

Mobius Current Sensors

Higher Functionality, Lower Cost



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This presentation was delivered at the Vendor Showcase at Metering Europe 2005 in Barcelona on 22nd September 2005.

Summary

- Market trends in static meters
 - What this means for current sensors
- Introduction to Mobius current sensor
 - Construction
 - Performance
 - Costs
 - Integration issues
 - Applications
- Current sensor comparisons
 - CTs, shunts, Mobius
- Integration of Mobius into iCon in the USA

This is an outline of the contents of this presentation. We look at the market trends that are forcing meter manufacturers to re-visit their designs, and then present the Mobius sensor as a solution able to meet these new requirements. We compare Mobius with the existing mainstream current sensing technologies, and finally showcase Mobius inside Sensus Metering System's iCon meter family.



Trends in Static Energy Meters

- Ability to measure accurately at lower currents
 - “Standby” power levels – 30 to 50W
- Ability to measure at higher currents
 - Higher capacity service
- Increased accuracy
 - Gain and phase stability over temperature
 - Better linearity and dynamic range
- Better tamper tolerance or detection
 - 2-wire current measurements – 2 sensors needed
- Cost competition

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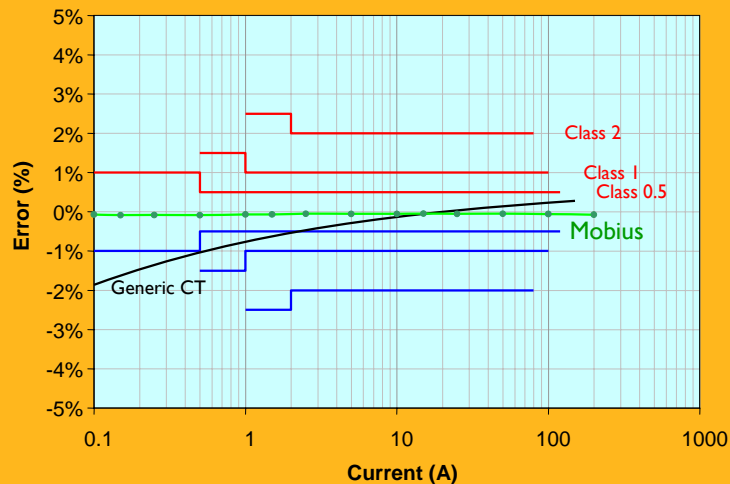
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From our contacts in the industry, these are the trends that we see going forwards in static metering. There has been a steady growth in the standby power consumed in residential services (this is the power consumed by TV's, videos, HiFi's, PC's etc when in standby mode). This falls below the threshold that current direct-connected IEC meters are certified for accuracy, yet can represent many hundreds of kWh consumption annually.

At the other extreme of the meter's performance, we see an increasing demand for meters with an extended maximum continuous current rating, caused by the increase in residential services such as air-conditioning, high-power electric showers, electric cooking appliances, etc. We also see increasing requirements for higher basic accuracy meters, which demands better linearity and dynamic range of the sensor. In certain markets, tampering is prevalent, and tamper-resistant sensors are needed, as well as the ability to measure both currents in 2-wire services to detect tampering. Finally, there is continuing price pressure, so all these added features need to be delivered without adding significant cost to the meter.

Trends in Static Energy Meters



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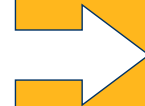
Standby power is 0.1-0.2A typically, falling outside the class 2 and class 1 accuracy specifications.

The accuracy limits are: class 2 (20(80)), class 1 (10(100)), and class 0.5, following the proposed OIML IR-46 draft for whole-current meters.

The black curve shows the typical uncorrected performance of a “generic” CT sensor. The curvature of the response is as a result of the magnetisation current required to excite the magnetic material in the core. It clearly has good enough performance for a class 2 meter. For class 1 it can meet the requirements, but some care is required. For class 0.5, this particular CT is starting to struggle, and some form of linearisation or correction is required. The data for Mobius (green line/dots) is real, measured data on a 200A Mobius sensor, and you can see that the sensor comfortably exceeds the class 0.5 requirements (in fact, as we’ll see later a whole additional order of magnitude performance at low currents).

