Power Monitoring for Connected Lighting Systems

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Agenda

- **Metrology Evolution**
- **Power-Monitoring Implementations**
  - System Characterization
  - Software
  - Hardware
    - Zero-Cal
  - Distributive Scheme
- **Power-Monitoring Examples & Uses**

Metrology Evolution

Electric Utility Meters

- Strict/high-end requirements
- Government regulation
- Standards (e.g., IEC62053-21/22)
- High volume

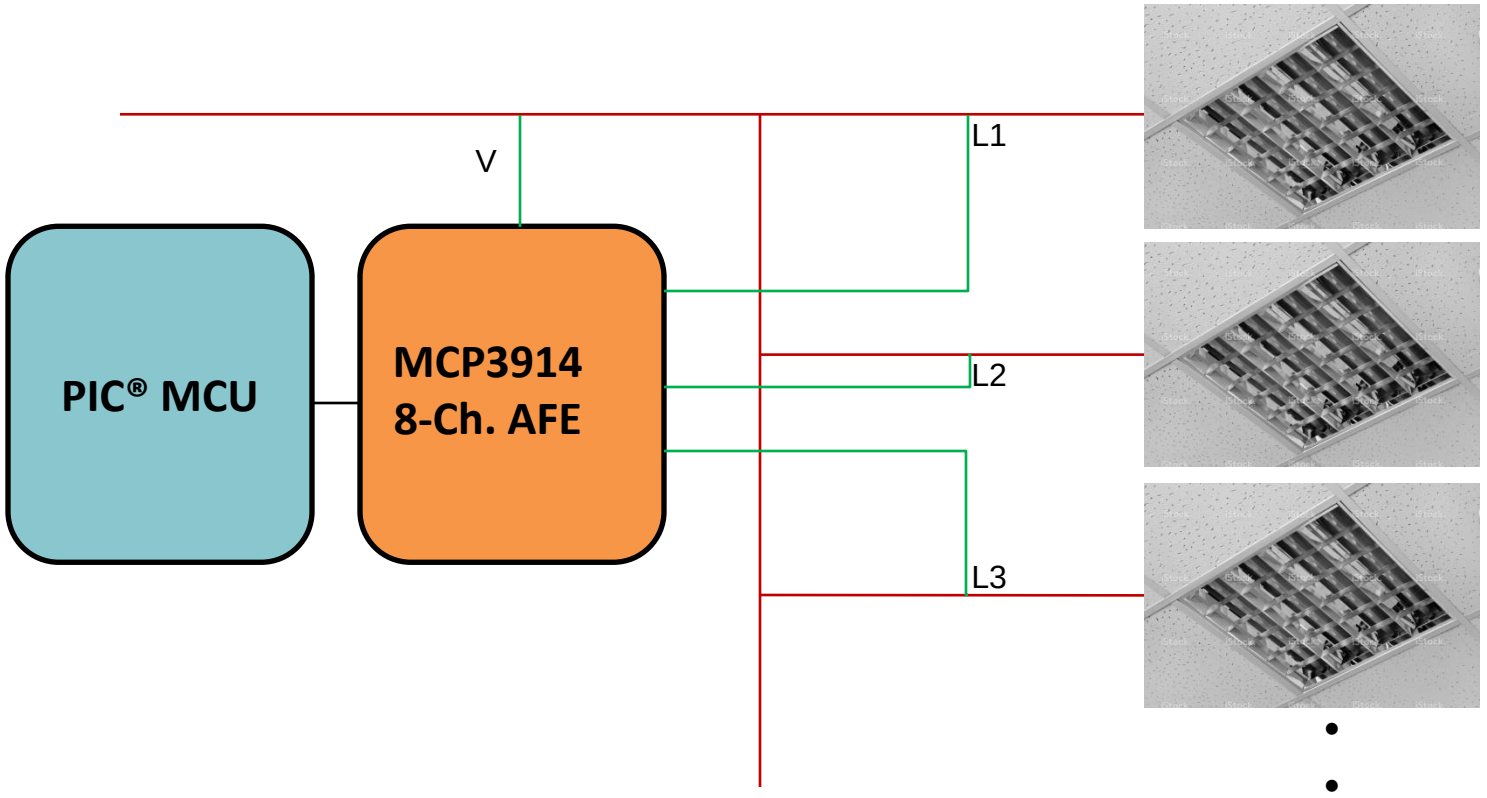
Power Monitoring

- Provides more granular data
- Dependent on connectivity
- Moving to utility-grade or revenue-grade accuracy

