

# Zeroing in on ZigBee (Part 2)

## Chipsets and Source Code

*Last month Pete introduced the ZigBee low-power radio standard and underlying IEEE 802.15.4 layers. In this article, he describes the development resources you'll need to create your own ZigBee projects. He covers both the chipsets and the source code.*

Last month I described the ZigBee low-power radio standard and the underlying IEEE 802.15.4 layers. Now I'll focus on the development resources you can use in your own ZigBee projects. I'll describe affordable chipsets and source code.

### SIMPLE PROTOCOL

ZigBee exhibits robust, reliable communications through an auto-configuring mesh network architecture. You'll soon be able to concentrate on the application by relying on ZigBee to provide the transceiver, RF channel, and protocol. This is achieved with only one transceiver IC incorporating the physical layer and software on the microcontroller that provides part of the medium access controller and higher layers. These layers coexist with the application running in the same code space.

The protocol is simple and efficient. You can use a medium-powered, 8-bit microcontroller. As little as 16 KB of flash memory is required for a simple device. ZigBee was designed for extremely long battery life. It will eventually enable home automation, cable replacement, and industrial sensors.

### USABILITY

You've seen press releases stating that some new IC has been tested in an exciting new area of electronics. Frequently, however, access to the new technology is blocked, because the samples are only for approved development partners only, or because of the sheer complexity of the devices. Let's take a look

at how to obtain affordable ZigBee-compatible hardware and software and use it at the chip level.

If you can place the transceiver and controller ICs on your own PCB in a suitable way for use with an 8-bit microcontroller, you can markedly reduce the cost of a project. This is desirable because a typical application for which ZigBee is suited may be comprised of many nodes. Using the naked IC on your own PCB

makes key fob-size projects a reality.

Sometimes it seems as though the growing complexity of these evermore capable standards are moving beyond the scope of designers with limited amounts of time and test equipment. Would you leap into a quick 802.11.x project on a rainy Sunday afternoon given the bare chipset and a soldering iron? Even using a ready-made solution with a PCMCIA card interface requires 30-odd I/O lines.