What is Mobius ?

- Mobius is an implementation of a Rogowski coil
 - Inherently linear - no magnetic material
 - DC field and current immunity
 - Galvanic isolation



Rogowski coil:

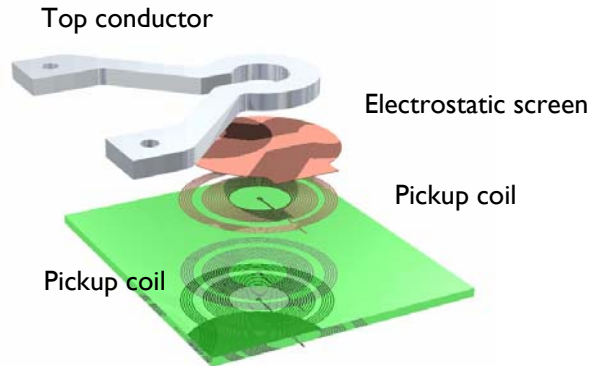
- Requires precision manufacture
- Susceptible to interference
- Requires magnetic shielding

Mobius:

- Precision 'for free' in PCB
- Low susceptibility to interference
- No magnetic shielding needed

Traditional Rogowski coils are doughnut-shaped windings and, when made exactly to specification, are sensitive only to current that flows through the aperture, and not to current that does not pass through the aperture. Making a traditional Rogowski coil is notoriously hard, requiring expensive precision manufacture. In practice, it is very hard to achieve the ideal performance, and Rogowski coils traditionally suffer from susceptibility to AC magnetic fields (i.e. they respond to current that does not flow through the aperture), requiring the use of shielding to achieve the required immunity. Mobius is different – we think of it as a Rogowski coil, since it has the same di/dt response, and all the same benefits, but it is a unique and patented planar implementation made using circuit board coils. Such coils achieve the precision of placement needed for magnetic field immunity, but without the costs. The designs therefore have minimal susceptibility to external AC fields, and consequently no costly magnetic shields are needed.

Mobius PCB Construction



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The Mobius sensor construction is very simple. Current flows through a conductor, usually made of copper. The exact shape can be customised to suit individual requirements. An electrostatic screen layer separates the conductor from two pickup coil layers in the PCB. These coils are designed using our know-how and IP to be sensitive only to current flowing in the top conductor, and immune to other AC fields.

Mobius: Key Features for Metering



- PCB coils, separate main conductor
 - Basic sensor can be stand-alone
 - Signal conditioning can be integrated with sensor
 - Sensor can be integrated into meter circuit board
 - Customisable for:
 - mechanical fit
 - electrical/isolation requirements
- Ideal for higher currents
 - 20A rms to 320 A rms
 - Good overload tolerance (35x for 100ms)
 - Limited only by conductor cross-section
- Proven in 200A ANSI metering application
 - Sensus Metering Systems iCon family



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Mobius is typically customised to suit the application, rather than used as a separate component. The same circuit board that forms the sensor coils can also be used for other parts of the meter. The layout of terminals or the enclosure requirements generally drive the mechanical layout. The design is well proven in the ANSI market (see inset picture).



Mobius: Cost and Performance



- Uses standard PCB layout rules and materials
 - Low cost, standard processing
- Excellent thermal stability (-40° to +85°C)
 - 10 ppm/°C temperature coefficient
- Excellent bandwidth
 - 25 kHz (3dB) typical
- Low induced emf from external AC fields
 - Complex, optimised layout of balanced coils
 - Exceeds requirements of IEC 62053-21/22
 - Immune to both uniform and non-uniform AC fields
 - Adjacent sensors possible for polyphase meters
 - 80 dB isolation at 30mm separation

