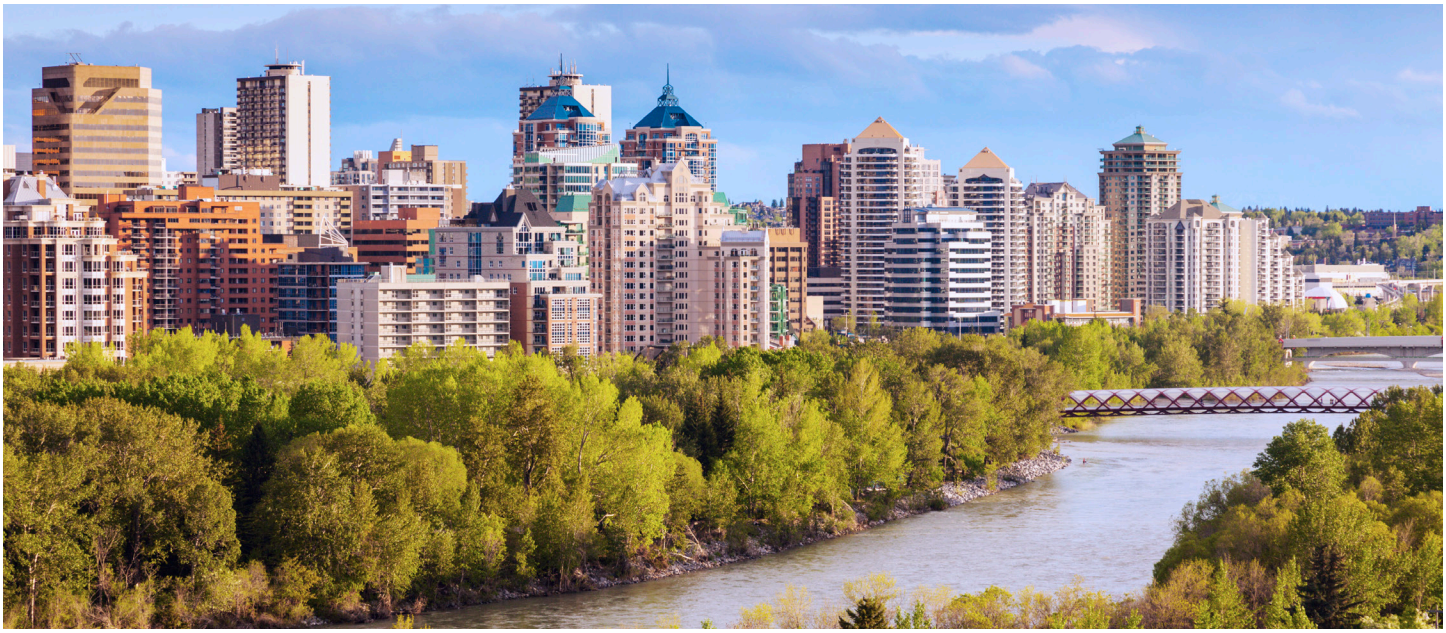
LoRa Technology: How Calgary Built and Utilizes One of the First City-owned LoRaWAN™-based Networks



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ABSTRACT

Municipalities are embracing smart city technologies and Internet of Things (IoT) solutions to provide better services for citizens. The City of Calgary has evolved over the past two decades into one of the most innovative cities in Canada. In this white paper, we explore the successful strategy and steps taken to build a comprehensive communication infrastructure. We then review the selection process and development of one of the first City-owned LoRaWAN-based infrastructures for managing data from sensors, and how The City has leveraged Semtech's LoRa® devices and wireless radio frequency technology (LoRa Technology). Finally, we detail three use cases underway that have fostered innovation and accelerated IoT development in Calgary.

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BUILDING A FOUNDATION FOR PERVASIVE CONNECTIVITY

The City of Calgary's record of innovation illustrates its drive for a stronger economy and success in adopting new technology to improve the lives of its residents.

The City of Calgary's Information Technology (IT) business unit has achieved its long-term vision for a connected city. Over the past 20 years, it has acted on a comprehensive development plan to build a critical communication infrastructure with a goal to improve City services. This was accomplished, in part, by connecting as many of The City's assets as possible, including staff, buildings, street lights, fleet vehicles, cameras and traffic controllers using an expansive fiber optic network, and a variety of wireless solutions.