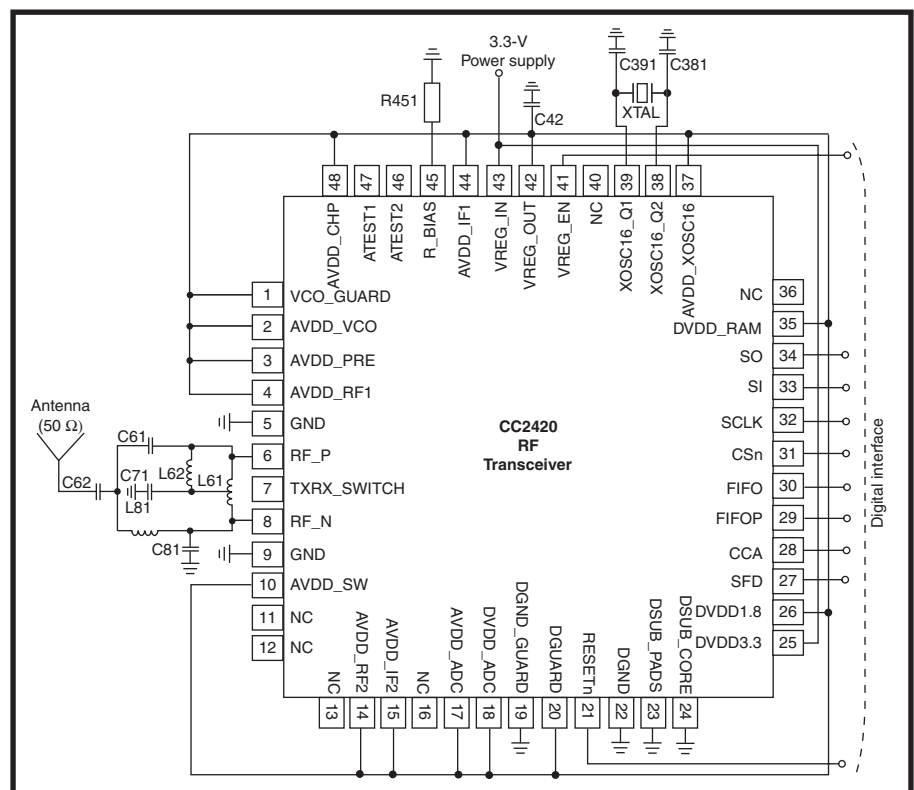


Figure 1—Sure, you say, here comes another one of those single-chip transceivers that somehow has managed to morph itself into a complicated, messy RF jungle by the time it makes its way from the sales brochure to the application diagram. With the CC2420, however, this promise is almost entirely kept.<sup>[1]</sup>

The packaging is also against you because of the advent of ball grid array packaging. It's nearly impossible to work at the chip level with chip-scale packing. I define the birth of a new standard when the average electronics designer can buy a product sample in a leaded package at a reasonable low-quantity price without having to rely on \$100,000 of RF test equipment to get it working. The CC2420 was the first product to deliver that ability on the workbench.

### CC2420 802.15.4 KIT

Chipcon boasts that the CC2420 is the first transceiver IC to meet both the IEEE 802.15.4 and ZigBee standards. Of course, there's meeting the standards, and then there's the ability to produce a workable cost-effective product. After using the evaluation kit, I can say that Chipcon has produced both in the first version of silicon.

Chipcon's hardware support and software tools keep you ahead of the complexity curve. The single-chip implementation limits the RF circuitry to just the antenna and its matching network

(see Figure 1). The PC-based SmartRF Studio software makes configuring and using the evaluation kit a breeze.

Fortunately, soldering the CC2420 (although fairly tiny) is just under that critical threshold where doing it yourself is still doable. The CC2420 QLP-48 package with a 0.5-mm lead pitch is a challenge, but it's one I've been able to cope with. Products like PCB iron-on artwork transfer paper has allowed amateur PCB makers like me to easily produce tracks and clearances with 10-mil (0.01") track widths and clearance. A friend of mine regularly does 7 mils with a clothes iron and a slosh of etching acid!

As well as the physical challenge of the intricate surface-mount packages, software drivers are the other big impediment to experimenting at home. Often, a lack of information in the datasheet and the need to program 100 registers consigns hopeful efforts to the waste bin. When success is achieved and the results are posted on a web site, the person responsible is rightly proclaimed a hero.

ZigBee, or even a full 802.15.4 link, would take more than an afternoon to

develop your own software for, but you'd be able to get something useful fairly quickly. To prove the RF link, simply use the serial port to confirm two-way serial communication with the CC2420. A simple register setting then places it in Transmit or Receive Test mode, so you can check if the hardware works.

Making a simple one-way, point-to-point link is the next step. Then, a simple two-link is accomplished by implementing mode control by manipulating the CC2420 state machine. If you need more than a master/slave relationship, add a simple MAC protocol such as aloha (time slots) or check for a clear channel before transmission. You can add more features at this point. Encryption, link quality indication, and dynamic power output level control would be nice. But wait. This is starting to sound like 802.15.4! Why don't you just download the free code from the Chipcon web site?

Most of what you need is included with the CC2420DBK demonstration board kit. You can download the files from Chipcon to make your own PCB. The schematic, BOM, and PCB layout

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are all there. You can use the free source code for the IEEE 802.15.4 layer. If you don't want to make the PCBs yourself, they're available on the web site for \$50. The software isn't a full implementation of the IEEE 802.15.4 MAC, but it's enough for basic message sending and acknowledgment. The full IEEE 802.15.4 MAC software is free if you sign a licensing agreement. Although both versions were written in C for the Atmel ATmega128L microcontroller, they port easily to other microcontrollers.

