REDUCING DEVELOPMENT TIME FOR MEMS DEVICES

MEPTEC

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Si-Ware Systems

ASIC SOLUTIONS

OPTICAL MEMS TECHNOLOGY

TIMING PRODUCTS

SI-WARE SYSTEMS (SWS) IN BRIEF

Established in 2004 as a design house and IP provider

- Demanding A/M-S & RF solutions with emphasis on timing, sensing and wireless applications

Founded by experts from the IC and MEMS industries

Evolved into a standard products and custom ASIC provider

- 3 distinct divisions
  - ASIC Solutions (ASD): MEMS interface ASICs
  - Timing Products (TPD): all silicon clock oscillator – SCO™
  - Optical MEMS Technology (OMTD): Optical MEMS (MOEMS) based products

Privately held, growing and profitable since inception

More than 90 design and product engineers

Headquarters in Cairo, Egypt and U.S. Subsidiary in Los Angeles, California

MEMS DEVELOPMENTS

Advances in MEMS manufacturing and packaging technologies

More and more companies are doing MEMS

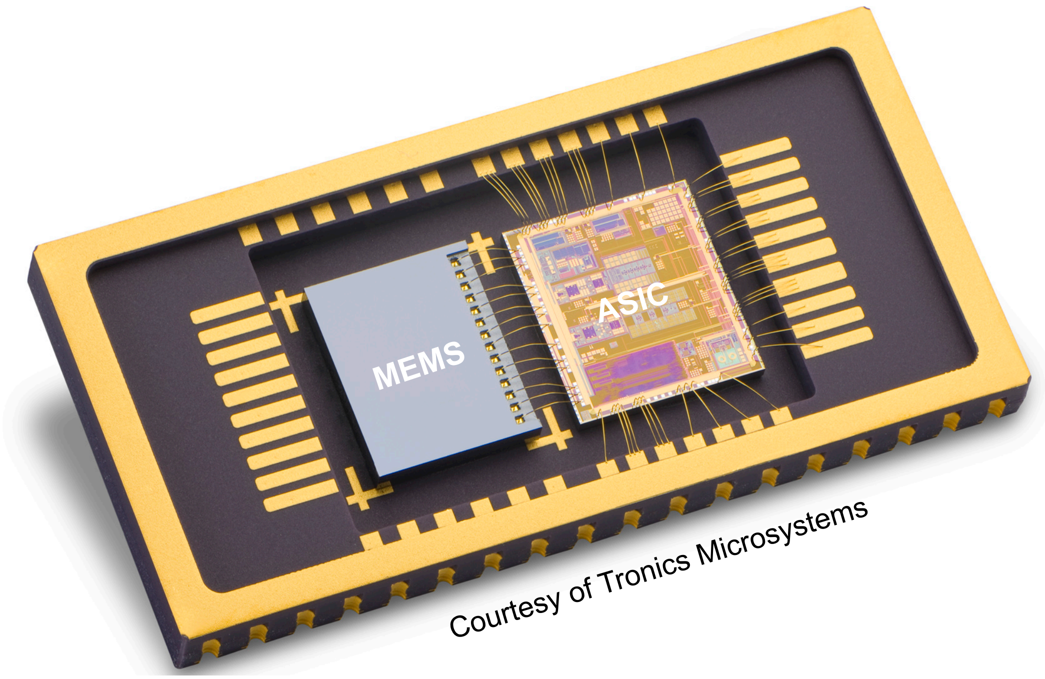
- Established semiconductor companies adding MEMS capabilities
- Many startups emerging with very promising MEMS devices

More access to MEMS + exploding market = increased competition

- Quick development time required
- MEMS development already challenging
- ASIC development requires a solid understanding of the MEMS
  - If MEMS is not validated then relying on models

ASIC in a MEMS Product

MEMS Module = MEMS + ASIC in a Package



Courtesy of Tronics Microsystems

ASIC DESIGN CHALLENGES FOR MEMS

What an ASIC can do for MEMS?

Sense

- C, R, L, resonance frequency → digital output

Actuate

- Precision bias voltages
- High voltage actuation

Compensate

- MEMS and ASIC process
- Voltage and temperature variation
- Nonlinearities
- Trimming and calibration infrastructure → storage (NVM/Flash)

Communicate – Control – Process

- Serial interface to read/write data (I2C, SPI, custom)
- Wireless interface (Bluetooth, ZigBee, ISM)
- Control loops
- Digital post processing

ASIC DESIGN CHALLENGES FOR MEMS

IC Design Expertise Needed

Depending on the performance requirements, but most probably

- Mixed-signal system design and verification
- High resolution data converters
- Precision references
- Low jitter clock generation
- DSP and signal control
- Temperature sensing and compensation techniques
- Power management
  - Voltage charge pump, linear regulators, etc.