Heather Reed-Fenske, Chief Information Technology Officer (CITO) for Calgary, oversees the investment, planning, delivery, and sustainment of The City's technology infrastructure. "We started small," explains Reed-Fenske. "A crucial aspect to our success in building a foundational fiber optic infrastructure was working with each of The City departments and aligning with their capital construction projects. If they were going to build a new road or start a construction project in our fast-growing city, we would make sure that we had a conduit in place to put fiber optic cables there."

Through this process, without government grants and very little access to additional capital funding, the IT business unit was able to deploy more than 300 miles of dark fiber. A Multiprotocol Label Switching (MPLS) network was then implemented using the fiber optic network to provide a high speed, highly reliable, redundant, secure and low maintenance data network. IT then took a more proactive fiber strategy to City Council and secured additional funding to enable continued development for The City's underlying fiber backbone and a new IoT network.

The City also owns 10 radio towers, which are connected through the MPLS network. On these towers, The City implemented a broadband fixed wireless network. Wi-Fi access points were also installed at many traffic intersections. This private wireless telecommunications network provides coverage and data transfer for public safety organizations, water, transit, camera monitoring, and supervisory control and data acquisition (SCADA) systems. This last-mile technology allowed Calgary to avoid monthly service expenses, including leasing lines from carriers, and optimized asset tracking for its 3,345 City vehicles.

> "It takes forethought, commitment and action to build communication infrastructure to support a smart city ecosystem."
>
> – Heather Reed-Fenske, CITO, The City of Calgary

CITY NETWORK OF THINGS

The Innovation & Collaboration division of The City of Calgary IT business unit was tasked with evaluating IoT technology as a possible avenue to expand its communication blueprint and evolve into a "smart" city.

The strategy was to help Calgary become more sustainable by bringing openness to data sharing and technology usage within the entire community. The intended outcome was to solve problems and foster innovation with internal business units, civic partners, educational institutions, and industry.

"We started this process in 2015 by engaging The City's 32 business units, including their leaders and workers from the field. We set out to understand the big picture as to what they needed from IoT for their business units, and also determine their major concerns, benefits and anticipated return on investment," said Nan Xie, Sr. IT Engineer, The City of Calgary.

After conducting extensive requirement gathering sessions, the division concluded they would embark upon building a City-owned, secure and resilient IoT infrastructure leveraging Semtech's LoRa Technology. The analysis identified potential risk areas of data privacy, the need for secure connections and raised questions about future vendor lock-in due to evolving industry standards.

The Innovation & Collaboration team envisioned a City Network of Things platform (CNoT) to be used not only by The City's business units but, to be readily available to industry partners. By sharing IoT capabilities with the business community, companies would have a testbed to develop technologies that could help their businesses grow and become more successful.

Staff from the IT business unit's Field Mobility Solutions team created the following six-point rubric to evaluate emerging IoT technologies during its discovery phase:

Security	Since plans for CNoT were to be used by many of the 32 business units within Calgary, some of which have applications that are ultra-critical and communication-sensitive, building a platform that enabled end-to-end cyber security was paramount.
Industry Leader	The universe of network technology providers is expansive. Fierce competition exists as major players race to build momentum and gain market share. A proven technology leader with a global footprint and an established ecosystem was desired.
Open Standard	Interoperability between multiple technologies, flexibility for development and an ability to manage the system by The City engineers played key determining factors.
Reliability	The climate in Calgary is quite challenging. With extreme temperature ranging from 98ºF in the summer to -40ºF in the winter, the network, equipment and sensors had to be durable and weather resistant.
Scalability	With plans for massive adoption, it was important to evaluate modulation schemes and address concerns for over-saturation of airwaves. The City required a profound understanding of frequency behavior in overlapping network regions.
Cost	The City's vision is to eventually scale and connect tens of thousands of devices and sensors. With budget constraints, Calgary needed to consider expenses for deployment and long-term device management to determine the viability of the project.

"We were interested in evaluating industry standards to select a prospective solution for our smart city. Our goal was to develop a City-owned IoT ecosystem named CNoT (City Network of Things). It needed to ensure interoperability and meet the cyber security requirements of several applications."

