Detecting Drones Using a Real-Time Spectrum Analyzer

APPLICATION NOTE

No one denies, flying a drone can be fun. For RC and photography enthusiasts, a drone is a source of entertainment, and with a camera attached, a provider of breathtaking birds-eye views.

In a few short years, the number of drones, or unmanned aerial vehicles (UAVs), purchased has soared. In the US alone, the FAA projects the small model hobbyist UAV fleet will more than double from an estimated 1.1 million vehicles in 2017 to 2.4 million units by 2022[1]. Worldwide, Teal Group's 2018 World Civil UAS Market Profile and Forecast projects that non-military UAS production (Commercial, consumer and civil government systems) will total $88.3 billion in the next decade, soaring from $4.4 billion worldwide in 2018 to $13.1 billion in 2027, a 12.9% compound annual growth rate.[2]

While most drone operators use good judgement when flying their drones, unfortunately, some do not, as evidenced by a number of recent drone related headlines:

- December 2018 – *"Boeing 737 Passenger Jet Damaged in Possible Midair Drone Hit,"* Bloomberg.
- December 2018 – *"Gatwick Airport: Drones ground flights,"* BBC News.
- January 2019 – "*FAA says drone sightings temporarily halted traffic into Newark airport,"* Reuters.

In situations where a drone is operating where it shouldn't, the potential ramifications can be catastrophic. As a result, organizations need real-time, accurate, simple to operate and cost-effective solutions for detecting drones flying in or near restricted airspace. In this application note, we'll discuss considerations when looking for a drone detection solution.

Drone Detection Basics and Considerations

When looking for a drone detection solution, it is important to have a basic understanding of how most hobbyist and commercial drones operate.

Nearly all hobbyist and commercial drones:

- Are controlled locally within a visual range of about 1000 ft.
- Are controlled remotely within 2-3 miles using First Person View (FPV)
- Operate in the 2.4 GHz unlicensed band for control (approx. 80 MHz bandwidth)
- Use 5.8 GHz unlicensed band for first person view (FPV) video feeds (20 MHz or less)
- Employ return to home (RTH) when control signals are lost or weak
- Use transmission signal technologies available from only a few suppliers, making identifying a drone easier
- Utilize drone control signals that normally hop across multiple frequencies and can be up to 80 MHz wide
- The FCC has designated that drones can only be operated in the unlicensed bands, including the 2.4 GHz, 5.8 GHz, 900 MHz and 433 MHz bands

In the following sections, we'll discuss a couple of approaches to detect a drone's presence using Tektronix rugged, portable and affordable RSA306B and RSA507A spectrum analyzers. The first method discussed is a basic manual method for detecting a drone's presence. The second is more advanced and provides information on setting up an automated drone detection system.

Basic Drone Detection

Basic drone detection can be performed with a Tektronix RSA306B or RSA500 Series Spectrum Analyzer and Tektronix DataVu-PC software.

As drone operators generally use a first-person video (FPV) link to track of the drone's location, the first step in looking for a drone's presence is to scan the 5.8 GHz band to look for burst signals that are present as the drone and controller communicate to each other.

As mentioned above, hobbyist and commercial drones transmit video in the 5.8 GHz unlicensed band. Transmitting video or control signals from the drone to the pilot results in recognizable bursts of RF energy that occur as the transmitter and receiver acknowledge receipt of data.

The Tektronix RSA306B and RSA500.

