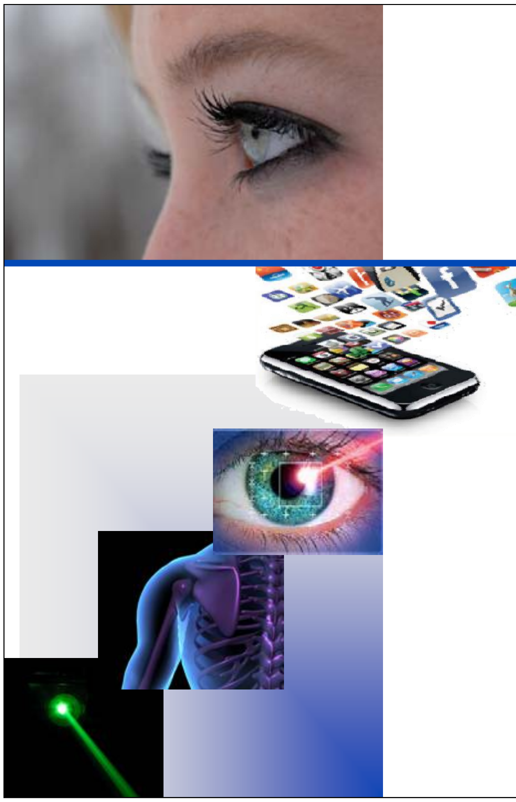


Micro Motion for Optical Instruments

…inspired by your smart phone

Presented by
David Henderson
Founder, CEO and CTO
New Scale Technologies
www.newscaletech.com

<transcript>

This is David Henderson, and I'm happy today to be talking to you about micro motion for optical instruments and how the latest technology for smart phones is enabling smaller, more precise products in non-consumer imaging applications.

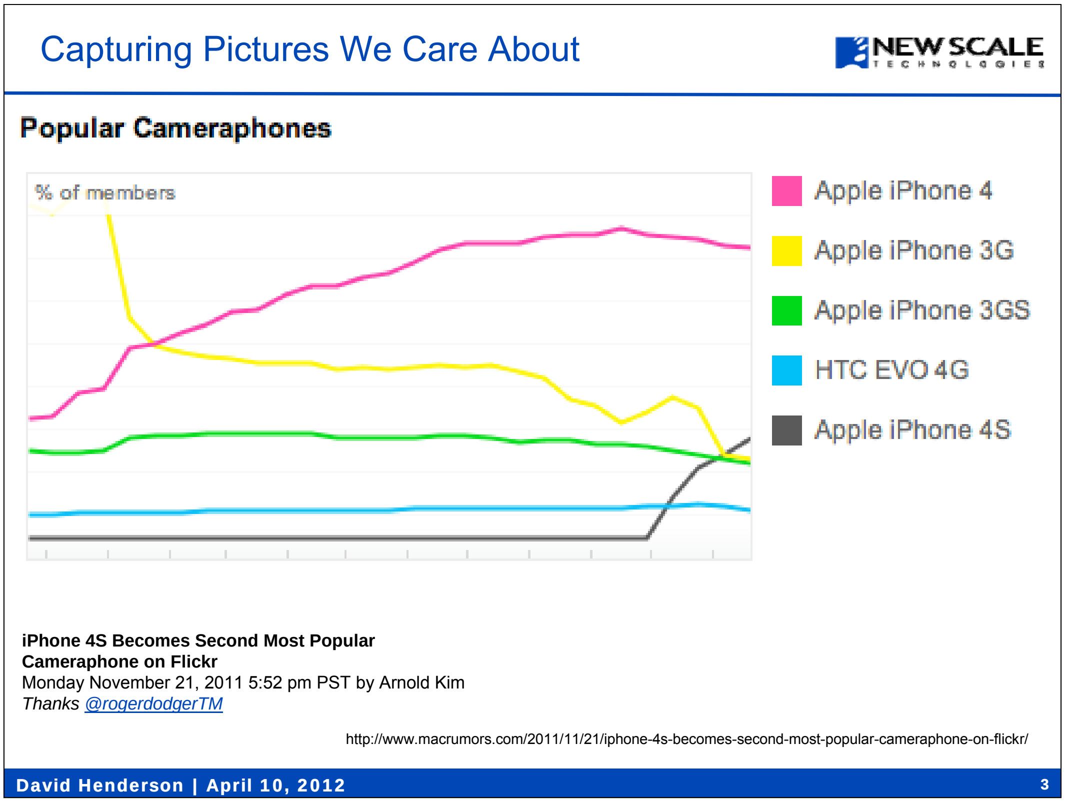
© New Scale Technologies

The Smart Phones That Never Leave Our Side

David Henderson | April 10, 2012 2

Most of us carry around in our pockets a smart phone that represents some really incredible technology in miniaturization in a lot of areas. Especially with latest camera phones, this has created the opportunity for you to carry around with you a camera that's really almost as good as a camera you would buy separately as a point-and-shoot camera. Embedded in that camera is some incredible optical technology and some incredible motion technology that is on the scale of just a few millimeters in dimension.

© New Scale Technologies



The result of that is evident in a lot of ways. Perhaps you've noticed it when you watch the news and you see the first images or video coming from a newsworthy event; most of that's coming from someone's mobile phone. It's also noteworthy that we're capturing a lot of pictures we care about, pictures we want to share for example on a site like Flikr. Here you can see some of the most popular smart phones on Flikr, such as Apple and HTC - Samsung's not here but it's also a popular phone – that can capture images that are worthy of sharing or archiving. Some get printed, but a lot of times they're simply shared here or in another media like Facebook.

Recent public marketing from Apple talks about the phone camera being “the only camera you need.” That’s the camera you carry around in your pocket, you can trust it with your family vacations, you can trust it with those special moments that you want to keep forever. Digging into the technology of that and understanding what is happening at the optical level is captured below these two images.

There are very intense optical assemblies, optical design around plastic lenses, polymer lenses, and this case a five-lens assembly in a camera that’s only about 6 mm thick. Some of the major innovations that are taking place are increasing the aperture – increasing the amount of light that can get into the camera and onto the image sensor – and that means a lower F-stop. The result of that is you have a much more demanding requirement for focus.