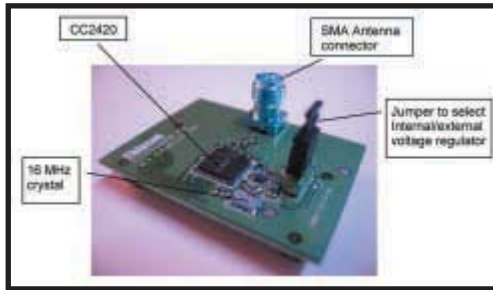
The easiest approach would be to copy the PCB exactly and use the free GNU AVR gcc cross-development tool. Chipcon strongly recommends that you copy the reference design as closely as possible. If you want to develop a two-layer PCB, you should keep the ground via positions as close as possible to the location on the original board. Of course, FCC licensing is another story. The first stage is to get to a working prototype!

The documentation for the CC2420DBK demonstration board kit states that practical testing outdoors with line of sight (LOS) resulted in a range of 170 m at 250 kbps (zikes!). The simplicity of this information surprised me, because IC vendors usually provide ambiguous range performance information.

I actually used the CC2420DK development kit for range checking. It consists of a pair of motherboards (CC2400EB) and their respective transceiver plug-in boards (CC2400EM), as you can see in Photo 1.

I was initially discouraged by the presence of a Xilinx Spartan II FPGA on the motherboard. Why so complex? But my disappointment vanished when I discovered that the FPGA is only used to configure the evaluation board in a variety of different setups. The FPGA routes signals so that the on-board microcontroller controls the plug-in transceiver board. In another configuration, the plug-in transceiver board connections are routed via the headers to your processor board when prototyping with your own microcontroller.

The process of setting up, including the installation of the SmartRF Studio evaluation software on the PC, took



**Photo 1**—Your next 802.15.4 project will look this simple. The IC is 7 mm x 7 mm. Chipcon encourages you to copy the PCB layout and adapt it for your own needs. You need a four-layer PCB to guarantee the quoted performance.<sup>[2]</sup>

less than 20 min. I found that it wouldn't work on some of my USB ports. Apart from this, things went extremely well. Getting the two boards set up for a range check was as simple as selecting Normal View, Packet TX, Start Packet Transmit on one of the boards, and Start Packet Receive on the other. I then checked for the lights that flash after a reception. Link quality statistics were displayed in real time on the PC. The CRC and packet count information was great, but the RSSI didn't work. A separate piece of software can be used for packet sniffing.

I unplugged the board configured for reception, performed a walk-around range check, and continued to look for the flashing of the LEDs. Using this technique, I found reliable reception everywhere in my 1,100-square-foot, single-level wood house. Reliable transmission occurred when transmitting through three walls with the doors closed, even when partially shielding the receiver antenna with my hand and placing it right on top of other operating electronic equipment.

Taking it outside, I found reliable reception 90' away through one wooden wall out to the backyard. Walking down the street, I got intermittent operation as far as 100 yards away from the transmission end inside my house. I even got reliable reception from 12' away after disconnecting the antenna on the receiver!

The version of the IC I tried suffered from excessive current draw in Shutdown mode when the internal 1.8-V regulator was in use. This was corrected in a later silicon revision, along with an address recognition problem.

Now let's take a look at a simple software application example. A pair

of the CC2420DB evaluation kits running the example program will establish a point-to-point RF link, sending data packets containing a 5-byte payload (see Listing 1). The payload will be transmitted when the potentiometer is turned, or the switch, S2, is held down. The first byte of the payload contains the potentiometer value, which controls the PWM duty cycle of the LED at the receiving node. This example isn't a full-blown ZigBee application, or even a proper 802.15.4

implementation, but it illustrates the basics of doing something useful with the hardware. (Well, assuming blinking LEDs enthral you!)

Listing 2 shows how pressing the button and noting the status of the yellow and green LEDs can perform a simple range check. This is a simple but useful example. To keep things simple, only a small subset of the IEEE 802.15.4 standard is implemented in this example. A pair of CC2420DBs running this program will establish a point-to-point link on a single channel. The frame format conforms to 802.15.4, but it doesn't implement any other MAC properties. The full IEEE 802.15.4 MAC software can be obtained for free after signing a licensing agreement.

## DIFFERENT CORE CHIPSETS

Now let's review some of the transceivers implementing 802.15.4 and ZigBee standards. I'll concentrate on describing each of the different core chipsets rather than commenting on each implementation.