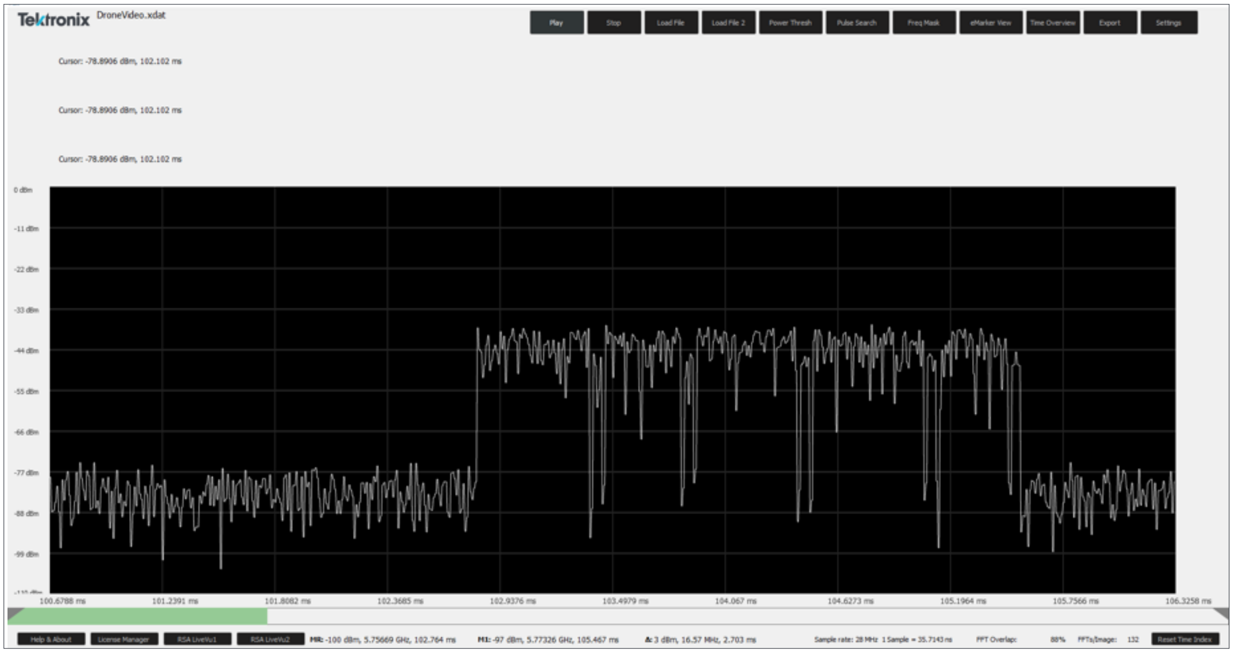


FIGURE 1 . Video burst from 5.8 GHz frequency band.

As shown in Figure 1, the video burst characteristics are readily detected even from the power vs time scan measurements. When in real-time mode, even more accuracy is possible by using the real-time I/Q captured data. This is discussed and shown below in Figures 2 and 3

A second method to detecting a single, or multiple drones is to scan the 2.4 GHz band. By ignoring Wi-Fi and Bluetooth communications, you can examine the signals that are left. Within the 2.4 GHz space, multiple drone operators could be flying at the same time. To uniquely control each drone, even when multiple drones coexist in the same airspace, requires complex signalizing that is only available from a few chip vendors. The waveform signatures used for this purpose are unique and can be identifiable.

