greater tolerance than 6% so as to allow greater latitude in the field. What therefore motivated the development of an automated torque wrench calibration routing is the desire to achieve a near perfect calibration to compensate for less than ideal downstream conditions. Below an approach is outlined that captures the letter of the Standard with reduced cost and time.

Automated approaches to torque wrench calibration exist, but the inaccessibility of the internal spring in the IIC class of wrench used at the microwave test bench, combined with ISO6789 constraints, has made automation difficult. The new technique described here rests on several developments: a low energy coupling means to the internal wrench spring; [2] a computer algorithm for controlling the arm of the wrench to move in a predetermined arc, as well as controlling the internal force of wrench spring to put well defined tension on the claw end of the tool thereby increasing or decreasing torque; [3] an iterative convergence means that avoids oscillation at extremely small values of torque - accomplished by using micro-degree stepper controls and a traceably calibrated torque transducer where an algorithm alternately controls the wrench arm and spring tension while recording the output of the transducer until convergence to small delta values has been achieved; [4] a GUM module that integrates the uncertainty calculation into the actual calibration in an automated manner within a feedback loop so as to cause the application to terminate only when a tight, present tolerance has been achieved.

This approach relies on using a low energy custom coupling to the internal tension means that has no component of force in the direction normal to the wrench handle's axis. The wrench, as pictured in the figure, is made to sit in the pocket of a fixture that puts the force point at the center of where a human thumb engages the wrench handle, consistent with ISO 6789 6.3E. The fixture is then made to move in an arc determined by the algorithm after the user has set both the desired arc and torque values. The computer algorithm alternately moves the arm, records the output of the transducer - and increases or decreases spring tension as needed in a real time feedback loop - until the preset torque value recorded by the transducer is within a threshold set by the user and the uncertainty constraint. This is not unlike the manner in which a technician would perform the adjustment of a wrench – the difference being that the converged to value is unambiguous, arrived at under repeatable and reproducible conditions, and achieved under fully automated control.

Enhanced features include the ability of the algorithm to pre-load the wrench per ISO6789 Sec. 6.3.1D, the ability to feather the preset convergence point in order to integrate out noise, and the ability to calculate a final uncertainty that includes the carried forward uncertainty of the transducer and Type B uncertainties related to the properties of the wrench, and to physical lab conditions during calibration, respectively.

When the wrench is removed from the fixture it is adjusted and calibrated to within, typically, +/- 1% tolerance (though in a production environment that can be expanded to 2% or greater)) – a value that includes uncertainty as established in the final GUM module. This removes the repeatability concerns associated with manual testing and considerably expedites the process. Further, it satisfies the initial goal discussed above of providing some breathing room relative to tolerance during wrench deployment due to the tight tolerance achieved in the lab.

Torque wrenches of the Type IIC “break-away” class are relatively simple devices. Their core components are a spring made from fatigue resistant steel, an open wrench socket integrated with a ball joint that engages the spring, and a means of tensioning the spring to put a force on the ball joint which in turn sets the final torque. When deployed, a combination of factors – from temperature variation at the work bench, to steel fatigue, to differing holding patterns associated with different users,

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as well as to conditions that are related to the period and frequency of use (for example, first day's use vs. later intra-day use) - all conspire to introduce variability in the application of consistent torque with a well bounded tolerance.

It is imperative, in order to realize a manageable tolerance in the field, to initially achieve a tight tolerance band during calibration in the lab. The automated procedure outlined here constrains the inevitable mechanical variance of a process that is normally carried out by hand. By tightly bounding both the wrench holding point and the arc of force application (as viewed in two planes) - and by the use of a feathering algorithm that achieves fast and robust convergence to a preset torque value without oscillation – a calibrated value with uncertainty can be achieved that goes well beyond anything achievable by manual tuning.

Upon deployment, a wrench so calibrated is better able to withstand the variability of physical conditions that test the tolerance boundaries after calibration for this class of wrench.

This work was done by V. R. Spelman, MSEE, and E. Milstein, of ATX Labs, Vineyard Haven Massachusetts.