Power-Monitoring Implementations

Distributed Power-Monitoring Scheme

- A centralized power-monitoring unit can monitor multiple loads (i.e., lighting bays, room, floor)



Distributed Power-Monitoring Scheme

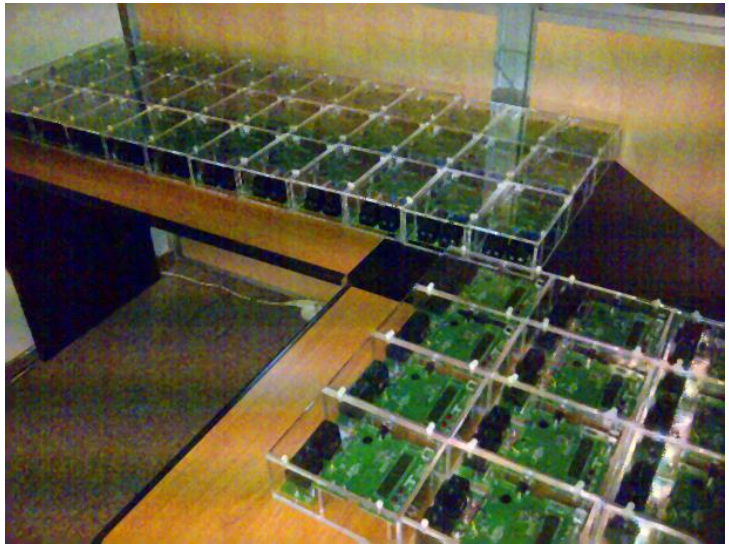
- **Distribution Point**
  - AFE provides input up to 8-Ch.: 1 voltage & up to 7 current loads
  - Paired MCU does the calculations
  - Implementation cost is thus divided among multiple units
  - Less granularity

Characteristics	
Accuracy	0.1%
Hardware	<$5.50 / 7
Software	Moderate
Calibration	1

System Characterization

- **Characterize a set number of production units**
- **Estimate power usage based on current conditions**
  - Rough idea of power usage
  - Sensitive to changes in production

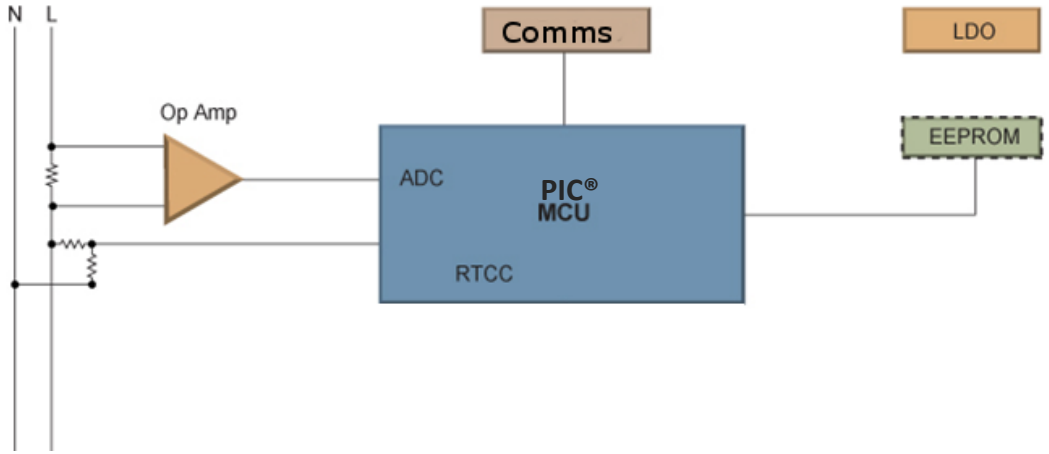
Characteristics	
Accuracy	10-20%
Hardware	No added hardware
Software	Low
Calibration	None