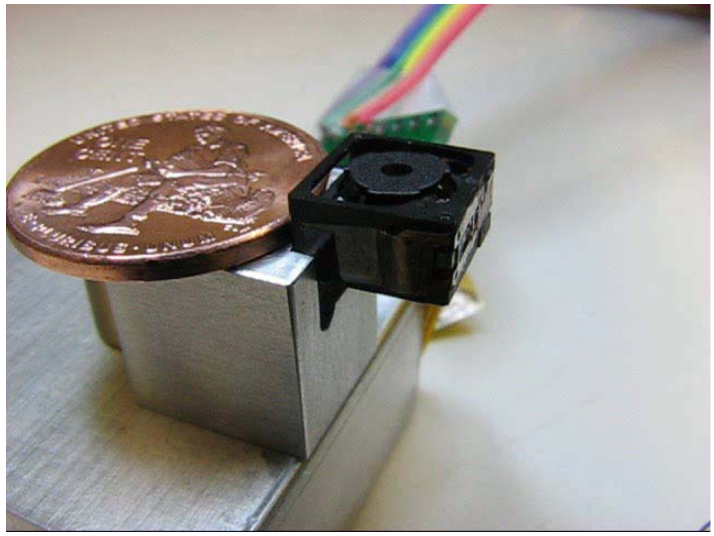
In some of the earlier phones, focus was fixed and you couldn’t really optimize the image, for example try to take a picture of a business card. Some of the newer smart phone cameras have very precise ability to move the lens in front of the image sensor and move with micron precision and also move with very small tilt. and I’ll talk in a minute about what that means in specific numbers. The end result is an increasing demand on the precision of lens movement, and that is being met by the next generation of motion technology.

© New Scale Technologies

Tiny Camera Phones Need Tiny Focus Motion

Small. Precise. Smart.

- 8.5x8.5x3.8 mm
  *Module Z height dependant on travel
- M6 lens diameter
- 0.25 g lens
- > 400 µm stroke
- < 28 dBA
- 1 µm resolution
- >10 mm/sec
- 30 µm/10 msec
- Tilt < 0.1 degree
- 10 mW avg power (CAF use case)



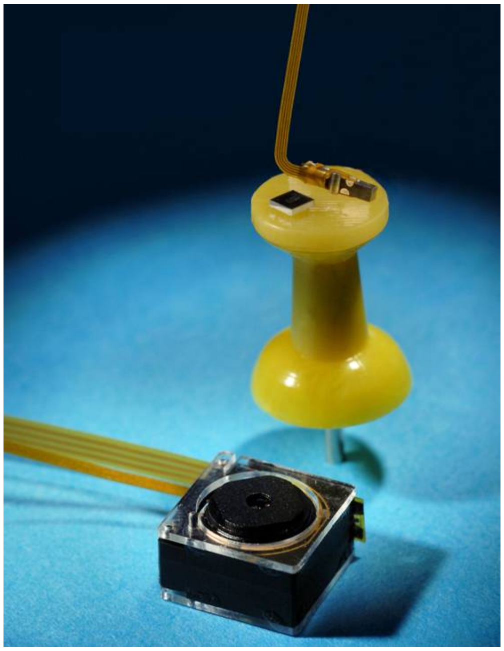
Video: Ultra-Thin Auto Focus (UTAF)

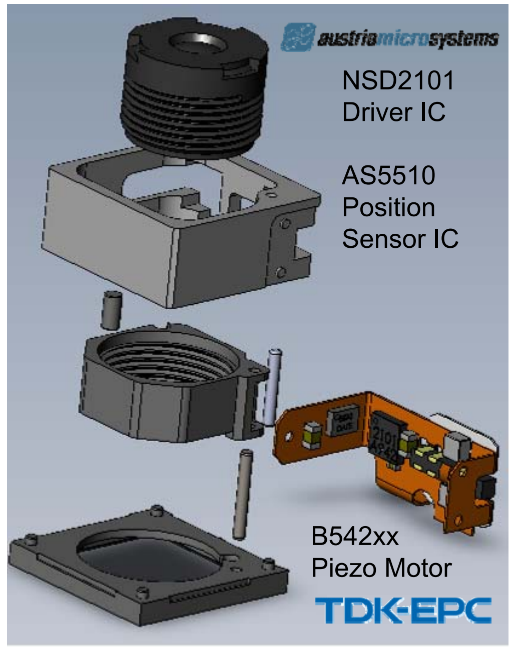
David Henderson | April 10, 2012 5

When we talk about a motion system for a micro camera this is one example . You can see some of the critical parameters that define a great motion system at this scale. Size is about 4 mm not including the image sensor. Lens diameter 5 mm, mass of the lens 0.25 gram. Excellent position resolution and low tilt are very important. It also needs to operate quietly; you don’t want noise picked up by your microphone.