– Sylvain Mayer, Manager, IT, The City of Calgary

LoRa TECHNOLOGY

The City of Calgary's IT business unit researched available IoT technologies and analyzed the feasibility for its municipal applications. The team reviewed LoRa Technology, NB-IoT, CAT-M1, Sigfox, and Ingenu.

Semtech's LoRa® devices and wireless radio frequency technology (LoRa Technology) was selected as the Low Power Wide Area Network (LPWAN) for connectivity combined with LoRa-enabled devices, sensors and gateways as the tools to provide data communication.

"We discovered the LoRaWAN™ protocol has many unique advantages, including built-in security functionality, low implementation and operating cost, suitability for battery-operated sensors and excellent network coverage performance," noted Sylvain Mayer, Manager, IT. "More importantly, LoRaWAN is an open-standard technology which will provide us with flexibility and better control of the system."

LoRaWAN is an ideal IoT protocol for low data rate, low power and long-range sensor applications in a variety of vertical markets. The success of LoRa Technology in LPWAN IoT applications speaks for itself: IoT networks based on the LoRaWAN specification have been deployed in over 100 different countries with an ecosystem supported by more than 500 contributing members of the LoRa Alliance™.

LoRa (Long Range) is a proprietary spread spectrum modulation technique derived from existing Chirp Spread Spectrum (CSS) technology. It operates in a fixed bandwidth channel (typically 125Khz for uplink channels and 500Khz for downlink channels). LoRa modulation uses orthogonal spreading factors allowing the network to make adaptive optimizations of individual end-node's power levels and data rates that preserve end-node battery life.

"End-to-end cyber security was a key consideration when we started building our LoRaWAN-based network. We engaged experts to perform vulnerability analysis and assessment. We examined many security aspects of the network, including key encryption, packet verification, key management, and device hardening."

– Colin Adderley, Engineer, IT Solutions, The City of Calgary

SUCCESFUL DEPLOYMENT

The City of Calgary is one of the first cities in North America to build a municipality-owned, carrier-grade LoRaWAN network.

Through an RFQ process, TEKTELIC Communications, a leading global LoRaWAN-based radio equipment manufacturer and provider of LoRaWAN service platforms in Calgary, was the vendor selected for Calgary's IoT connectivity implementation phase. TEKTELIC's executive team and engineers shared deep insights into the technology and provided the necessary equipment for deployment.

The LoRaWAN-based network initially started with three carrier grade mega gateways installed on radio towers throughout The City. The gateways are capable of supporting 16-channels on the receive side and two-transmit channels. Each gateway provides up to a seven-mile radius of coverage in a dense urban environment. An additional 10 pico gateways have been installed for spot deployments.

There are active sensors from The City and The University of Calgary communicating data on the network for various use cases, including smart agriculture, asset tracking and noise monitoring. The LoRaWAN infrastructure was built with the city's security considerations in place and is segregated from the corporate data network.

"Infrastructure is the key to enable and accelerate technology adoption for municipalities. Thanks to our existing fiber network and radio towers, we were able to deploy an industrial-grade LoRaWAN-based network with minimal additional cost," recalls Reed-Fenske.

The LoRaWAN-based network is intended to foster future innovation and accelerate IoT development for Calgary. The City is working with Calgary Economic Development (CED), as part of the Living Labs initiative, to provide its LoRaWAN network to technology startups to develop and test their IoT products. Living Labs allows the testing of ideas in a real-world environment, fostering growth and supporting investment in Calgary's local economy. The LoRaWAN-based network will also provide The City with the ability to use this technology to accelerate efficiencies and solve future problems in an achievable and cost-effective way.

The success of Calgary's smart city approach has been presented at a number of conferences across Canada. During these sessions, Calgary's team provides real-world advice to other municipalities, government organizations and industry leaders.

The City of Calgary won the Minister's Award for Municipal Excellence in 2018 for its City-owned LoRaWAN-based network project. The annual awards recognize the innovation and creativity of larger municipalities with populations of 500,000 or greater in Alberta.

"One of my favorite things is to hear about the great things happening in Alberta's municipalities. With these awards, we get to share success stories with the rest of the province and recognize hard work, dedication and out-of-the-box thinking. This is a true celebration of local government."

– Shaye Anderson, Minister of Municipal Affairs, Government of Alberta

A CULTURE OF COLLABORATION

An important part of The City's success has been collaboraion with City business units and operations. In a municipality with so many different lines of business, siloed systems can emerge and represent a major challenge.