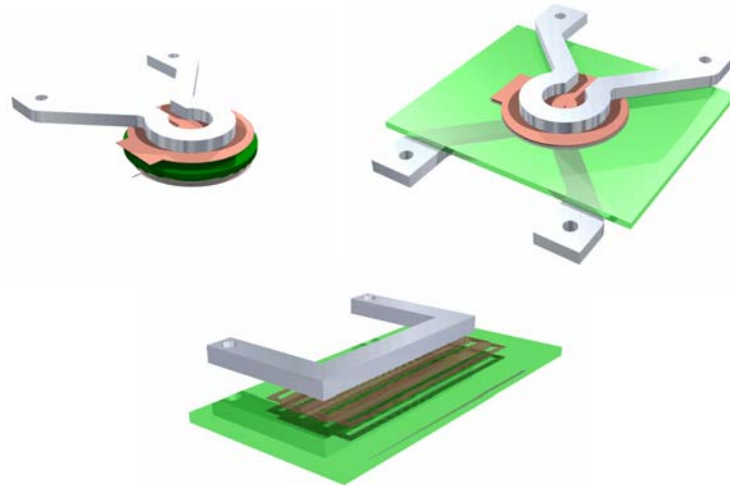
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Mobius is made using standard PCB processing, with standard design rules. We have used a number of different PCB suppliers, with no significant issues. In large volumes, typical circuit board costs just a few cents per square centimetre, so you can see that the fundamental cost of the sensor itself is very low. Temperature performance is excellent – usually an order of magnitude better than other parts of the meter – and the wide bandwidth means that harmonics are accurately recorded. The AC field immunity comes from the optimised layout of the sensor coils. The layout is deterministic, calculated by Sentec using our know-how and expertise, and designs can achieve immunity both to uniform AC fields, and to non-uniform fields that result from aggressive attempts to tamper. Designs can also achieve excellent immunity to adjacent sensors – typically 4 orders of magnitude at 30mm separation.

Mobius: Configurations



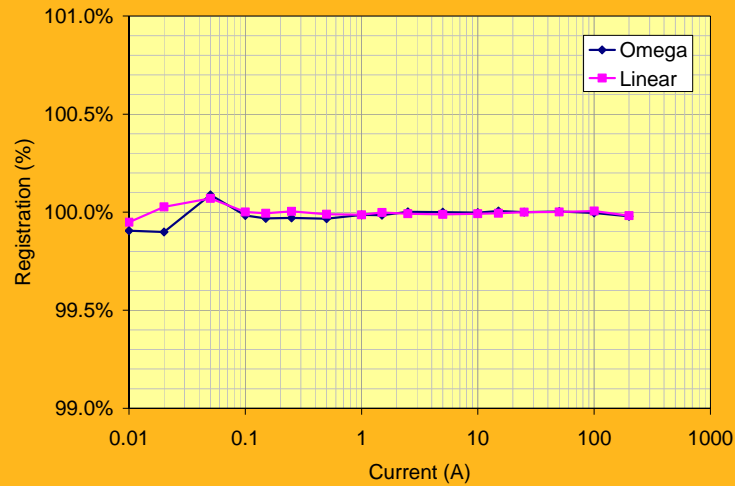
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Mobius can be configured in many different forms – not just the omega design, but also linear designs, and Sentec is able to customise the design to specific requirements.

Linearity (200A full scale)



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Mobius performance graph: note that the horizontal scale extends from 10mA upwards, and the extent of the vertical scale is only $\pm 1\%$ (previous graph was $\pm 5\%$). You can take it from this superb performance that Mobius will not have any inherent problems meeting the accuracy requirements for any metering application – performance is generally limited by the silicon used to interface to the sensor (and other design constraints of the meter).

AC Magnetic Field Immunity





- “Achilles Heel” of other Rogowski coil solutions
 - Good immunity requires high precision and cost
- Achieving immunity is the core of the Mobius IP
 - Optimised coil design based on physics and modelling
 - Uniform and non-uniform (gradient) fields rejected
- Small effects with 0.5mT AC field (62053-21)
 - 7mA typical error
 - Corresponds to 0.07% error for a 10-100 A meter
 - IEC limit is class accuracy
- Even a shunt can be influenced at this level
 - Loops formed in connecting wires are susceptible

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AC field immunity is a subject of some interest, because traditionally it has been the weak point of Rogowski Coil designs – hence it is worth re-iterating the performance of Mobius in this respect. The immunity that Mobius achieves is that the heart of the patents and know-how that cover the sensor design. The effects under the standard IEC tests are substantially lower than permitted, and comparable to the levels of coupling that you see in shunt-based meters: a 4x4mm square loop connecting to the shunt sense connections will couple a comparable signal level to the Mobius sensor, and with high-current shunts, it is very hard to achieve such a small enclosed loop area.