© New Scale Technologies

Small, Precise and Smart Motion System - UTAF



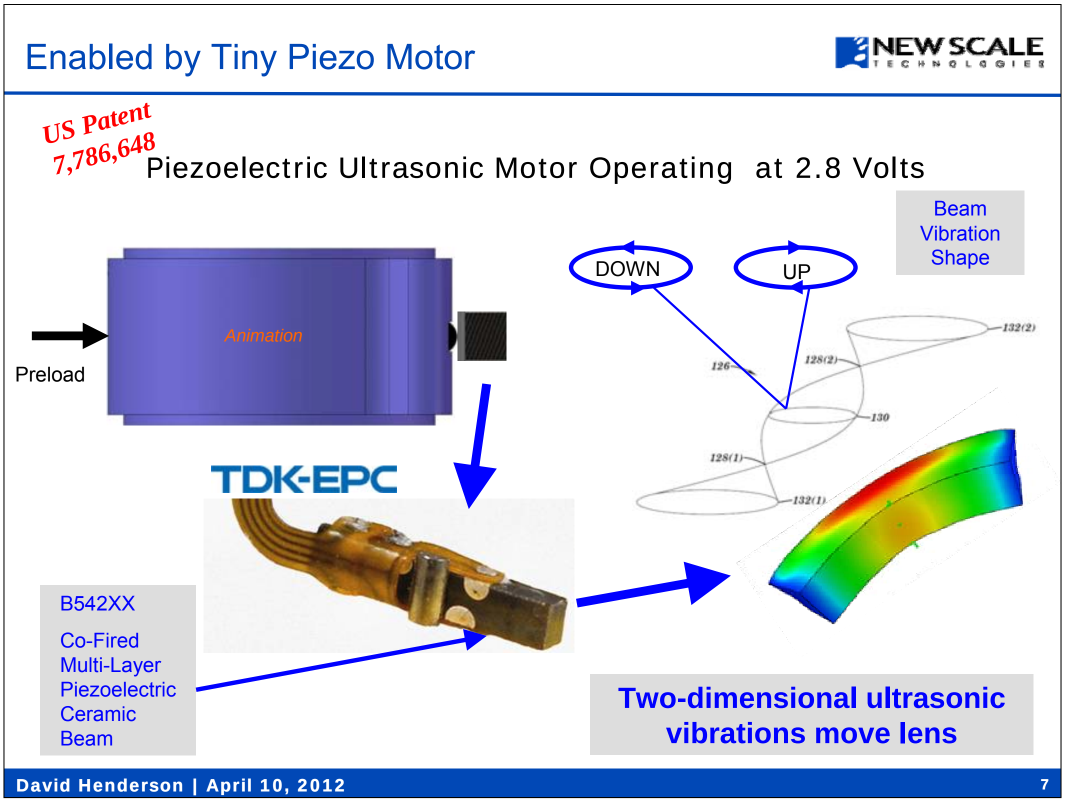


David Henderson | April 10, 2012 6

Let's look under the hood at how this kind of smart motion is created. One example is our UTAF or ultra-thin autofocus module, based on piezoelectric actuation. Fundamentally the idea is you're creating ultrasonic vibrations that create force that can be added together to create continuous long-range bi-directional movement, in this case of the lens.

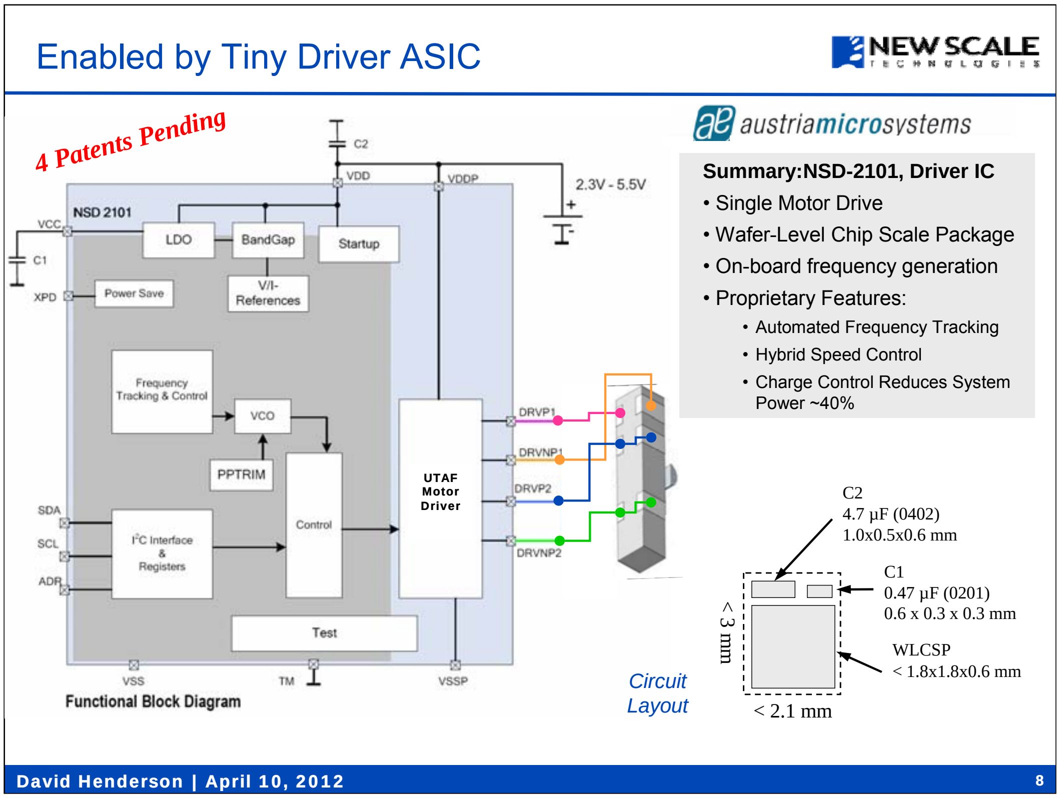
Just as important as the piezo motor is the ability to integrate in the same package a position sensor, and also the driver IC that can operate and excite the ultrasonic resonance of the motor. These together create a small, precise and smart motion system.

© New Scale Technologies



Let's look deeper at the technology of an ultrasonic motor. The animation (see the webcast at Laser Focus World) shows the piezo beam generating a two-dimensional vibration of the beam. In one direction of vibration the lens moves up, in the other direction it moves down. This is coupled to the moving lens using a preload so it's a frictional coupling that enables precise motion – in this case over several hundred microns of total movement. This beam is only 0.4mm in length and 0.8 x 0.7 in cross section.