MEMS Interfacing Issues

Typical issues arise from un-modeled or unidentified effects by MEMS developers

- Electrical parasitics (capacitance, resistance)
- Parasitic oscillation modes
- Nonlinear effects
- Design parameters temperature dependency of MEMS device
- Non idealities in MEMS manufacturing
  - Alignment mismatch (mechanical coupling, off-axis error)
  - Electrical mismatch (offset capacitance)
  - Quality factor variation
  - MEMS sensitivity variation

Some sensor specs depend on the sensor architecture

- High correlation of MEMS device specs and readout circuitry specs
- Overall MEMS performance is affected by the selected architecture

Many design iterations in MEMS development

- MEMS main parameters can vary from design to design
  - Change in resonance frequency
  - Change in electrical signal ranges
  - Changes in actuation voltage requirements

Many MEMS specs can not be estimated or calculated without testing in the lab

MEMS SENSOR DEVELOPMENT LIFE CYCLE

INERTIAL SENSOR DEVELOPMENT PLATFORM

SWS61111

ASIC	Communication Board	Software
Highly Configurable	USB Powered & Operated	Easy-to-Use GUI

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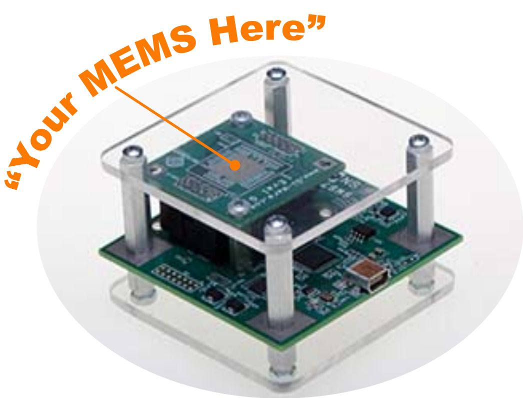

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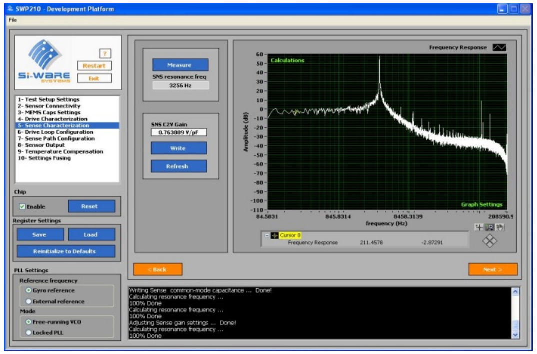
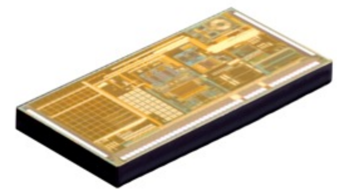


HIGH PERFORMANCE INERTIAL SENSING ASIC

SWS1110



Single-axis MEMS accelerometer and gyro interface

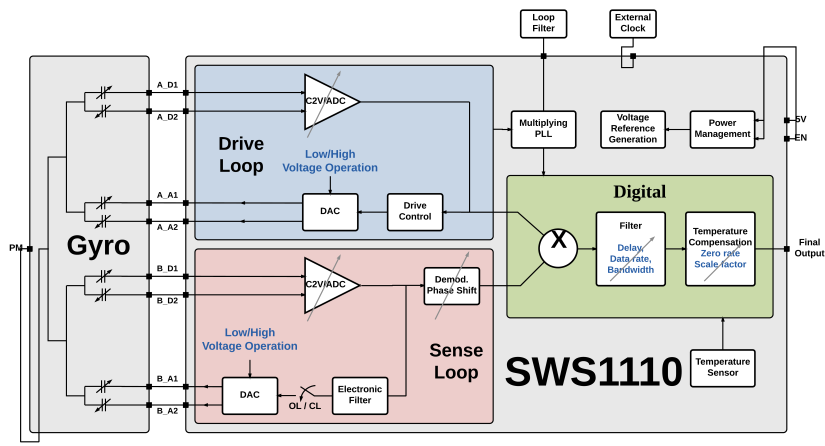
- OL & CL (force-feedback) operation

Highly configurable

- Used successfully with several gyros and accelerometers

Key Features

- Ultra low-noise – achieves noise < 50 zF/√Hz
- Programmable front-end with trimmable ranges
- High performance ADC with 17.5b ENOB
- Programmable actuation voltage (2V up to 8V)
- Full temperature compensation
- 14b temperature sensor integrated
- Proprietary technology to eliminate harmful coupling
- Supports resonance frequency up 30kHz
- Self clocked with low jitter PLL
- Digital output, SPI
- Self test indicator

