Unipolar Resonant Capacitive Power Transfer For Surface—Powered Cyber-Physical Systems

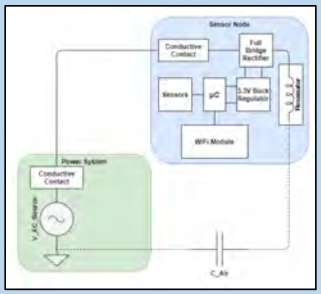
Jonathan Dean, Michael Coultis, Tyler Marcrum, Brandon Nieman, Dr. Matthew Pearce, and Dr. Charles Van Neste

ABSTRACT

Sensors are a critical part of many Cyber-Physical Systems (CPS), and providing power to them is becoming increasingly challenging due to routing constraints. Wireless Power Transfer (WPT) can offer solutions that reduce the routing constraints, but many wireless power transfer approaches are complex, not scalable, or are not feasible for continuous power delivery to multiple sensors. We propose an efficient, inexpensive, simple, and scalable method for continuously providing power to sensor nodes using Quasi-Wireless Capacitive (QWiC) power transfer. QWiC power transfer allows for power to be transferred capacitively or over a conductive surface, simplifying routing constraints and transmitter complexity by removing the need for a dedicated transmitter. In this experiment, we demonstrate surface powered sensor nodes with a peak efficiency over 68% and multiple sensor nodes being powered over a single surface.

DESIGN

Figure 1. Sensor Node Design[2]



EXPERIMENT

Figure 2. Prototype Sensor Node[2]

Figure 2. Second Sensor Node Prototype

Figure 3. Communication Diagram

Figure 4. Third Sensor Node Prototype[3]

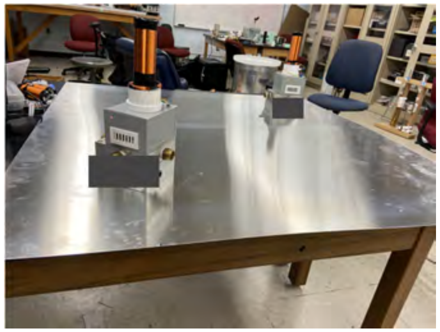


Figure 5. QWiC Efficiency Calculation

$$\eta = \frac{P_{Load}}{P_{Source} - P_{Rsource}}$$

Results

The QWiC Efficiency is calculated by removing the supply loss from the system efficiency as shown in Fig. 5. The QWiC Efficiency for the first and second prototype sensor nodes are shown in Fig. 6 and Fig. 7.

Figure 6. First Sensor Node Efficiency[2]

	Single-Contact
QWiC Efficiency	52.6%
Rectifier Efficiency	46.6%
DC/DC Converter Efficiency	65.5%

Figure 7. Second Sensor Efficiency

	Single-Contact (Source)	Single-Contact (Load)
Frequency	4.424 MHz	4.424 MHz
Voltage (rms)	22.9 Vrms	28.2 Vrms
Current (rms)	132 mArms	141 mArms
Phase	-39°	-73°
Power (ave)	2.35 W	1.03 W
Resonator Loss (ave)	0.8712 W	-
QWiC Efficiency	69.6%	-

The third prototype sensor nodes are operating together on the same plate. The efficiency shown in Fig. 8 is the total system efficiency, as it does not take into account losses generated by the plate's self-capacitance or the loss from the source impedance.

Figure 8. Second Sensor Efficiency[3]

	Source	Load 1	Load 2
Frequency	5.4 MHz	-	-
Voltage	75 Vrms	9 Vrms	17.4 Vrms
Current	640 mArms	285 mArms	162 mArms
Phase	-44°	58°	-32°
Power	5.451 Wrms	1.359 Wrms	0.955 Wrms
Efficiency	42.4%	-	-

CONCLUSION/FUTURE WORK

QWiC has been demonstrated as a simple, scalable, and potentially efficient method for providing continuous power to multiple CPS at once. Power factor correction will allow the efficiency to be improved. The resonator (helical coil) size can be smaller in the future or can be changed to a flat-spiral coil. In addition, the resonator could have tuning capabilities added to set the resonant frequency to a desired frequency.

REFERENCES

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[3] Dean, J., Nieman, B., Marcrum, T., Pearce, M., & Van Neste, C. (2021). Unipolar resonant capacitive power transfer as a method for powering wireless sensor nodes. Unpublished Manuscript, Tennessee Technological University.

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