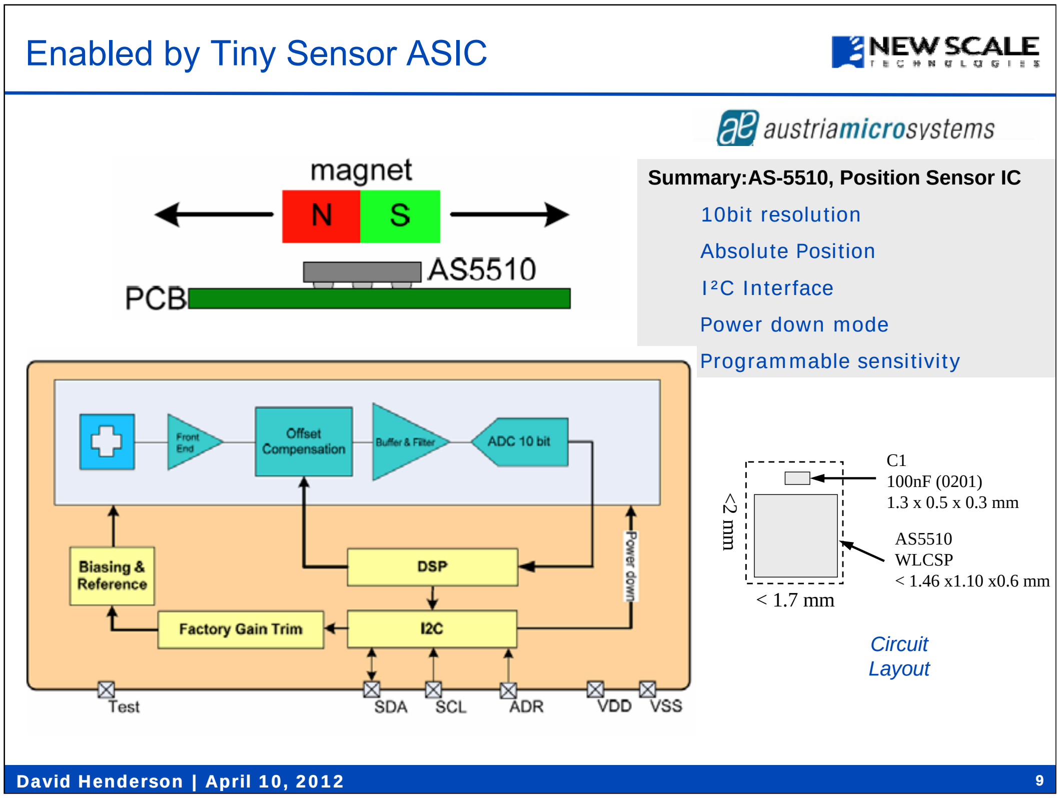
© New Scale Technologies



How do you operate this motor? We use a custom ASIC developed in partnership with austriamicrosystems. What is really impressive is not just that this chip generates the 2-phase ultrasonic vibrations in the beam, but also includes on-board frequency generation, with two modes of speed control. It has automated frequency tracking so it not only generates the frequency but automatically locks on to the mechanical resonance of that ceramic beam, and that will vary with temperature and manufacturing variations, so this feature is critical and part of the "smart" system.

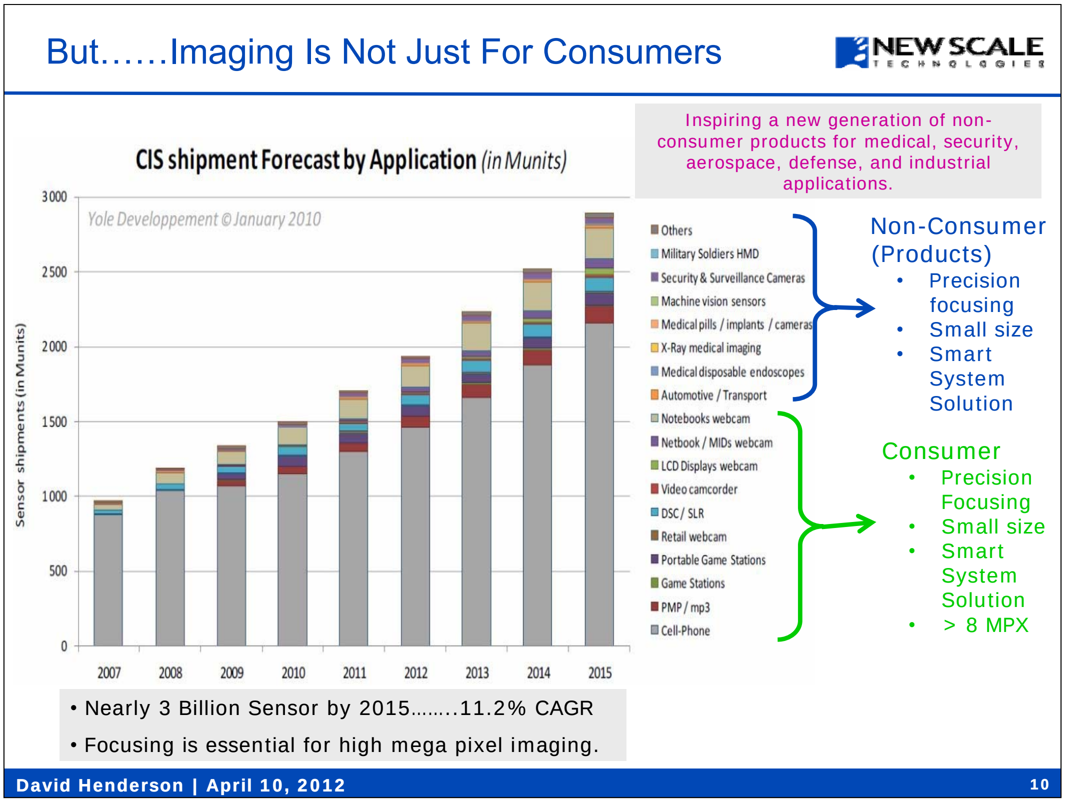
Speed control is critical because the input voltage to this chip is directly from the battery, typically about 3 V, but as the voltage of the battery changes so will the speed of the motor. So the chip allows us to automatically compensate for battery voltage changes and still maintain precise, repeatable motion. Finally, it has embedded charge control, that is to say a patented method for full-bridge switching which reduces power use by 40%. The overall size of the chip is 1.8 x 1.8 x 6 in a wafer-level chip-scale package.

© New Scale Technologies



We also have to measure location of the lens. The ultrasonic motor is a friction device, so it does require a position sensor for repeatable motion. In this case we use a tiny hall sensor to measure movement of lens. A magnet is attached to moving lens and the hall sensor detects the magnet as the lens moves, and converts it to a 10-bit digital output. Both the drive IC and position sensor are digitally controlled through 12C.