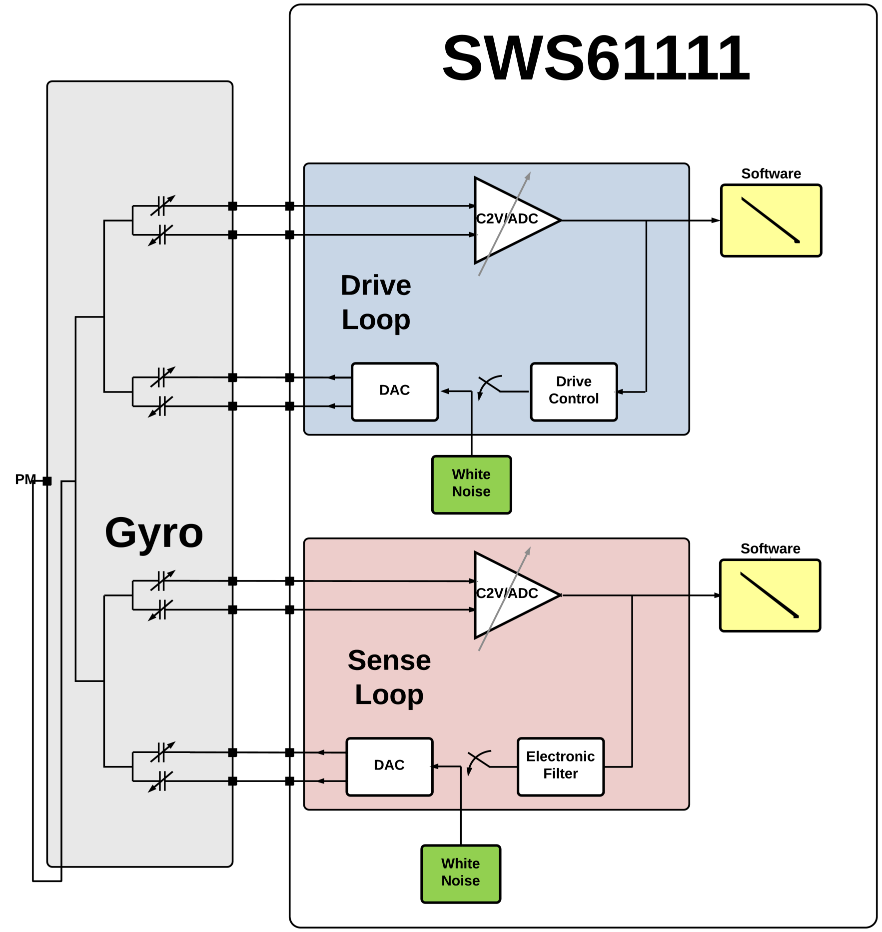


Supports inertial sensors with

- Different drive frequencies
- Different sensitivities
- Different capacitance ranges
- Different loop configurations (OL or CL)