"We are trying to build for the future. With our IoT network, from an IT perspective, we want to get a little ahead and help people see the possibilities before us, so we don't end up with 30 different IoT platforms," stated Reed-Fenske.

Calgary envisions its CNoT will be used by many of The City's 32 business units to eventually connect tens of thousands of sensors. It can also be used as part of Living Labs, an initiative The City is progressing to offer City infrastructure and assets to companies, researchers and individuals. Living Labs allows the testing of ideas in a real-world environment, fostering growth and supporting investment in Calgary's local economy.

In addition to alliances with other City business units, the IT business unit has formed key partnerships with members of the community:

Calgary Economic Development – Works with business, government and community partners to position Calgary as the location of choice for attracting business investment, fostering trade and growing Calgary's workforce.

The Urban Alliance – A research partnership between The City of Calgary and the University of Calgary encourages and coordinates the seamless transfer of cutting-edge research for the benefit of the community. The U of C was ranked number one in both Canada and North America among young universities by the 2016 QS World Universities Ranking and has an enrollment of approximately 25,000 undergraduate and 5,000 graduate students.

The Computer Science Department – The University of Calgary was instrumental in the evaluation of LoRaWAN, including measurement plans and analysis of data. Students continue to evaluate how many gateways to use, spatial correlation between sensors and how should they be configured for different applications.

The Department of Electrical Computer Engineering – collaborated with the Urban Alliance to develop a remote and real-time noise monitoring use case for the city.

TEKTELIC Communications – The Calgary-based company develops and manufactures high-performance wireless products. With its proven RF expertise, TEKTELIC's complete set of products and design services enabled the city to quickly develop and transition from a smart city concept to production.

In less than six months, TEKTELIC, in partnership with Semtech's engineering team, was able to deploy a LoRaWAN-based network in Calgary. Then, TEKTELIC either provisioned or built the LoRa-enabled devices used to validate several proofs of concept.

"When people think of the Internet of Things, they have a mindset that it is really complicated. They may believe you need to have an internet service provider or cellular provider to get your devices set up to achieve long range communication. But it's not the case with LoRaWAN."

– Majid Ghaderi, PhD, Professor, Computer Science Department, University of Calgary

DEVONIAN GARDENS – USING DATA TO MAINTAIN A BOTANICAL OASIS

Devonian Gardens is a three-acre horticultural refuge in downtown Calgary on the top floor of The CORE Shopping Centre. One of the largest indoor gardens of its kind, it boasts more than 10,000 ground cover plants, 500 trees, a 900-square-foot living wall, koi ponds and a children's play area. This impressive green-space, perched above 116 retail stores, is maintained by The City of Calgary Parks.

The main challenge for the indoor garden is creating a healthy environment for 43 planter beds, some with multi-levels, of tropical exotic interior plants and 27 different species of trees growing in a three-acre area.

Devonian Gardens has beds that vary in size and depth. A soil monitoring sensor is part of the proof of concept (PoC) to measure volumetric water content (VWC), soil temperature and electrical conductivity (EC). VWC provides the ability to understand irrigation performance against the species' requirements. EC measures the salinity of the soil which helps in fertilization for optimal plant health. The combination of light, water, air, and soil characteristics help reduce disease and penetration of pests. Utilizing LoRa Technology to gain an understanding of these fundamental characteristics helps provide more efficient and predictive outcomes for managing these assets, given the environmental challenges.

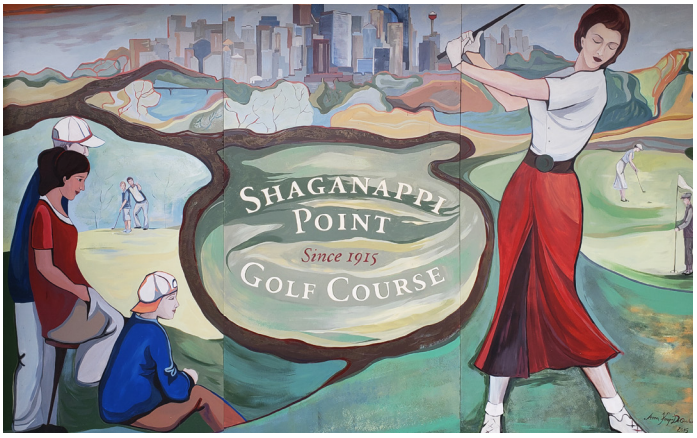
Danielle Zadunayski, horticulturist at Devonian Gardens since 2011, noticed some trees were exhibiting signs of light stress. What appeared as big and healthy growth, was, in fact, the canopy compensating for low light levels. The leaves grew to a much larger surface area in order to receive more light. This caused the trees to become top heavy and list dangerously to the side.