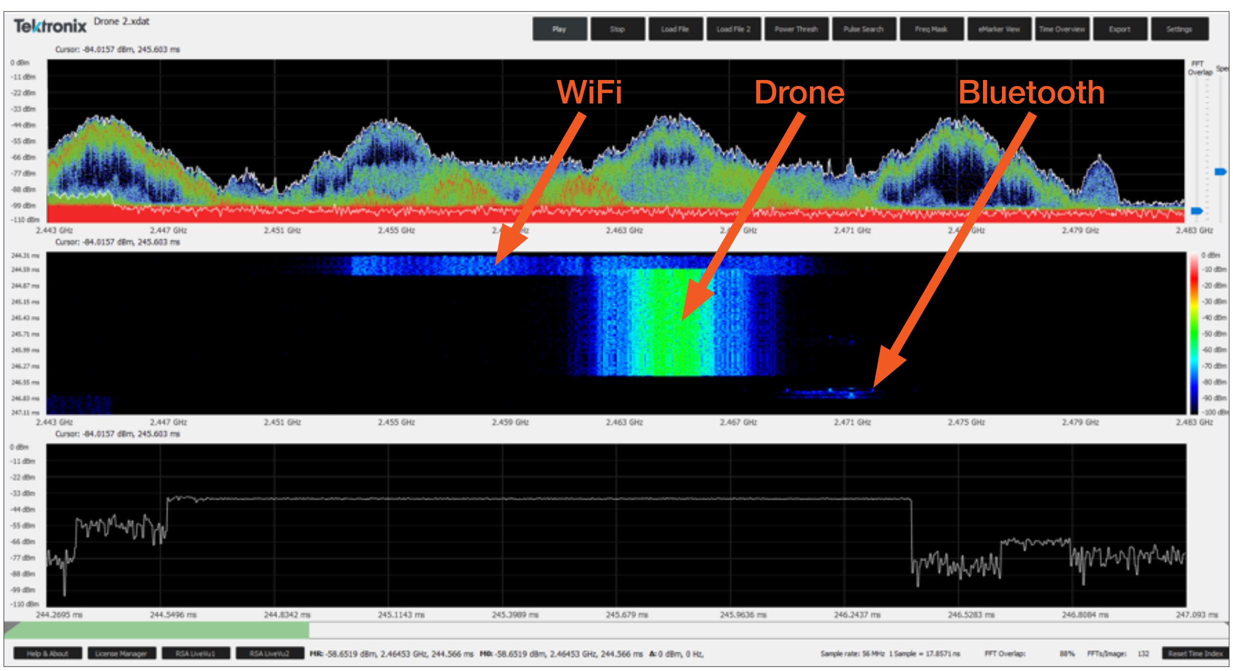


FIGURE 2. Control bursts from 2.4 GHz frequency band.

Even in the more congested 2.4 GHz band, the control signals are readily identified as in the display shown above using the real-time I/Q captured data.