© New Scale Technologies



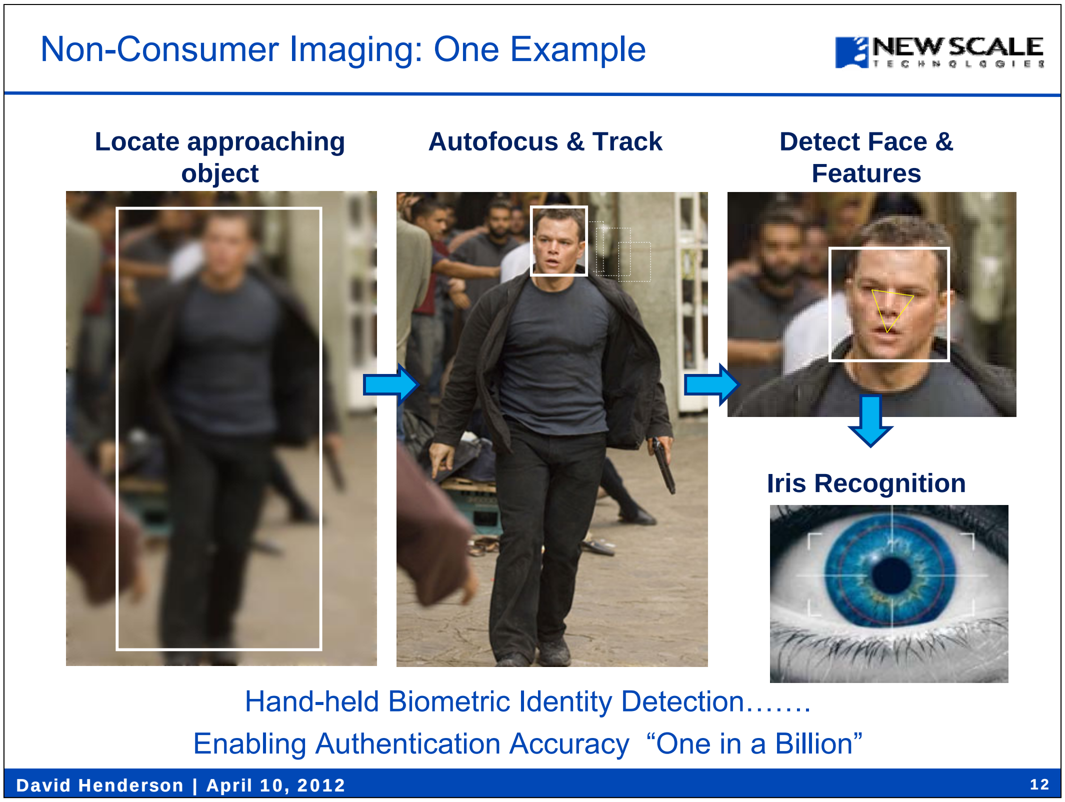
We have talked about the kind of technologies that are now available for smart phone cameras. But the market for imaging is about a lot more than smart phones. You can see it's projected that by 2015 nearly 3 billion image sensors will be produced with a 11.2% CAGR. This is a major trend in imaging world-wide, and it's not just consumer products but non-consumer products including medical, security, aerospace, defense and industrial.

What is really clear is that the incredible technology achievements in the smart phone space are enabling a whole new generation of non-consumer products. The realization of incredibly small image sensors (CMOS sensors with 8 or 13 megapixels in a 1/3 format or less), polymer optics that can be made very small, and finally precision focusing made possible by products like our UTAF – are all enabling development of smaller, more precise products.

© New Scale Technologies

There are differences, though, in non-consumer imaging. Generally the optics are mores specialized. You're not trying to take a beautiful picture of your family on vacation, you're trying to collect information. Because the optics are more specialized they're typically larger in diameter and have more mass, and you typically need more stroke to got your full range of focus.

© New Scale Technologies

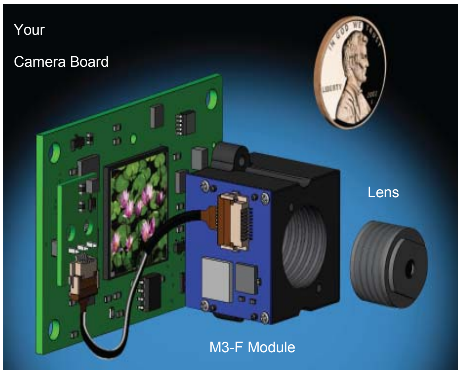


One example is biometric detection. Especially handheld devices where you want, for example, to image the iris of a person with enough accuracy and fidelity that you can detect one in a billion. This is happening in India today; every person is being registered as a citizen with their ID being defined by their iris. This is going to enable banking, getting ID cards, getting public services, all the things that in the US we might identify with our SSN.

To enable that kind of one in a billion accuracy requires custom optics, precision understanding of lighting – you need IR lighting and IR cutoff filters. You need to capture images at a variable distances so you can identify the person without the person having to move their head and wait for the machine to tell them that they're in focus. These are all features being enabled by smart phone technology.

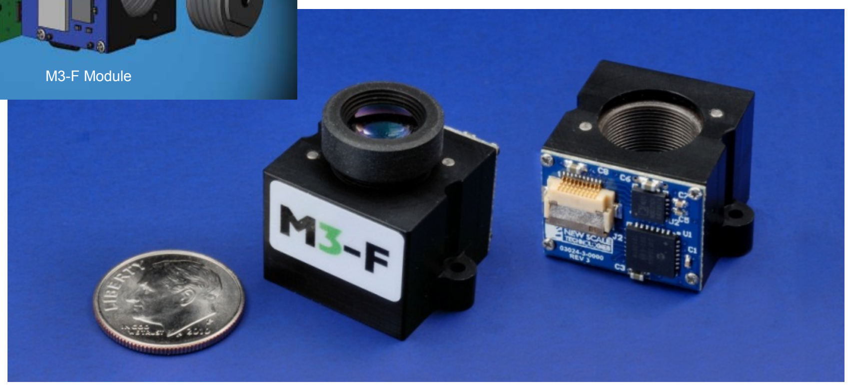
© New Scale Technologies

Small Motion System for Focus



Steps to Designing a Camera:

1. Select/design the image sensor
2. Select/design the optics
3. Select the motion system



Looking at a specific example, this shows an implementation of a focus system with a board camera and a lens. In the camera design process there are really three steps.