Software Based

- **System microcontroller's ADC can be used for power measurement**
  - Requires additional MCU resources
  - Requires signal conditioning
  - Provides good to moderate accuracy, dependent on the effort

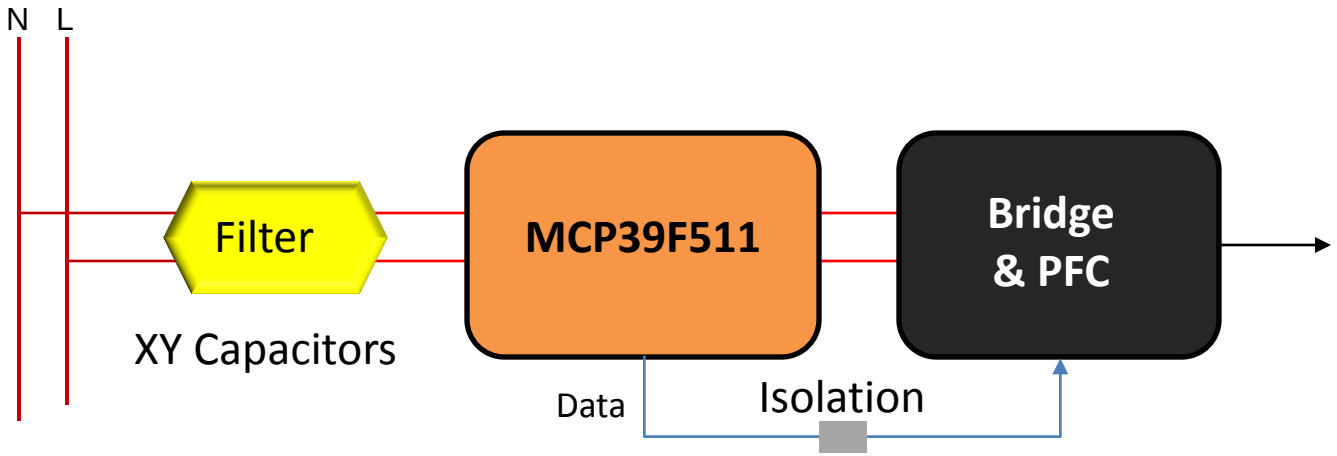
Characteristics	
Accuracy	1% to 5%
Hardware	<$0.80
Software	Complex
Calibration	1 to 2 point



Hardware Based

- **Dedicated power-monitoring IC**
  - Provides all power calculations
  - Event monitoring
  - Best accuracy
  - Zero-cal can significantly reduce production cost

Characteristics	
Accuracy	0.1% to 2%
Hardware	<$1.40
Software	Low
Calibration	1 to None

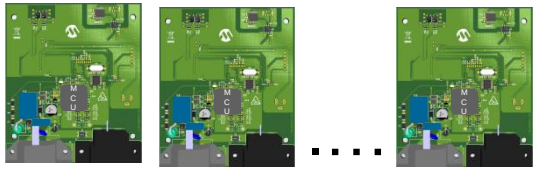


What a Power-Monitor IC Offers

- **Revenue-Grade Accuracy**
  - Active, reactive and apparent power
  - Active and reactive energy accumulation
  - True RMS current, RMS voltage
  - Line frequency, power factor
  - Zero crossing detection pin
  - Event monitoring

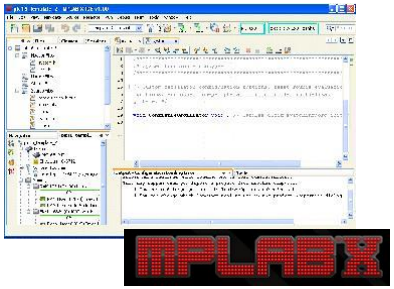
Zero Calibration

1. X pre-production units built and calibration data recorded

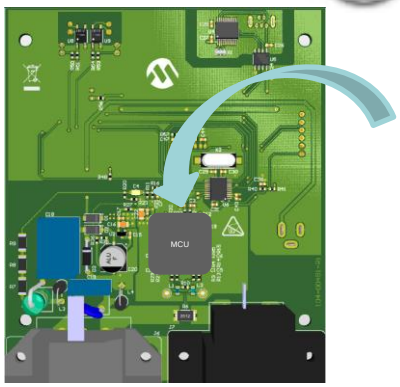


2. Determine **mean** values then Cal values

3. Cal values incorporated into application code Or QTP part #



4. Program application software into MCU
   A) In-circuit
   B) Pre-programmed by Microchip (QTP)



5. Ship to your customers

Example Zero Cal.