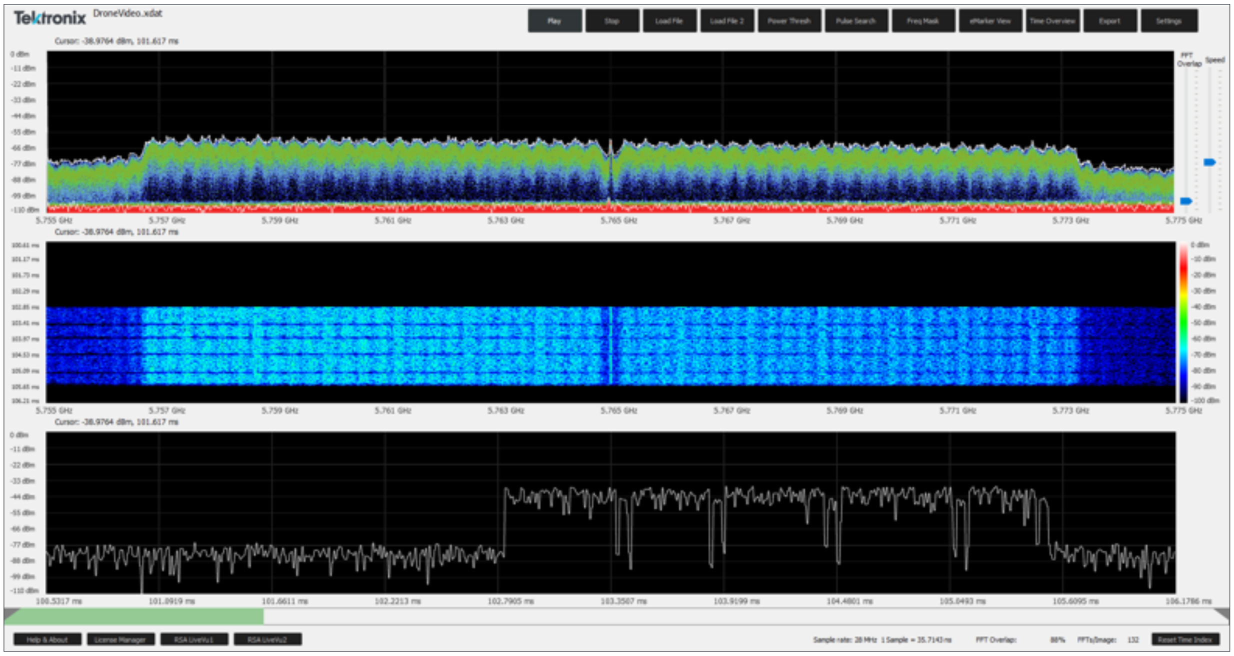


FIGURE 3. Video burst from 5.8 GHz frequency band using I/Q processing.

When the first or second method indicate the existence of a possible drone, the next step is to capture I/Q data from the signal. The recorded data can then be used to potentially identify the manufacturer of the drone.

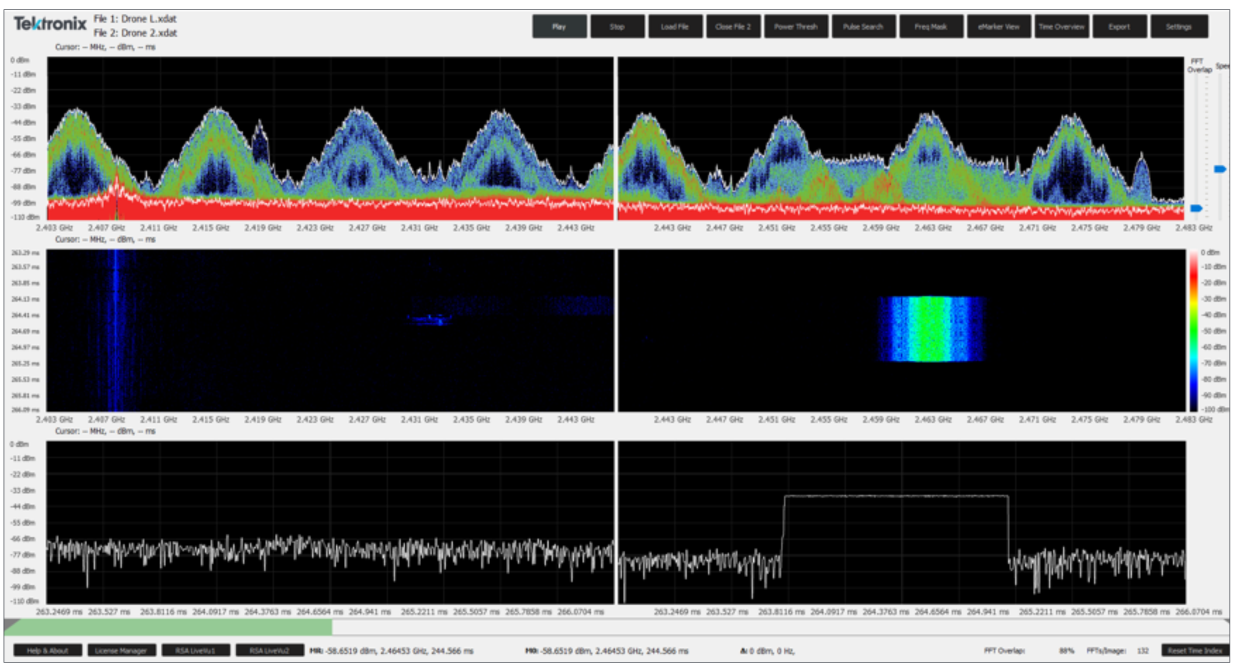


FIGURE 4. Dual RSA mode showing the hopping frequencies and sequences of the drone controller.