To test the technical capability of LoRa-enabled photosynthetically active radiation (PAR) sensors in creating and maintaining appropriate lighting throughout the seasons, Devonian Gardens installed a PAR sensor in one flower bed as a PoC. With PAR readings from different positions, specialists will be able to quantify light spatially in the garden. A spatial representation will help in future species selection and placement, and maintenance and future lifecycle of lights for optimal plant health. They could also use temperature, humidity and barometric pressure sensors to measure vapor pressure deficit (VPD) and characterize this over the physical space to ensure optimal plant health. VPD is the difference between the amount of moisture in the air and maximum amount of moisture the air can hold when it is saturated. The positive results of the PoC have led to the development of a business case to implement sensors across the entire gardens. The industrial grade sensors for the smart agriculture application were provided by Decent Labs, while the temperature and humidity sensors, and gateways were supplied by TEKTELIC Communications.

Devonian Gardens has just begun analyzing sensor data to re-evaluate how lighting is placed inside the garden and moving plants with similar requirements to specific areas. Zadunayski foresees less plant attrition, less maintenance, and increased garden health using concrete data to validate her daily horticultural observations and recommendations.

> "By far, my most difficult challenge is keeping the plants well lighted, so they can experience consistent and healthy growth throughout the year."
>
> – Danielle Zadunayski, Devonian Gardens' Horticulturist, Calgary Parks, The City of Calgary

SHAGANAPPI POINT – TRANSFORMING GOLF COURSES WITH IoT



The City of Calgary recently celebrated 100 years of municipal golf at its first public course. Shaganappi Point began as a bare-bones 18-hole golf course serving a community of 80,000 Calgarians. Approximately 2,000 golfers played the course in its first year, 1915. Tees were equipped with coconut mats, and greens were composed of a mixture of sand and crank-case oil, a common practice at the time.

Calgary's population has grown to more than 1 million and Shaganappi Point has expanded to 27-holes, a 44-stall driving range and a club house. The course sits on a bluff along the south bank of the Bow River offering magnificent views of Calgary's downtown skyline. During its annual season, from April to November, golfers play an average of 90k-100k rounds of golf.

Calgary Recreation is working with Information Technology at The City of Calgary to test the IoT sensors, software and LoRaWAN network to determine if a low-cost solution exists to effectively track pace of play. Slow play may diminish the overall golf course experience and ability to retain customers. Depending on the results of the pace of play PoC, The City may choose to deploy sensors in City-operated fold courses to determine accurate tee time intervals, make course adjustments and better predict revenue impacts.

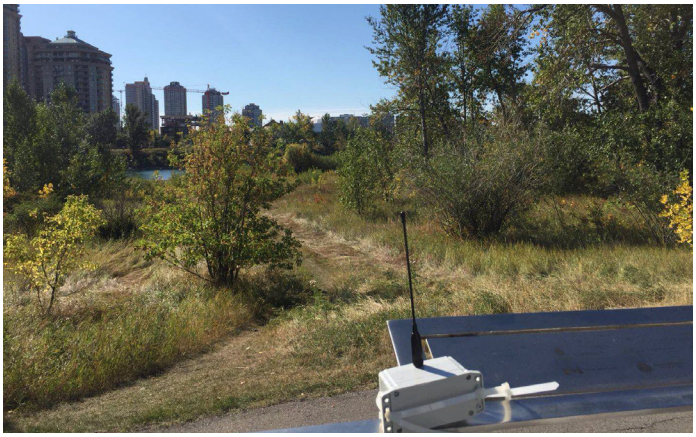
In addition, with real-time golf cart location information, guest experience will be enhanced. As pace of play anomalies are detected, course marshals may be dispatched to support golfers in need of assistance.