One is what ‘s your image sensor: what type of image do you need to capture, how many megapixels, what kind of processing is required to create the information necessary for you instrument?

The second step is to think about what kind of optics are needed. What’s your focal distance and focus range? What wavelength? Is it color or black and white?

Third is the motion system. How do you have to move the lens to achieve optimal image focus and avoid tilt or delays that slow down the image capture? This is true in mobile phones and also in non-consumer applications.

© New Scale Technologies

Precision Motion for Focus

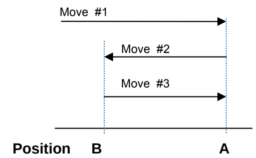
NEW SCALE TECHNOLOGIES

Resolution

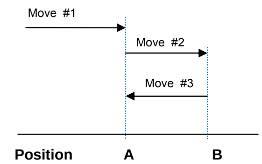
- Minimum resolvable distance the lens can move
- Fine control over the lens motion

Repeatability

- Measure of a system’s ability to return the lens to a previously defined position
- In many algorithms, better repeatability means better focusing
- Direction in which the target position is approached impacts repeatability (Fig. 5)
- Unidirectional positioning, in which the target position is approached from the same direction every time, provides better repeatability



(a) Uni-directional positioning: (1) The element is moved to Position A. (2) It is then moved to Position B. (3) It is returned to Position A. Target Position A is approached from the left in both moves.



(b) Bi-directional positioning: (1) The element is moved to Position A. (2) It is then moved past A to Position B. (3) It is returned to target Position A, however, it approaches Target Position A from the opposite direction than it did in move #1.

David Henderson | April 10, 2012 14

When you are trying to define the focus system, resolution and repeatability are two of the first parameters to consider.

© New Scale Technologies

Precision Motion for Focus

Accuracy

- Measured by total error in the system
- For the test data shown: the range from peak of 15 µm on the forward direction curve, to peak of -4 µm on the reverse direction curve, or a total of about 19 µm.

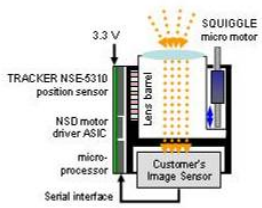


Figure 4: Simplified system diagram

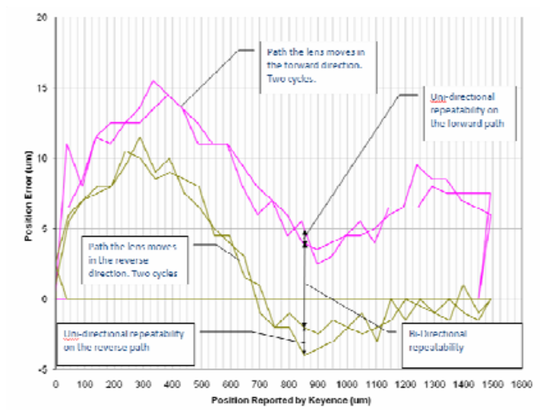
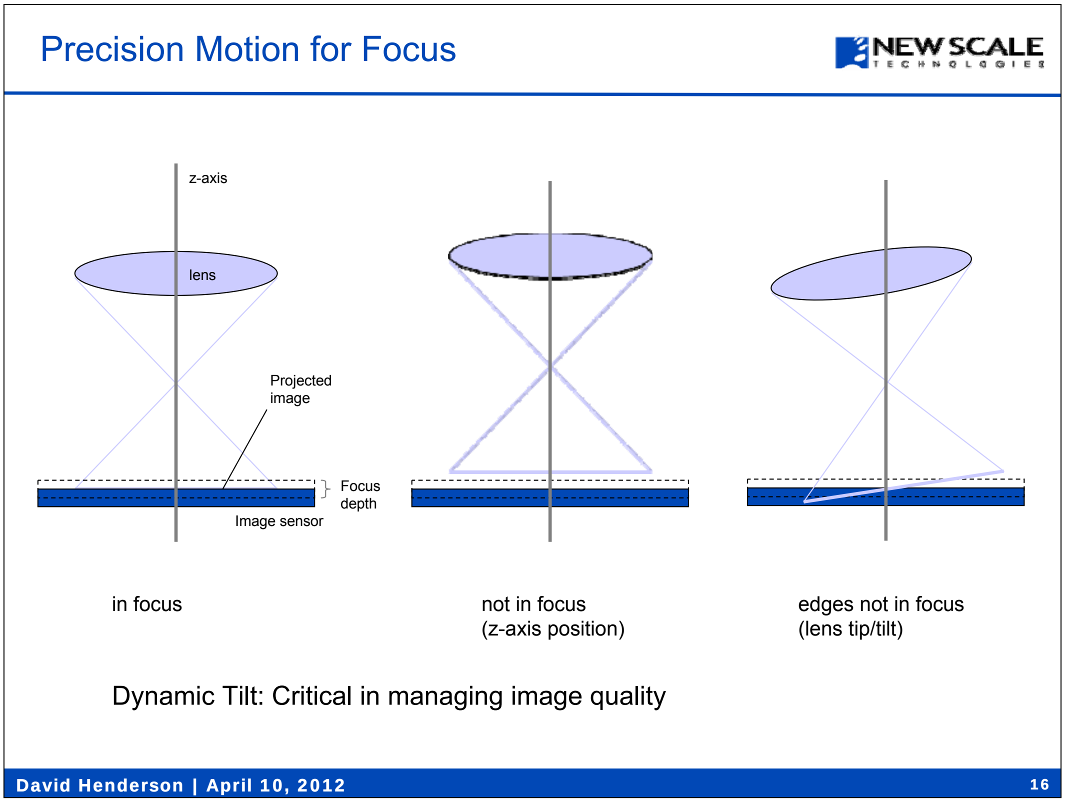


Figure 6: M3-F module repeatability and error measurement results

Accuracy is another consideration: The ability to achieve a certain position relative to an independent standard. It is a reflection of the quality of the position sensor.

© New Scale Technologies



A very important factor in precision is how straight the lens moves, or dynamic tilt. The diagram shows the impact of tilt conceptually. With increasing F# the depth of focus is reduced so sensitivity to tilt is increased. If your tilt is greater than the depth of focus, you'll never have an image that's completely in focus.