It should be noted, drone control signals normally hop across multiple frequencies and can be up to 80 MHz wide, while the Tektronix RSA306B and RSA507A Series real-time mode is 40 MHz wide. To collect data across the entire frequency span, DataVu-PC has a special mode where it can utilize two RSAs to provide an 80 MHz wide detection capability. With an 80 MHz wide detection capability, it's possible to see the entire frequency hopping sequence to potentially determine the drone manufacturer or chip vendor, with greater accuracy, and take appropriate counter measures. Dual RSA mode showing the hopping frequencies and sequences of the drone controller across a full 80 MHz is illustrated below in Figure 4.

Automated Drone Detection

While the headlines cited above related to sightings involving airports, drones have created concerns for other entities as well, including event venues and military bases. With the large perimeter that needs to be monitored, having an automated drone detection system can detect drone presence without interrupting other operations.

Creating an automated drone detection system is simplified by networking multiple Tektronix RSA306B, or RSA500 Series spectrum analyzers together and utilizing software such as Erisys RF Solutions' SpectrumVu®. SpectrumVu is an advanced software package that provides fully autonomous monitoring of the RF spectrum, can record unknown spectral events and generate alerts upon the discovery of unknown signals.

To set up an automated drone detection system, nodes, which include the spectrum analyzer, an antenna and an Intel NUC, are set up around the outside perimeter as illustrated in the La Guardia Airport diagram (Figure 5). The nodes can be networked to a central operations center to provide comprehensive coverage of the perimeter and flight paths. By utilizing multiple nodes, it's possible to identify a drone's location on the x-y-z axis.

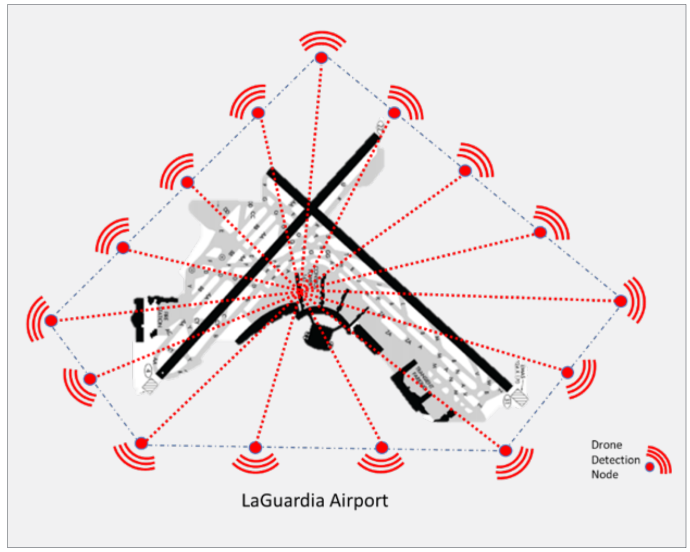


FIGURE 5. For illustration purposes only. Source: faa.gov.

With this system, the RF spectrum is autonomously monitored 24/7. Triggers can also be set on unknown signals or on signals with power above user-defined thresholds to create alerts. Known, unknown, and event signals are captured by the real-time spectrum analyzer and displayed on the SpectrumVu dashboard as illustrated in Figure 6.