Performance vs. IEC 62053-21/2

- Half-wave (DC and even harmonics)
 - No effects – performance limited by signal processing
- Phase fired control (odd harmonics)
 - Excellent performance – wide sensing bandwidth
- Sub-harmonics
 - Performance limited by signal processing
- Continuous DC induction
 - No effect
- 0.5mT AC induction
 - Significantly exceeds specification

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This slide covers the main IEC tests that are not part of the ANSI test requirements that Mobius has passed in North America – Mobius will have no issues passing these tests (though we have not formally tested an IEC design to date).

Signal Conditioning



- Integrator to calculate current from di/dt
 - Op-amp based analogue integrator (poor stability)
 - ADC and digital integrator (high accuracy)
- Energy metering IC's
 - E.g. Analog Devices ADE7753/8/9
 - Direct connection to sensor – digital integrator
 - Real, reactive and apparent power
 - E.g. ST Microelectronics STPM01
 - Direct connection to di/dt sensor
 - Second channel for tamper detection
 - E.g. Teridian (formerly TDK) 71M6511
 - Integrated MCU
 - Customisable for direct connection to di/dt sensor



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Five years ago, the only solutions for Rogowski-like meters were either to use an analogue integrator (which can be problematic for ultimate accuracy, since the capacitor value used in the integrator affects the meter accuracy), or to use an ADC and implement a digital integrator in a signal processor (note – actually this is not hard – the integrator is can be implemented using a simple first-order IIR low-pass filter at ~ 1 Hz). However, in the last three years, Analog Devices has provided a number of chips that directly connect to Mobius, and this year, both ST and Teridian have released designs as well. There is now a significant choice of solutions, and we expect more manufacturers to follow.



Applications and Benefits

- High-accuracy energy metering
 - Accuracy class 0.5% and 0.2%
- Isolated current sensing
 - Arbitrary isolation (e.g. 6kV) possible
 - Multiple current channels (e.g. anti-tamper)
 - Polyphase metering
- Cost-sensitive current sensing
 - Avoiding cost of CT and associated bus-bars
- Compact current sensing
 - Planar construction allows small sensor volume

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Mobius is particularly beneficial for higher accuracy, or when isolated/multi-channel sensing is needed, or to beat the costs of higher-end CT solutions. It can be made small and compact, allowing for reduced mechanical costs.



How do Sensors Compare ?



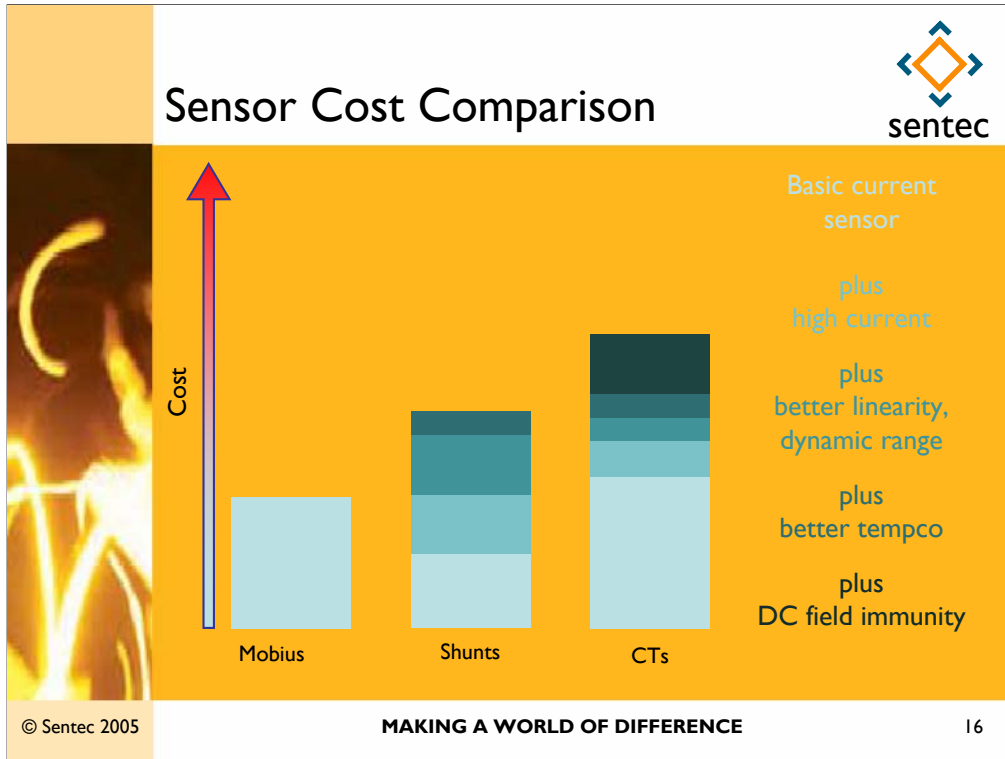
- CT cost increases with
 - Higher current (larger core)
 - Better linearity and dynamic range (core material)
 - Better tempco (core material, electronics)
- Shunt cost increases with
 - Higher current (more material)
 - Wider dynamic range (better electronics)
 - Better tempco (better alloy and construction)
- Mobius
 - Linearity and tempco inherently good
 - Cost inherently low
 - Minimal cost impact for higher maximum current
 - Proven dynamic range