Small units of LoRa based-sensors are placed underneath the seat of each golf cart. Sensor data is transmitted via LoRaWAN-based network to a TEKTELIC KONA Mega IoT gateway. The gateway is connected to a TEKTELIC network server. The GPS sensors used are provided by GlobalSat. Custom application software, developed by SensorUp, provides the necessary real time and historical course usage data on a web-based dashboard that can be viewed on a computer or mobile device.

"Understanding how fast people are playing on a golf course will elevate customer experience and support revenue maximization."

– Dawn Burke, Golf & Sport Development, Calgary Recreation, The City of Calgary

CITY OF CALGARY: REMOTE AND REAL-TIME ACOUSTIC MONITORING



Noise ordinances aim to reduce the amount of noise pollution in a city, but noise assessments and monitoring are performed infrequently and are complaint-driven. The City of Calgary set out to build a network of low-cost acoustic sensors to improve noise monitoring in its urban environment.

The Urban Alliance, a research partnership between The City of Calgary and the University of Calgary, was created to eliminate legal and financial red tape, and coordinate the seamless transfer of technology research for the benefit of the community. Dr. Henry Leung heads the Robotics and Sensor Networks Group

in the Department of Electrical Computer Engineering at U of C. He collaborated with the Urban Alliance to build a LoRa-based sensor using Edge analytics to characterize noise and initiate a pilot use case on The City-owned LoRaWAN-based network.

Leung's team of researchers' first contribution to the project was the hardware design of the sensor, which did not previously exist. Their fabrication used low-power wide area radio transceivers to enable data transmission between the sensor nodes and the network server. The LoRa-based sensors are battery operated for ease of deployment, low-power to limit network maintenance, robust for continuous operation in Canadian weather, and possess limited amount of in-situ data processing.

The second contribution by the team was the development and testing of data analytic algorithms that allow sensors to autonomously detect and classify acoustic events. The researchers will use machine learning techniques to distinguish between noise sources such as construction, traffic, gunshots, and music.

To put the innovations to test, several of the new LoRa-based sensors were placed at the Circle Carnival event at Shaw Millennium Park in September 2018. Allocated at different locations around the park, the sensors were programmed to compute the average noise level over a window of three minutes. The pilot was a success. When the noise level rose above 85dBC, the sensors sent a warning packet through the LoRaWAN-based network. In the future, this feedback can be proactively provided to concert promoters to ensure noise restriction compliance.

The next evolution will be to characterize sound such as trains, road noise, drag racing, gunshots, and construction that cause noise problems for residents, then spatially correlate over time and location. That data will help improve noise management and enforcement during public events by automatically alerting bylaw officers when noise thresholds are exceeded, saving The City time and money.

"Measuring noise is important to everyone's quality of life. It is something that is difficult to characterize and has traditionally been expensive to do."

– Nan Xie, Sr. IT Engineer, The City of Calgary

IT'S ONLY JUST BEGUN

The IT business unit of The City of Calgary and its LoRaWAN-based network have brought IoT awareness to Calgary. Several business units and leading industries have requested information about CNoT, and are motivated to work closely with IT to develop IoT solutions.

In the near future, The City will be adding more radio gateways to maximize coverage across the northeastern and southern areas of Calgary. Future pilot projects include vehicle and equipment tracking, smart parking, and monitoring of building energy, water levels, and water pressure.

By providing smart city capabilities such as remote monitoring of its assets, The City of Calgary anticipates reducing trips to sites, improving operating efficiency, transforming preventative services, and providing scientific information that will serve its citizens.

"LoRa Technology and LoRaWAN are exciting for The City of Calgary because we have the opportunity to provide data visibility to processes and services that we traditionally have not been able to. We can use IoT data to make our work more efficient and provide a better return on our investment to our citizens."

– Nan Xie, Sr. IT Engineer, The City of Calgary

ABOUT SEMTECH

Semtech Corporation is a leading supplier of high performance analog and mixed-signal semiconductors and advanced algorithms for high-end consumer, enterprise computing, communications, and industrial equipment. Products are designed to benefit the engineering community as well as the global community. The Company is dedicated to reducing the impact it, and its products, have on the environment. Internal green programs seek to reduce waste through material and manufacturing control, use of green technology and designing for resource reduction. Publicly traded since 1967, Semtech is listed on the Nasdaq Global Select Market under the symbol SMTC. For more information, visit **www.semtech.com**.

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