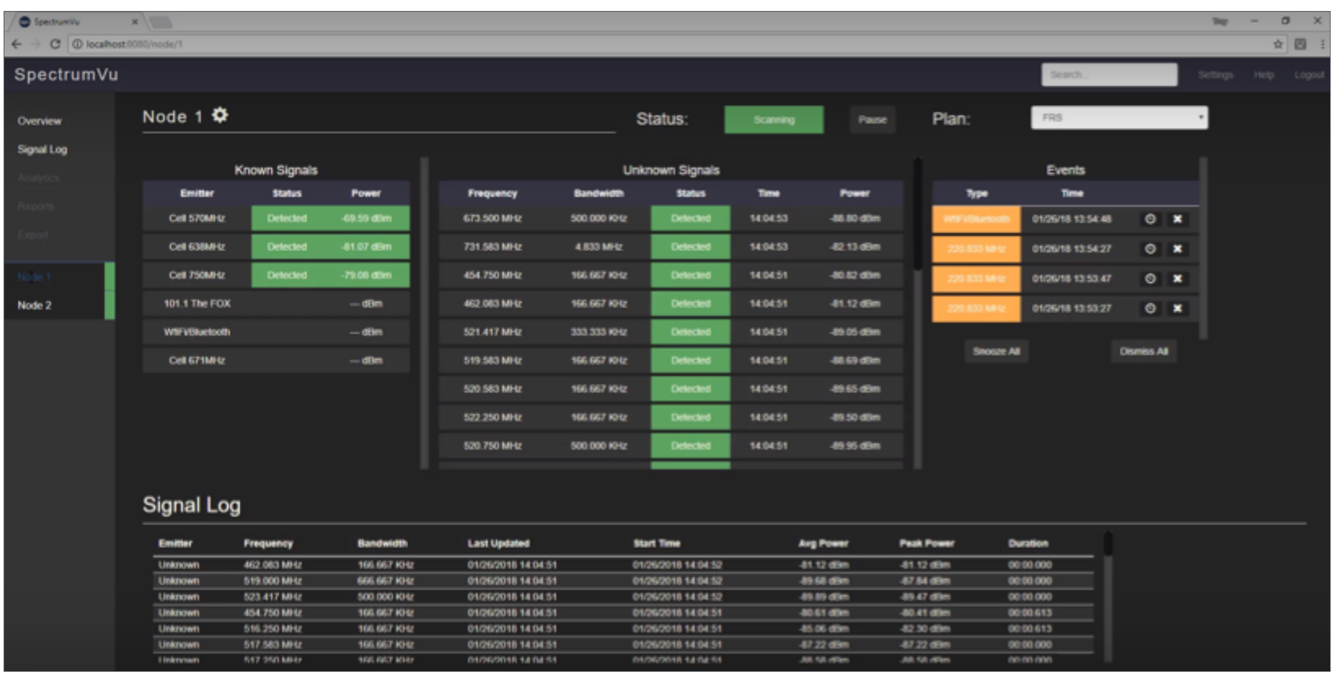
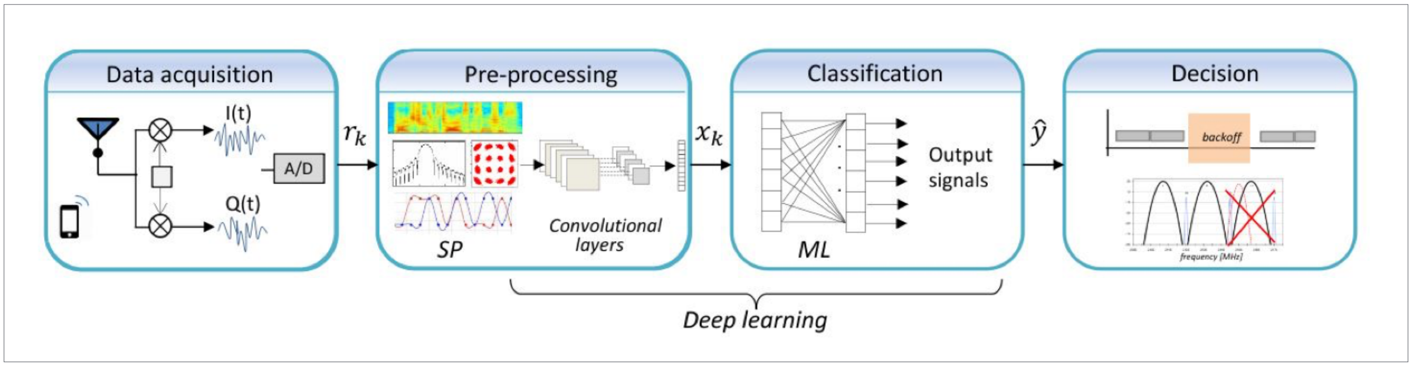


FIGURE6. SpectrumVu can automatically send an alert to security personnel whenever a suspicious signal is detected.