MEMS sensor parameters measured

- Resonance frequencies
- Existing parasitic modes
- Quality factor



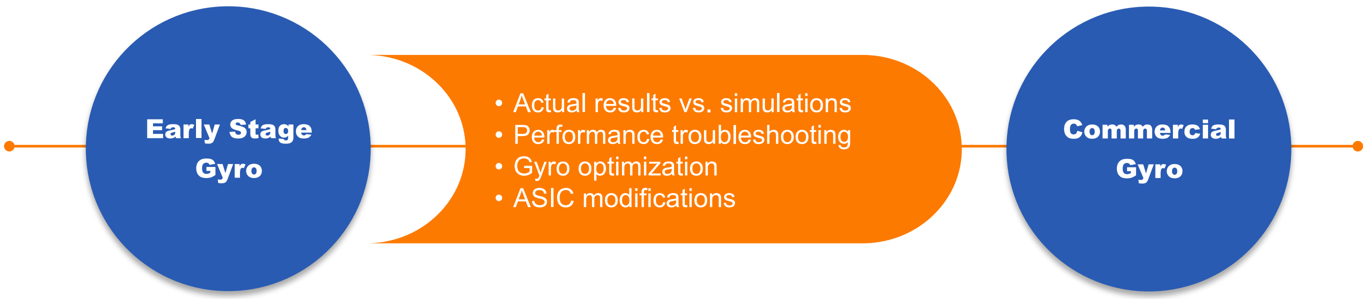
PLATFORM EXAMPLE #1

High Performance Gyro

High performance, single-axis gyro

- Directly matched SWS1110 ASIC

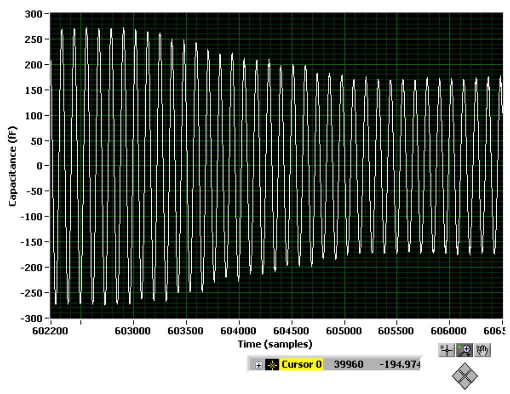
Assess early stage gyro in preparation for final design and commercialization



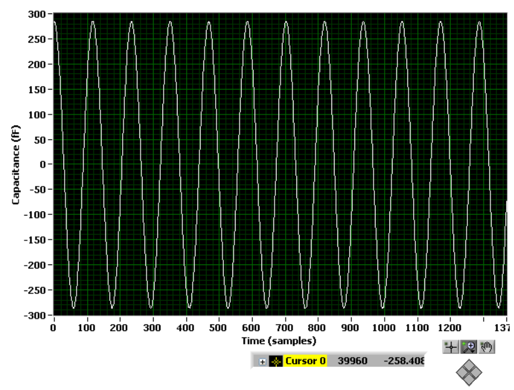
Drive loop and oscillation non-linearity

- A working drive loop helped to identify highest obtainable drive amplitude
- Comparison with simulations

Varying Oscillation at Higher Drive Amplitudes



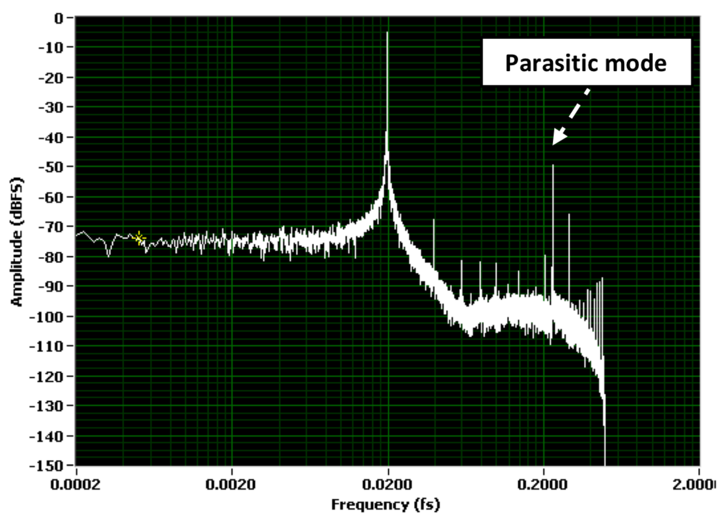
Stable Oscillation at Lower Drive Amplitudes



Sense path characterization

- White noise actuation injected by ASIC
- Parasitic mode of operation was affecting CL operation

Parasitic Mode of Operation



PLATFORM EXAMPLE #2

2-Axis Consumer Gyro

2-axis gyro for Optical Image Stabilization (OIS)