More than a few companies use the Chipcon 2420. I'm sure there are good and bad implementations out there. So, the following review will be beneficial if you want to muck in at the chip level rather than the module level. The advantage is that if you place one of the chips on the PCB, you're looking at \$15 for the entire transceiver in low quantities, assuming you are already doing your own PCB for the project.

I'll also describe some alternatives to implementing a strict ZigBee solution on the transceiver ICs. The topic of this article is cutting edge. The ZigBee Alliance ratified the upper layers of the ZigBee standard in October 2004.

The 802.15.4 portion is more firmly established. There are alternatives to the upper layers of ZigBee if you want an easier ride until ZigBee is more freely available to people who are on a budget.

Let's pick up where I left off by

focusing on alternative protocols that can run on the CC2420. Remember, chips like the CC2420 only give you the physical and MAC support layers. Chipcon is going to package the CC2420 with a ZigBee software stack for \$2.30

per unit in large quantities. I'm also excited about the upcoming launch of the CC2430, which will include a microcontroller, RAM, and flash ROM in the same package as the RF transceiver.

An alternative to ZigBee is to choose your own simplified protocol or buy one off the shelf. One such alternative comes from Moteiv, a company founded by three Berkeley students who worked on the open-source TinyOS wireless network system. Their Telos product with a Texas Instruments MSP430 microcontroller doesn't require any programming boards or development software. It has integrated USB and the tools for compiling. It's approximately \$130, but offers an instant on approach backed by the availability of open source code.

Ember's EM2420 was co-developed with Chipcon. It's the same IC, but it isn't currently available to the general public in low quantities. According to the datasheet, the chip is only available with a licensed Ember networking stack. It's targeted to approved 8-bit processors.<sup>[3]</sup> This means Ember only has relationships with serious developers. It can't sell small quantities of hardware for casual developers to play around with. Still, it may ship one to you if you can come up with \$13,950 for the EM1020 developer kit (plus shipping!).

The 802.15.4 hardware in the form of the EM2420 and CC2420 was ready long before the ZigBee standard was ratified. This didn't stop companies from developing their own ZigBee-like transport/network layer. Ember's is called EmberNet.

If you want ZigBee included without running the ZigBee layers on your own controller, then Oki Electric Industry Co. might be able to help. Last May it announced the first IEEE802.15.4 and ZigBee single-chip solution. This leaves just the application layer for you to implement. CompX sells PCBs based on this IC.

A key member of the Zigbee Alliance, Freescale recently released the MC13192 2.4-GHz RF transceiver data modem. The 13192DSK evaluation kit is similar in principle to the Chipcon CC2420DBK. You get two nodes for \$199. Each node has the MC13192 transceiver and MC9S08GT60 low-power microcontroller. The microcontroller is preloaded with sim-

**Listing 1**—A simple blinking LED example grounds some of the theory in easily understood C code courtesy of Chipcon's simple wireless dimmer/RF range tester demonstration. This excerpt shows how your application uses a function prototyped in the RF library to perform an application-specific task based on the contents of the received payload.

```
// BASIC_RF_RX_INFO* basicRfReceivePacket(BASIC_RF_RX_INFO *pRRI)
// DESCRIPTION: This function is a part of the basic RF library,
// but must be declared by the application. Once the application
// has turned on the receiver, using basicRfReceiveOn(), all
// incoming packets will be received by the FIFO interrupt
// service routine. When finished, the ISR will call the
// basicRfReceivePacket() function. Please note that this function
// must return quickly, since the next received packet will over
// write the active BASIC_RF_RX_INFO structure (pointed to by pRRI).
// ARGUMENT: BASIC_RF_RX_INFO * pRRI
// The reception structure, which contains all relevant info
// about the received packet.
// RETURN VALUE: BASIC_RF_RX_INFO*
// The pointer to the next BASIC_RF_RX_INFO structure to be used
// by the FIFO ISR.
// If there is only one buffer, then return pRRI.
BASIC_RF_RX_INFO* basicRfReceivePacket(BASIC_RF_RX_INFO *pRRI) {
    // Adjust the led brightness
    PWM_SET_DUTY_CYCLE(pRRI->pPayload[0]);
    // Blink the green LED
    SET_GLED();
    halWait(10000);
    CLR_GLED();
    // Continue using the (one and only) reception structure
    return pRRI;
} // basicRfReceivePacket
```