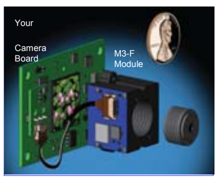
© New Scale Technologies

Smart Motion System for Focus

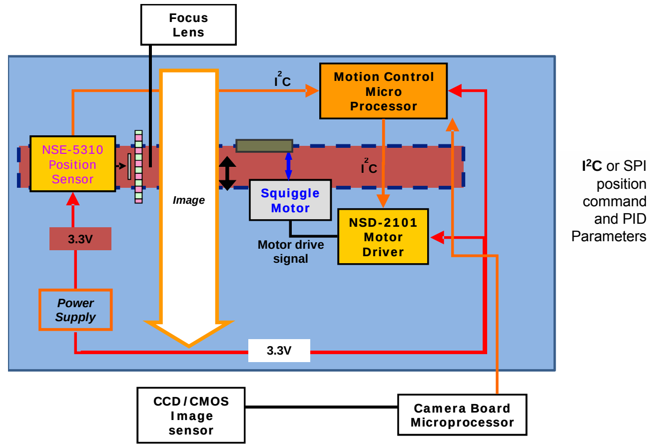
NEW SCALE TECHNOLOGIES

Piezo Motor & NSD2101 Drive ASIC

Linear Encoder: NSE5310



M3-F S-Mount on Image Sensor & Lens



David Henderson | April 10, 2012 17

We’ve discussed smallness and precision. Now, what does it mean to have a smart system?

A smart system includes a motor, position sensor, drive electronics and microprocessor so that for integration into a larger system all that’s required is DC power and digital commands, either by I2C or SPI. But these are high-level ASCII commands such as “move to this position.” So the software integration with the larger system is done very quickly and without need for deep knowledge of how the motion system works.

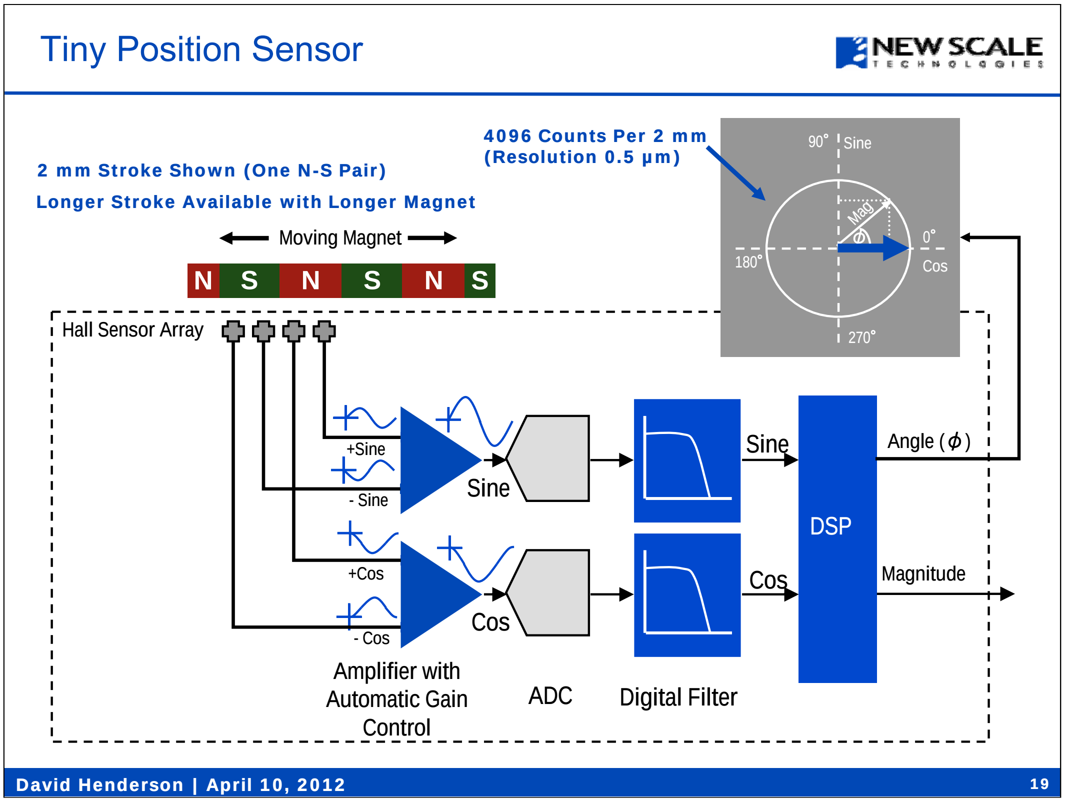
© New Scale Technologies

We talked previously about our UTAF motor which is a simple piezo beam that is ultrasonically vibrated and pushes against the lens to move it.

For the non-consumer space where the mass of the lens is increased from a quarter gram to up to 5 grams, we use our SQUIGGLE ultrasonic piezo motor. The ultrasonic vibrations of the piezo elements cause rotation of the screw, and this causes translation along its axis. The tip of screw has a rounded surface , which pushes against a flat surface on the lens holder to move it. A small spring load is needed to engage the screw thread and maintain contact.

The square fame of the motor is 2.8 x 2.8 mm. As with the UTAF, this motor operates at 2.3 V (we typically recommend operating it at about 3.3 V). It is the smallest linear motor in the world of comparable force and stroke. You can get a sense here that the stroke could be 10-20 mm; we recommend 3-6 mm which is more than enough for most optical applications. It has push force 10-20 grams, so this is a very powerful motor for its size. And because we wrap the ultrasonic vibrations around the thread it's very easy to take submicron steps with this motor even down to 0.5 or 0.2 microns.

© New Scale Technologies



In order to realize a true precise and smart system you need a position sensor of comparable size. The schematic shows an advancement of the hall sensor previously mentioned, which provides long-range measurement with 0.5 um resolution.