Set-up: 1% shunt, 1% voltage divider, internal oscillator

UNIT #	VOLTAGE	CURRENT	POWER	FREQUENCY	% Error - Voltage	% Error - Current	% Error - Power	% Error - Frequency
800	220.1	5.0187	1107.76	50.28	0.04545	0.374	0.705454545	0.56
801	220.1	4.9691	1097.03	49.824	0.04545	-0.618	-0.27	-0.352
802	220.7	5.0185	1110.8	49.86	0.31818	0.37	0.981818182	-0.28
803	219.9	4.9493	1091.59	49.772	-0.04545	-1.014	-0.764545455	-0.456
804	219.7	4.9811	1097.31	50	-0.13636	-0.378	-0.244545455	0
805	220.1	5.0278	1110.03	49.964	0.04545	0.556	0.911818182	-0.072
806	219.6	4.9405	1088.32	49.894	-0.18182	-1.19	-1.061818182	-0.212
807	219.9	4.9594	1093.91	49.876	-0.04545	-0.812	-0.553636364	-0.248
808	219.7	5.0359	1109.59	49.93	-0.13636	0.718	0.871818182	-0.14
809	219.6	4.9602	1092.46	49.93	-0.18182	-0.796	-0.685454545	-0.14
811	220.1	5.0359	1093.91	49.876	0.04545	0.718	-0.553636364	-0.248
813	219.4	5.0005	1100.32	49.93	-0.27273	0.01	0.029090909	-0.14
815	219.8	4.9853	1099.1	50.07	-0.09091	-0.294	-0.081818182	0.14
817	218.6	4.9339	1081.59	49.548	-0.63636	-1.322	-1.673636364	-0.904
819	219.8	4.9981	1102.02	49.912	-0.09091	-0.038	0.183636364	-0.176
821	220.8	4.9969	1106.59	49.756	0.36364	-0.062	0.599090909	-0.488
823	219.9	4.9867	1100.01	49.964	-0.04545	-0.266	0.000909091	-0.072
				Min	-0.68182	-1.76200	-1.67364	-0.90400
				Max	0.72727	0.86000	1.12273	0.56000
				Average	0.00423	-0.43953	-0.17571	-0.15433

Results: <2% on 50 units, potentially <1.5% if optimized

Tradeoff Comparison

Characteristic	Distributed	System Characterization	Software Based	Hardware Based
Accuracy	0.1%	10% to 20%	1% to 5%	0.1% to 2%
Granularity	Medium	Low	High	High
Hardware	<$5.50 / 7	None	<$0.80	<$1.40
Software	Moderate	Low	Complex	Low
Calibration	1	None	1 to 2	1 to None

Power-Monitoring Examples & Uses

LED Lighting

- **Energy reporting for intelligent lighting systems, calculating energy costs and system optimization**
- **Integrated DALI protocol into our Power-Monitoring IC**

Commercial Ovens

- Precision heating to cook rapidly and consistently over thousands of cycles
- Allows them to adjust as power conditions change and as equipment ages

HVAC OEMs

- Provide end users with power-usage data to enable informed decisions
- Also, to prove their efficiency because competitors would lie!

Server Power Supplies

- Very fast voltage sag indication is needed to switch server loads
- Need high-accuracy monitoring, even at low-load conditions

Smart Plugs

- Smart plugs specifically designed to monitor coffee machines
- By power/current profile, they can determine cup size, coffee style, etc.

Conclusions

- Power-monitoring technology has become accessible
- Energy reporting and connectivity are key to intelligent lighting systems
- There are uses for power monitoring outside of reporting