**Listing 2**—Things are just as simple on the transmission side. This excerpt from the same file as Listing 1 shows you how to respond to events by transmitting information using the basicRfSendPacket function provided in the RF library.

```
// The main loop:
while (TRUE) {
    // Sample the pot meter value
    ADC_SAMPLE_SINGLE();
    ADC_GET_SAMPLE_8(ledDutyCycle);
    // If the dimmer value has changed by more than 1, then
    // transmit the new value automatically
    // Transmit also when the S2 button is pressed
    dimmerDifference = (ledDutyCycle & 0xFF) - pTxBuffer[0];
    if((ABS(dimmerDifference)>2) || (JOYSTICK_CENTER_PRESSED())) {
        pTxBuffer[0] = ledDutyCycle;
        if (basicRfSendPacket(&rTxInfo)) {
            // OK. Blink the yellow LED
            SET_YLED();
            halWait(50000);
            CLR_YLED();
        } else {
            // No acknowledgment received -> Blink the red LED
            SET_RLED();
            halWait(50000);
            CLR_RLED();
        }
    }
}
```

ple MAC (SMAC) software with which you can establish simple point-to-point or star proprietary network topologies. You can also download the 802.15.4 MAC source code for free and use it with higher-level routines. Metrowerks's CodeWarrior development studio for HCS08 microcontrollers is included. The on-board peripherals include two accelerometers, some switches, LEDs, and an RS-232 port for monitoring and flash memory programming.

The MC13192's lack of an on-chip transmit/receive switch is a potential disadvantage. The evaluation kit overcomes this with no increase in the bill of materials by using separate transmit and receive antennas. This less integrated approach results in a smaller package size, but you'd need an external transmit/receive switch in applications requiring a single antenna. The advantage of excluding the internal transmit/receive switch on-chip is that an external power amplifier can be used to boost the signal for greater range. However, both the Freescale and Chipcon ICs already have a transmission power of 1 mW, which is

twice the minimum required by the ZigBee specification.

Chipcon, Atmel, and Freescale will bundle their hardware with a ZigBee software stack developed by Figure 8 Wireless. ZMD is another main player with silicon. Its ZMD44101 is in the 868- to 928-MHz bands. ZMD is optimizing for a lower data rate of 40 kbps, which should make it a good choice for devices that require the most reliable communications at the maximum range.

According to William Craig, program manager for wireless communications at ZMD, the IEEE 802.15.4 standard provides for one channel (868.3 MHz) in Europe because of bandwidth limitations. The sub-1-GHz band is desirable for RF characteristics, where range and attenuation are at issue. Even more desirable is an increased frequency range providing more channels for the IEEE 802.15.4. ETSI may consider this requirement, William said. The ZMD44101 Fractional-N RF\_PLL design provides for software-controlled frequency selection that will accommodate emerging frequency standards. There is a

1% duty cycle restriction in Europe for 868 MHz, which means that it's currently suitable only for RFD end devices.

Atmel is also initially focusing only on the low bands with its AT86RF210 Z-Link transceiver and matching AT86ZL3201 Z-Link controller. It will offer a 2.4-GHz version of the transceiver IC before developing a single-chip solution.

As with Freescale, the ZigBee craze seems to be an excuse to hawk general-purpose components relabeled as "ZigBee-compatible." There are a few special features on these microcontrollers such as hardware AES encryption and a specialized random number generator. However, transceiver chips such as the CC2420 already do this in hardware, thereby allowing you to choose a true general-purpose microcontroller or reuse one from an existing application.