Processing pipeline for end-to-end learning from spectrum data.[2]

Recent innovations in neural network technology are utilized in SpectrumVu to automatically identify likely drone signals. SpectrumVu's StepNStare mode can step or tune to a 40 MHz chunk of the RF spectrum, record the I/Q data, and then step to a different 40 MHz band. This process repeats across the unlicensed drone spectrum, enabling the user to monitor the entire spectrum by processing small I/Q files continuously, using machine learning and waveform shapes. When the waveform properties match the neural network stored signal properties, SpectrumVu issues an alert to indicate the likely presence of a drone.

By utilizing machine learning, the unique RF characteristics of both the drone control signals and the drone first person video (FPV) video downlinks can be identified within the real-time bandwidth of the RSA automatically.

For additional analysis, unknown signals can be stored in an SQL database to accelerate drone identification and support additional analysis of the RF spectrum environment.

Conclusion

While drones provide hours of enjoyment and offer benefits for many applications, a misused drone can create dangerous situations. We've discussed basic characteristics of hobbyist and commercial drones and recommended spectrum analyzer performance capabilities. We've also presented both a simple method and an advanced, automated solution for detecting drones.

As illustrated, a real-time spectrum analyzer can be a valuable tool in monitoring the RF environment and detecting a drone's presence as a stand-alone or networked device. For organizations concerned with drones operating where they shouldn't, it is important to invest in solutions that provide real-time awareness, 24/7 monitoring and automated alert capabilities.

To learn more about Tektronix drone detection solution, contact your Tektronix representative at www.tek.com.

References:

1) *FAA Aerospace Forecast Fiscal Years (FY) 2018-2038,* Federal Aviation Administration, March 16, 2018, www.faa.gov/news/updates/?newsId=89870

2) Teal Group, July 16, 2018, www.tealgroup.com/index.php/pages/press-releases/54-teal-group-predicts-worldwide-civil-drone-production-will-soar-over-the-next-decade

3) *End-to-end Learning from Spectrum Data: A Deep Learning approach for Wireless Signal Identification in Spectrum Monitoring applications,* Merima Kulin, Tarik Kazaz, Ingrid Moerman and Eli de Poorter, December 11, 2017, arXiv:1712.03987v1.

Contact Information:

Australia* 1 800 709 465
Austria 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7627
Canada 1 800 833 9200
Central East Europe / Baltics +41 52 675 3777
Central Europe / Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400 820 5835
India 000 800 650 1835
Indonesia 007 803 601 5249
Italy 00800 2255 4835
Japan 81 (3) 6714 3086
Luxembourg +41 52 675 3777
Malaysia 1 800 22 55835
Mexico, Central/South America and Caribbean 52 (55) 56 04 50 90
Middle East, Asia, and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
New Zealand 0800 800 238
Norway 800 16098
People's Republic of China 400 820 5835
Philippines 1 800 1601 0077
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea +82 2 565 1455
Russia / CIS +7 (495) 6647564
Singapore 800 6011 473
South Africa +41 52 675 3777
Spain* 00800 2255 4835
Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2656 6688
Thailand 1 800 011 931
United Kingdom / Ireland* 00800 2255 4835
USA 1 800 833 9200
Vietnam 12060128

*** European toll-free number. If not accessible, call:** +41 52 675 3777

Rev. 02.2018

Find more valuable resources at TEK.COM

06/19 AH 37W-61576-0