We have a moving magnet with north-south poles. A hall sensor array measures changes in the magnetic field of the moving strip. The poles are 1 mm in spacing so that the sinusoidal pattern of the magnetic field detected by the array repeats every 2 mm. In the diagram, everything in the dotted line is on the chip itself. The amplifier and auto gain control mean the device is not sensitive to external magnetic fields. The sin/cos output is digitized and output as a 4096 count digital byte.

If you divide the 4096 count by 2 mm you come up with the resolution. Those of you familiar with optical scales, this is a similar kind of math. The big difference is that in an optical scale the period of one count would be tens of microns, here it's 2 mm. This is the smallest, lowest-profile submicron position sensor available and a perfect complement to the SQUIGGLE motor.

© New Scale Technologies

Small, Precise and Smart Motion for Focus

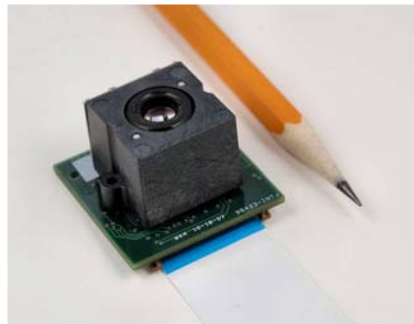
NEW SCALE TECHNOLOGIES

Biometrics – Medical Diagnostics – Surveillance

M3-F Developer's Kit Specifications	
Lens Type (Lens not included)	Accepts M12x0.5mm smaller lenses to M8x0.35 with adapter from your lens supplier
Lens Weight *	< 5 grams
Travel Range	Up to 1.5 mm
Housing Dimension	20 x 22 x 16 mm
Max Image Sensor Area (image sensor not included)	17 x 17 x 1.25 mm (including 1/2" and 1/1.8" formats)
Speed	> 5 mm/s
Resolution	0.5 µm
Hysteresis	None
Repeatability	Uni-directional: +/- 5 µm Bi-directional: +/- 20 µm
Linear Accuracy	± 30 µm
Angular alignment (Static tip/tilt)	<± 1 degree
Angular movement (Dynamic tip/tilt)	<± 0.15 degrees
Static Concentricity	<± 0.25 mm
Dynamic Concentricity	<± 0.02 mm
Input Voltage	3.1 to 3.6 Volts
Input Power **	< 0.5 Watts (5mm/s with 5g mass) < 0.13 Watts quiescent
Temperature /RH ***	5° to 70°C (lower possible) <95% RH non-condensing
Mean Time Before Failure	>2M Cycles (fixed orientation) 500K Cycles (random orientation)
Weight of module (without lens)	5.8 grams
Compliance	CE / RoHS

Key considerations:

- Lens Mass
- Travel range
- Resolution
- Repeatability
- Tip/tilt

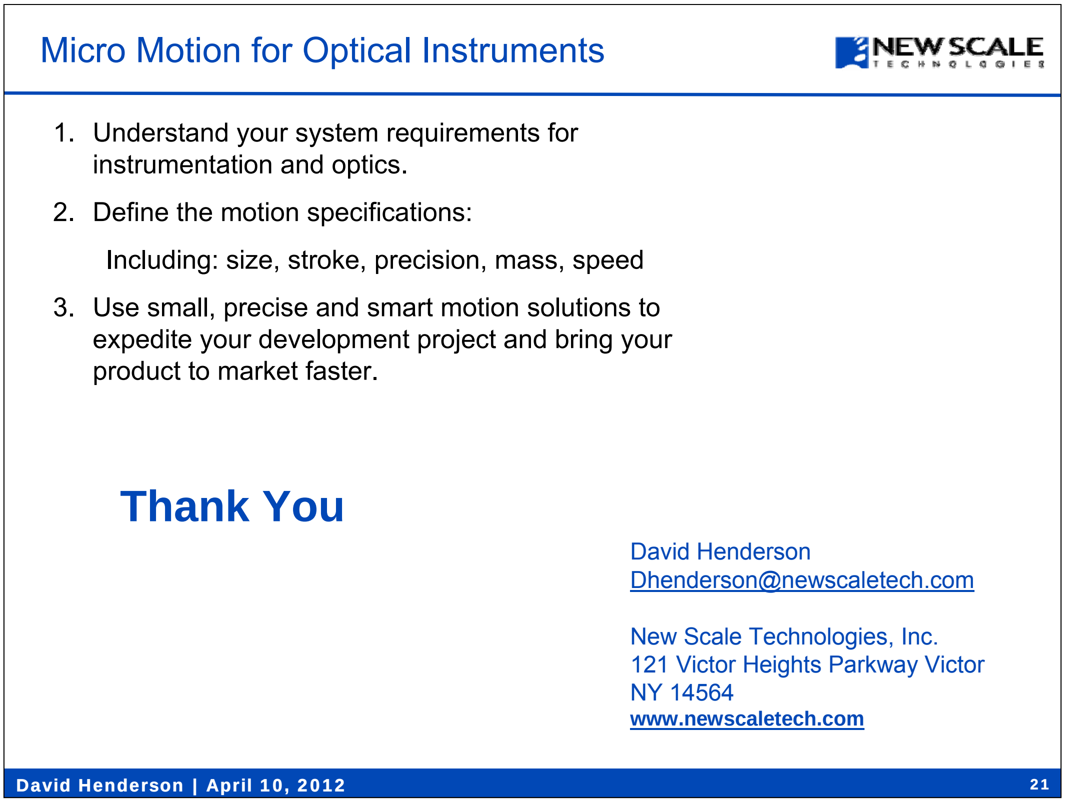


David Henderson | April 10, 2012 20

Everything we've talked about ties together, integrated into the M3-F focus module. This is the product we recommend for non-consumer imaging such as biometric, medical and surveillance applications.

Key considerations and advantages are the ability to move a large lens mass up to 5 grams over a travel range of 1.5 mm with a resolution from the sensor of 0.5 microns, repeatability of +/-5 microns uni-directional or +/-20 microns bi-directional, and angular tip/tilt better than 0.15 degrees. It is an example of a small and precise lens motion system, available today, that leverages the latest technologies derived from smart phones.

© New Scale Technologies



We are experts in motion control and eager to see how our micro motion can be applied to your optical instruments and realize the potential of miniaturization, integration, precision and really smart operation in your device.

© New Scale Technologies