One advantage is that the Atmel two-chip solution turns into a one-stop package for an entire ZigBee solution. The transceiver and microcontroller, including 802.15.4 in ROM and a ZigBee protocol stack sharing the 32-KB

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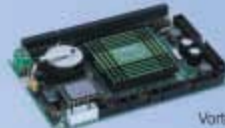
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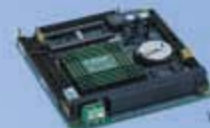
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	Chipcon CC2420 (Ember EM2420)	Freescale MC13192	ZMD ZMD44101	Atmel AT86RF210
PHY frequencies	2.4 GHz	2.4 GHz	Sub 1 GHz	Sub 1 GHz
Transmit receive switch	Built in	Not built in: Use two antennas or an external TR switch	Built in	Built in
Package size	7 × 7 mm	5 × 5 mm	7 × 7 mm	7 × 7 mm
Output power	1 mW	1 mW	1 mW	4 mW
Receive sensitivity (with 1% packet error rate). <sup>*</sup> 802.15.4 requires only -85 dBm.	-94 dBm	-92 dBm	-100 dBm	-95 dBm
Adjacent channel rejection (5 MHz). <sup>*</sup> 802.15.4 requires only 0 dB.	39 dB	23 dB	30 dB	23 dBm
Alternate channel rejection (10 MHz). <sup>*</sup> 802.15.4 requires only 30 dB.	53 dB	35 dB	40 dB	40 dBm
AES encryption	Supported by hardware	Relies on the companion microcontroller to carry out this function	Relies on the companion microcontroller to carry out this function	Relies on the companion microcontroller to carry out this function
CRC	Supported by hardware	Supported by hardware	Supported by hardware	Companion microcontroller has hardware support for this function
Other MAC support functions (link quality, clear channel assessment, transmit and receive FIFOs, and CRC checking)	Supported	Supported	Supported by hardware and microcontroller	Supported
Available now?	Yes	Yes	Yes	Yes
<sup>*</sup> Rejection and sensitivity figures may not be quoted with the same test setup in all cases. Consult the respective datasheets for more information.				

Table 1—On paper, the transceivers appear to offer similar functionality. The CC2420 costs \$2 in large volumes, and is obtainable for approximately \$10 per unit.

flash memory with your application, are sold together for \$6.75 in large quantities. Figure 8 Wireless supplies this ZigBee protocol software to Freescale, Chipcon, and Atmel. This will surely be one of the easiest ways to implement a ZigBee device at home. With the controller available in a 64-lead TQFP, or QFN, and the transceiver in a 48-pin QFN, it's still feasible to place these ICs on your own hand-soldered board.

Refer to Table 1 for a comparison of the four aforementioned transceivers. Some criteria (e.g., sensitivity) cannot be compared directly when considering transceivers supporting different PHY frequencies.

## FAST ENOUGH?

ZigBee is optimized for low-power operation, so its data rate isn't as high as Bluetooth or 802.11. If throughput is your biggest concern when designing your new wireless network, you should first address the question of speed. If you have any doubts about 802.15.4 throughput for your application, you can download a free network simulation tool and a model of 802.15.4 supporting Beacon mode.

By altering the numerous param-

eters, you'll be able to see if the network performance you want will be possible in terms of latency, throughput, power, and the number of nodes. The network simulation software is called ns2 (from the University of California, Berkeley). The 802.15.4 networking model was developed by the University of Southern California's Autonomous Networks Research Group. (Refer to the Resources section of this article for more information.) With these tools you can quell your doubts before committing to buying or developing hardware and software.

## WHERE TO NEXT?

After ZigBee is established, it will take over some applications where Bluetooth and other PANs or cable replacement technologies are currently in use. For the consumer, however, the biggest change will have to do with new applications that suddenly become economical after ZigBee reaches critical mass.

A wireless smoke detector serves as an example of a cost-reducing application. A smoke detector that hooks up to a home security system costs approximately \$40. Add the wiring and installation charges, and your

looking at a \$90 price tag. Smoke alarms without built-in communications cost as little as \$6. After manufacturers implement industry-wide ZigBee profiles for smoke alarms and security systems, you'll be able to add in a wireless smoke detector for roughly \$10. Upgrading an existing security system base station with a ZigBee adaptor would be a cost-effective solution, even if you're adding only a single ZigBee smoke sensor or intruder detector.

