Overcoming MEMS Measurement Challenges using the TEGAM Model 9072

Why MEMS

The Micro-Electro Mechanical R&D market has long needed a package solution for stimulation, observation, measurement, and recording of the motions of MEMS devices under test. TEGAM Inc. has recently delivered the first such system to North Dakota State College of Science.

As Micro / Nano Electro-Mechanical Systems (MEMS / NEMS) become increasingly smaller, researchers, students, and scientists need to come up with novel techniques to not only view, but also excite these small devices. MEMS devices serve a wide area of uses from airbag sensors to micro-nozzles in printers to video projection chips. The future hopes to bring more advanced devices such as micro cameras and micro engines that can be injected into the blood stream for missions such as location specific drug delivery and the clearing of arteries. Universities across the world are adopting curricula to implement MEMS based training so that the next generation of engineers and scientists are prepared for current technologies as well as what is to come on the scientific horizon.

MEMS Movement

TEGAM's products have been used for the excitation of MEMS devices since the advent of the technology. MEMS movement is typically achieved by the use of three tools:

1. A Waveform Generator
2. A Power Amplifier
3. A Fixture or Probe

To provide the proper stimulus one can use an Arbitrary Waveform Generator (ARB). These generators are typically limited to 10 Vp-p. The required stimulus amplitude may differ depending on the part being actuated. A Voltage Amplifier is used to increase low-level ARB amplitudes to higher excitation values which are needed to stimulate MEMS devices under test. It may require less voltage to actuate a latch versus a linear comb drive micro engine which has some k restoring force and embedded capacitance. Instructors and students should take precautions in selecting proper excitation values. Most devices have a nominal operating frequency, and amplitude. Researchers producing MEMS / NEMS based devices should start with low frequencies and voltages and gradually increase both until the desired result is achieved. Many amplifiers have fixed gains which help the user easily determine the amplified voltage.

The Problem

MEMS devices are usually so small that typical movement is undetectable without a visual aid. Researchers often use single observer optical inspection microscopes, however this method of observation provides limitations to groups who may want to collectively see what is happening in real time. Additional stimulus and measurement equipment is needed to complement a complete measurement system. North Dakota State College of Science offers a course in MEMS technology and is a member of Sandia National Laboratories University Alliance and Sandia Summit. Dr. Michael Burke, Director of Nano Science Training at NDSCS, is the professor who teaches that course. Professor Burke and the administration of NDSCS recently purchased a TEGAM Model 9072 MEMS Test Station so that their students can see in real time what is happening as they actuate MEMS devices acquired from Sandia. As a project for the class, students design their own MEMS devices. The 9072 provides a platform to stimulate, view, and measure their devices. Professor Burke explains that his decision to purchase from TEGAM was motivated by the fact that, "no one else had a complete system… I wanted to make sure that everything would work well together without having to plan the system myself." Dr. Burke plans on measuring unknowns such as displacement, theta, and stroke lengths during his course: "Thin Films / A MEMS Case Study".

The TEGAM Solution

The 9072 MEMS Test Station consists of:

1. 2732 Two Channel ARB Wave Generator
2. Software: Excel / WaveWorks DDS
3. 2350 Two Channel Power Amplifier
4. 2301 MEMS Fixture
5. Complete Dell Desktop PC
6. Microscope / Illumination
7. Cognex Vision System and Software

The ARB

TEGAM Inc. sells a wide variety of Arbitrary Waveform Generators that vary in price depending upon differing specifications. The TEGAM Model 9072 contains one Model 2732 (Figure 1).

The 2732 has two isolated channels that source two independent waves up to 50MHz. The 2732 also contains the largest memory of any other ARB in its class at 4 million points of data storage while maintaining a 14 bit resolution.
The 2732:

- Is ideal for users wanting very high precision while still needing high point count waves.
- Has the unique ability of setting the internal phase so that a user can generate dual waves and provide a differential in phase output from 0 to 360 degrees.
- Has the ability to trigger its own secondary wave at any point within the primary waves sequence.
- Can use either an internal or an external reference clock.
- Can be synchronized with other instruments.
- Has a significant cost savings when compared to purchasing two separate instruments.

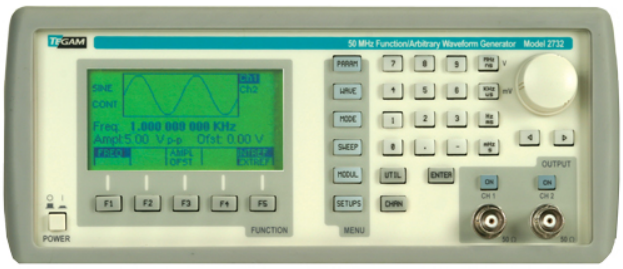

Figure 1 – TEGAM's Model 2732 Dual-Channel 50MHz Hybrid Arbitrary Waveform Generator.

Arbitrary wave data for the Model 2732 can be created using built in waves such as sine / square / pulse / ramp, etc. These waves can be created from the front panel using a start point, number of points for the designated wave, and wave type. This feature is valuable for the user who may not have time to review the manual in detail.

ARB Software

An included software package named WaveWorks DDS™ allows for point by point wave manipulation / creation. The final wave, up to 4 million points x 2 channels, can be downloaded using an RS-232 or GPIB connection. WaveWorks DDS™ also has the ability to import waveforms from most Tektronix, LeCroy, and Agilent Oscilloscopes.