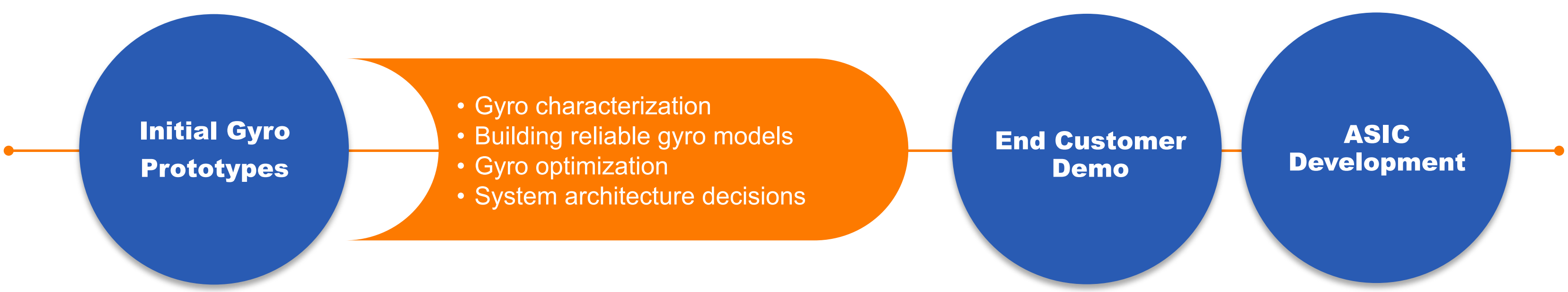
- Small size and low power
- Not a direct match for the SWS1110 ASIC

Had initial gyro prototypes and needed to characterize and evaluate

- Module prototypes needed to demonstrate to customers

Platform approach

- Daisy chained two ASICs together to create a platform that could work with a multi-axis device
  - Master slave configuration



PLATFORM EXAMPLE #2

2-Axis Consumer Gyro

Platform was used along the different phases of development

- Characterize gyro parameters and non-idealities
  - Optimizing and finalizing gyro design
  - Optimizing MEMS manufacturing process
  - Building a complete and accurate gyro model for ASIC development
- Demonstrate complete solution to customers
  - Valuable feedback on system specification
  - Ensures customer satisfaction from first silicon
- Optimizing and validating top level system trade offs
  - Studying different system level trade offs through the wide programmability of the ASIC
  - Studying and optimizing trade offs on the gyro level

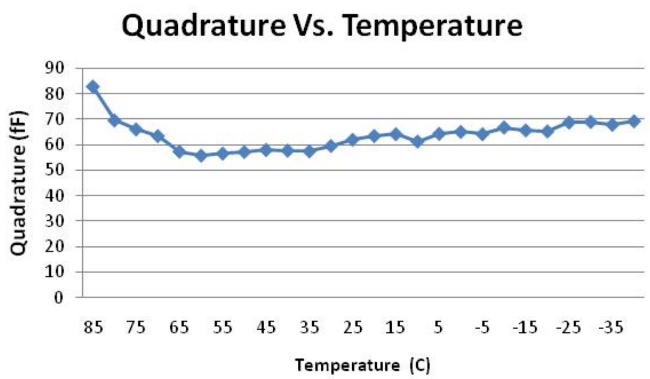
PLATFORM EXAMPLE #2

2-Axis Consumer Gyro

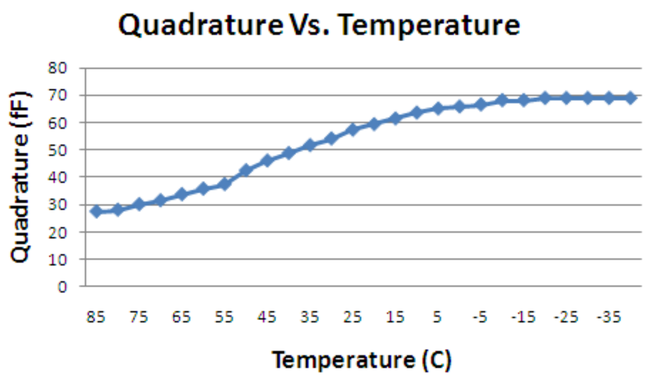
Quadrature error and temperature dependency

- Temperature evaluation indicates large quadrature error variation of yaw axis compared to roll axis
- Architecture of new customized ASIC designed to solve this behavior discrepancy

Temperature Evaluation
Roll Axis – Quadrature Error Signal



Temperature Evaluation
Yaw Axis – Quadrature Error Signal



CONCLUSIONS

Challenges

- MEMS development
- ASIC development for MEMS devices
- MEMS + ASIC as a final product

Time to market is critical

Capabilities needed in parallel

- MEMS evaluation and characterization
- Electronics development

Platform approach with validated electronics drastically reduces development time

Q + A

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Si-Ware Systems

ASIC Solutions

Optical MEMS Technology

Timing Products