The key hanger is an example of a new application. Right now, you probably use an RF key fob to remotely lock and unlock your car. Well, Freescale recently demonstrated a ZigBee solution that adds functionality to these devices. The ZigBee network will alert you when you misplace your keys. Say your cell phone and key fob are ZigBee nodes. The cell phone is the coordinator. The cell phone knows when it's home because it recognizes the other ZigBee nodes (e.g., a garage door lock, a universal remote, etc.). When these nodes are out of range, the cell phone assumes you're out and about. If your keys leave the cell phone's communication range, the phone will alert you before you get too far away.

# BitScope Pocket Analyzer

## USB Oscilloscope & Logic Analyzer

The new generation Scope  
for the age of microelectronics.



### 8 Channel 40MS/s Logic Analyzer

Capture digital signals down to 25ns with arbitrary trigger patterns.

### 3 Input 100MHz Analog DSO

Classic Analog Scope using a standard x1/x10 BNC probe. Additional inputs on the POD for dual channel operation.

### 8 + 1 Mixed Signal Scope

True MSO to capture an analog waveform time-synchronized with an 8 channel logic pattern triggered from any source.

### Real-Time Spectrum Analyzer

See the spectrum and waveform of analog signals simultaneously and in real-time

### Waveform Generator

Load up to 32K arbitrary waveform and replay via the onboard DAC (10MS/s) or a digital pattern from the POD (40MS/s)

### Turn your PC or NoteBook into a powerful Scope and Logic Analyzer!

See inside your circuit in the analog and digital domains at the same time to make tracking down those elusive real-time bugs much easier.

Pocket Analyzer combines a high speed sample-synchronized storage scope and logic analyzer with a programmable waveform and logic pattern generator. Also included is an integrated real-time spectrum analyzer and powered "Smart POD" expansion interface so you've got all bases covered!

About the same size and weight as a Pocket PC, this USB powered BitScope needs no bulky accessories. It's the perfect low cost "go anywhere" test and debug solution.



### Standard 1M/20pF BNC Input

200uV-20V/div with x10 probe  
S/W select AC/DC coupling  
S/W select 50ohm termination  
Arbitrary Waveform Generator

### BitScope "Smart POD" Connector

8 logic channels, 2 analog channels  
Dual channel capture from POD A/B  
Async serial I/O for external control  
Logic Pattern generator 32K 40MS/s

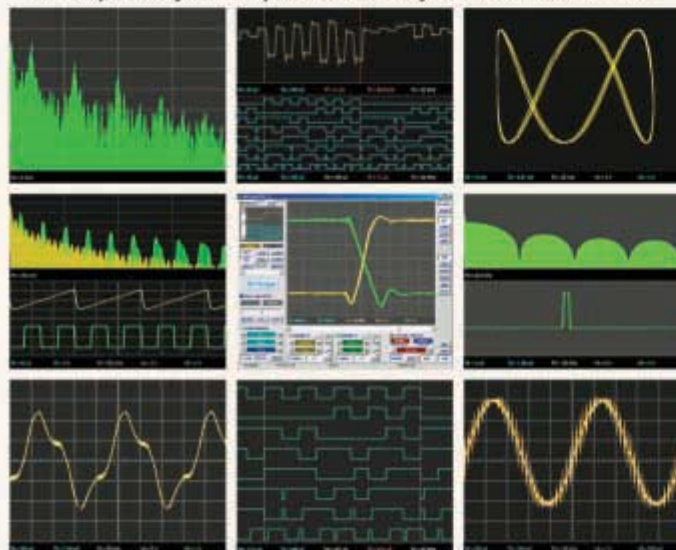
### BUS Powered USB 2.0 Device

Single USB cable to your PC  
Compressed data transmission  
Simple ASCII control protocol  
BitScope Scripting Language