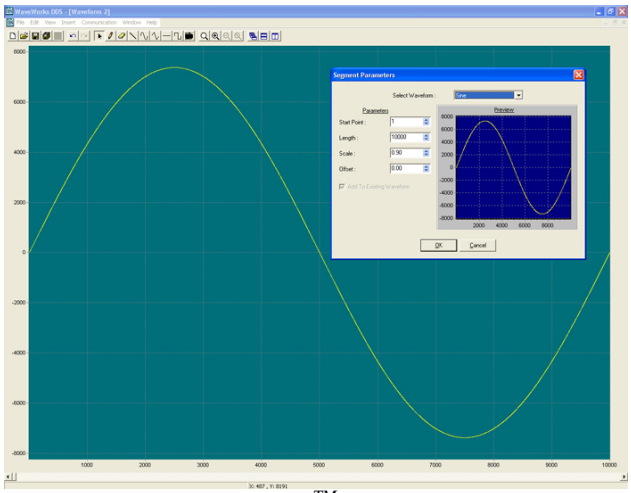

Figure 2 – WaveWorks DDS™ software is included in the 2732 which allows for complete wave construction.

Another useful tool for wave creation is Microsoft Excel which allows a user to create separate waveforms up to 65,535 points in length by using any typical math functions that would normally be available in Excel. Excel also allows the user to preview their data by using an Excel graph. The resultant data can then be saved into a file and imported into WaveWorks DDS™. This resultant data can then be sent to the 2732 via RS-232 or GPIB communication protocols. Using comma delineated import, the 2732 can import data from any program allowing a comma separated file such as MATLAB®, an oscilloscope file, or other device capable of producing a format that Excel can recognize. Excel can then be used to further modify the data if needed.

The AMP

The TEGAM Model 2350 has been chosen as the complementary amplifier to the 2732. The Model 9072 includes one Model 2350, two channel amplifier. Any fixed gain can be provided from the factory between x10 and x100. Custom gain selection provides maximum flexibility to the end user whose needs may vary depending on the signal source being used. Many MEMS devices require a stimulus in excess of 100 Vp-p, the 2350 has a maximum voltage output of 400 Vp-p covering the requirements of today's MEMS parts as well as delivering support for future technologies. With a continuous current of 40mA, the 2350 has the ability to drive capacitive loads up to 200pF while maintaining full power up to 200 kHz in frequency.

Figure 3 – TEGAM's Model 2350 Dual-Channel Power Amplifier.

The Fixture

Since MEMS / NEMS devices are so small it is necessary to use a tool or other device to access the very small contact locations that are needed in order to apply an electrical stimulus. A device known as a prober or probe station is often used to "touch down" on these small locations. These probe stations can be costly but oftentimes necessary for fundamental MEMS research. TEGAM has developed a unique solution known as a 2301 MEMS Test Adapter. Instead of using an expensive prober, the user can elect to have their device "packaged". Packaging involves using a wire bonding machine to bond wire to the pads that have been created during the fabrication process. These pads have been pre-designated as locations to apply stimulus, i.e. where the output from the power amplifier would be applied. Once the device has been packaged the MEMS device sits inside of a windowed integrated circuit (IC).

Figure 4 – TEGAM Model 2301 Four BNC to IC MEMS Adapter

The TEGAM Model 2301 accepts standard and wide dip packaged IC's with up to 24 pins or legs. The IC sits into a zero insertion force socket and the pins connect to wires inside of the adapter. The Model 2301 opens without tools, and connections can be patched from any pin of the IC to any of four onboard male BNC's.

Computer/Microscope/Illumination

The 9072 also includes a dedicated PC preloaded with software including:

1. WaveWorks DDS
2. Excel
3. Cognex control and Measurement Software

An included stereo microscope permits live stereo viewing or through-lens operation of the Cognex camera, at magnifications of up to 45X. 90X magnification can also be ordered depending upon the device under test's dimensions and future requirements. Every system comes with a dual-head illuminator so that the proper lighting can be applied. Lighting (perceived contrast and brightness) is a critical piece of the Cognex camera and visualization software. A c-mount adapter is provided to attach the Cognex camera to the microscope.

Cognex Vision System

The Cognex system is composed of a high resolution camera with an embedded controller. The camera is connected via an Ethernet cable to the control PC. The Cognex system was selected for its robust measurement utilities. The Cognex software allows measurement by comparative pixel analysis (every pixel has an associated brightness). Arbitrary objects can be defined such as circles, lines, line segments, etc. An Excel like layer exists so that powerful math functions can be entered. The result is that as MEMS devices move, values such as displacements, real time area, and change in theta can be computed and displayed. The visual system can be calibrated by user-printable cards. These calibration cards can then be used to calculate actual distances. Instead of pixel lengths, actual sub-millimeter measurement can be displayed along with true to life areas.

Summary

The TEGAM Model 9072 MEMS Test Station (Figure 5) has proven to be a powerful tool for the current generation of MEMS / NEMS researchers, students, and teachers. The system allows for high resolution, high voltage waveforms at an economical price. Using an external projector, instructors are able to use the system to demonstrate concepts to many participants while researchers / scientists have the capability of recording MEMS operation as movies so that they can collaborate with others.

For the fist time, the 9072 offers a complete system for actuation and visual measurement of MEMS devices.

Figure 5 – A complete TEGAM 9072 System.

Acknowledgements

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About the Author

Justice Richards works full time as an Applications Engineer at TEGAM Inc. and holds a BS in Engineering Physics and an MS in Physics from Case Western Reserve University. Much of Mr. Richard's education has been focused on MEMS design and development including a master's thesis on high temperature MEMS pressure devices.

Please contact TEGAM, Inc. for more information on the 9072 System or any subsystem including TEGAM's newest Function/Arbitrary Waveform Generator the two-channel Model 2732 with an outstanding 4 million point memory clocked at 125MS/s.

LabVIEW CE

Why TEGAM?

We help customers be more productive by making instrumentation easier to use, more accurate and faster. TEGAM's specific areas of expertise include waveform generators, precision amplifiers, RF power calibration and low level measurements.