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As we increase the current rating, linearity and dynamic range requirements, and temperature performance, CT's and shunts both increase in cost. Mobius gives us linearity and low temperature coefficient for free, and higher currents are achieved simply by using a thicker conductor.



For a basic 40 or 60A class 2 meter, clearly shunts are the lowest cost solution. Mobius and CT's are more costly, though roughly comparable with each other. However, as higher currents or better performance are required, cost is added to the shunt and CT solutions, whereas Mobius already delivers those features in its standard form. For higher performance applications, Mobius clearly has the lowest cost.

Mobius and *ICON*[™]



- Sensor in Sensus Metering System's iCon[™] meter family
 - Introduced in 2002
 - Single phase and polyphase variants
 - Exceeds ANSI C12.20 class 0.2 accuracy
 - Two board, cost competitive design
 - Approved at over 50% of US privately owned utilities
 - Over 3.2 billion hours of service in US so far
- Mobius allows market leading open architecture for AMR integration and upgrades
 - Compatible with nearly all AMR solutions in the US



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Mobius is the sensor in the class 0.2 ANSI-certified iCon meter. The design is field proven, and allowed Sensus to enter the electric meter market three years ago and immediately take market share. This market place is very demanding in terms of performance, with class 0.2 residential static meters becoming a standard utility requirement.

iCon Development



sentec

- Partnership with Sensus
 - Since 1999
- Developed whole product family
 - Residential 2/3 wire single phase
 - iCon APX C&I meter
- Sentec provides
 - IP
 - Know-how
 - Engineering services



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Sentec has worked with Sensus on the development of both residential single phase meters, and most recently on C&I polyphase meters (shown in the illustrations). There is no risk in working with the Mobius sensor – it is already part of a successful metering product, and Sentec is very experienced in integrating Mobius into electric metering applications, with expertise in related areas such as wide-range switch mode power supplies, and meeting stringent EMC requirements. We also have considerable expertise in manufacturing equipment such as resistive welding (for attaching the bus-bars to the circuit board) and precision automated calibration methods.

Mobius Current Sensor Summary



- Very high accuracy AC current sensor
 - with wide dynamic range
 - with superb rejection of EM interference
- Utilises low cost manufacturing techniques
 - Printed circuit board coils
- Cost-effective integration into electric meter
 - Already proven in ANSI market
- Now available for IEC market applications

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Mobius is proven in the ANSI markets, meeting the most demanding accuracy requirements. As well as its inherent low cost, it also eliminates and supply-chain insecurity that might arise from, for example, sourcing a CT, since the sensor itself is simply part of the circuit board design in the meter, and the specific design is owned by the meter manufacturer.

Enquires for Mobius should be directed to:

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