### External/Pass thru Power Supply

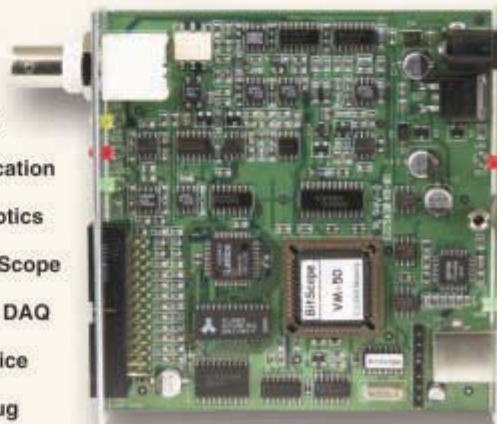
Auto senses an external supply -  
removes power load from USB  
for use with unpowered hubs.  
Supplies up to 500mA via POD

### BitScope and your PC provide an array of Virtual Instruments



BitScope DSO 1.2 software for Windows and Linux

- R&D
- Education
- Robotics
- Lab Scope
- Fast DAQ
- Service
- Debug



BitScope Pocket Analyzer uses highly integrated Surface Mount technology to provide functionality you would expect from scopes many times the size and price. Its programmable Virtual Machine architecture means new functionality can be added via software. For custom Data Acquisition, export directly to your spreadsheet.

[www.bitscope.com](http://www.bitscope.com)



The scheme could be applied to other devices too. No more lost sunglasses!

ZigBee is poised to become ubiquitous in home offices and factories, but I think the market may be overestimated. I'm a little skeptical about wireless technologies like ZigBee being relied on to control at least half of the functions inside commercial premises and certainly in most applications inside a wafer fabrication plant or auto factory. Sure, security is built in, but what if some malevolent person turns up with a high-power, wideband jamming device? DSSS is good at ignoring wideband noise up to a certain threshold, whereupon performance rapidly decays to nothing. Ditto for most other wireless systems.

Such an approach doesn't target the security layer. It simply makes transmission impossible because the clear channel assessment would always indicate a busy channel. Short-range versions used for prohibiting cell phone usage have been around for years. You can bet that these will be sold illegally on the 'Net to target the appropriate bands, if they aren't already.

Obviously, ZigBee nodes in a building will have sensible built-in behavior just in case communication fails. At worst, a sophisticated arsonist might want to defeat all smoke detectors in a certain area. At best, customers at a petrol station will be unable to pump petrol or pay for their purchases while some larrikin smirks knowingly from across the road. What if the business next door to the scene of the prank is operating a crane with a ZigBee-enabled emergency stop switch? Put simply, you need a secure physical medium such as copper or fiber (not air) connecting serious business assets. Wireless is for convenience rather than critical functions.

## NOW'S THE TIME

Until now, it has been difficult to make a real ZigBee node on a tight budget. Although ZigBee-compatible hardware has been readily available for more than six months, the software stack above the 802.15.4 layers is only now obtainable for free. The modest Atmel chipset price includes the ZigBee stack under sub-license at no additional charge. Other vendors are sure to follow suit.

For hardware, ready-built PCBs in

the form of evaluation kits are the easiest approach. Transceiver boards from Chipcon with the CC2420 are \$50 each. Freescale's 13192DSK evaluation kit with a microcontroller implementing an 802.15.4 MAC and RS-232 interface costs \$200 a pair.

There are a number of options for building your own hardware at a much lower cost. The components alone are less than \$15 per node in low quantities. Refer to the Resources section if you're interested in obtaining the schematics, BOMs, and PCB layouts.

Several vendors currently offer full-featured ZigBee development tools for the higher layers, but they're expensive. Sounds like an excellent idea for an open-source community-based project! In the meantime, you can use the same physical layer that ZigBee uses along with the free MAC source code from Chipcon and Freescale. You can do a simple star topology network using the MAC layer and a few of your own functions to complete a rudimentary ZigBee-like network. If you take this approach, your hardware will be fully ZigBee-compatible. If you plan on applying more sophisticated software as it becomes easier to obtain, you can begin ZigBee development immediately. Do you act now, or do you let the ZigBee zephyr pass you by? ☒

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