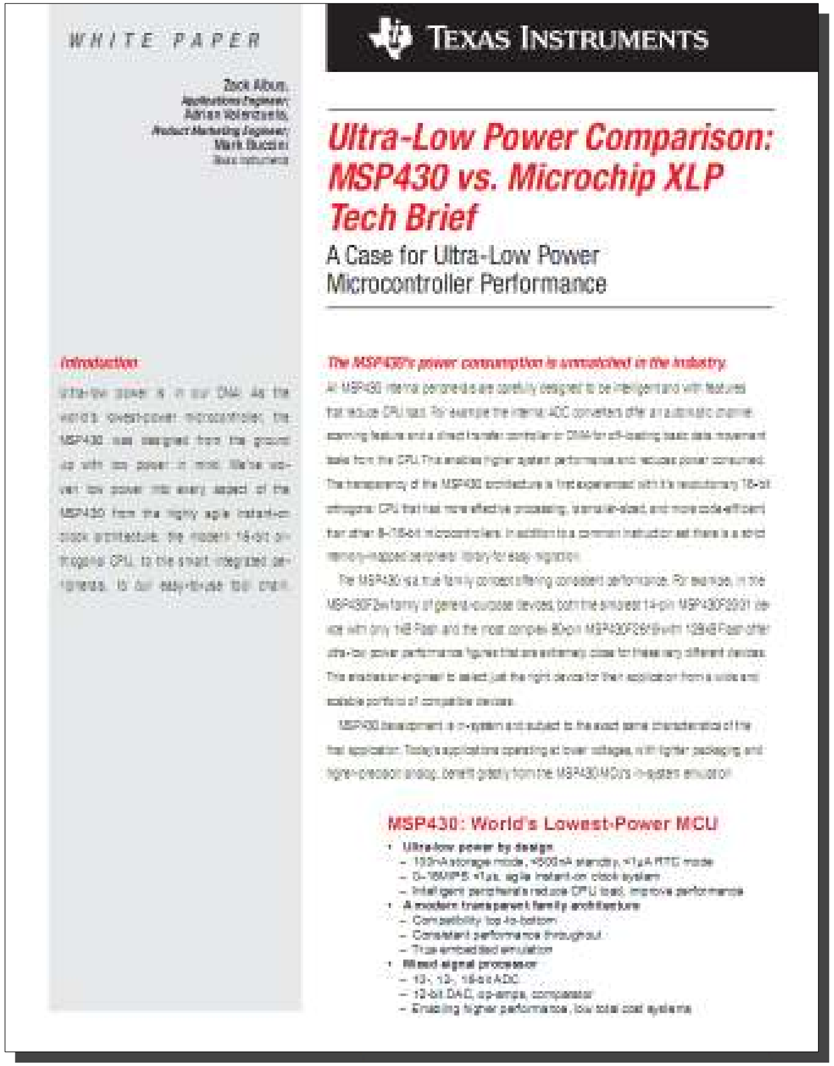
超低功耗（eXtreme Low Power）PIC®单片机

驳TI“白皮书”SLAY015
（简要版本）

TI的白皮书包含了哪些内容？

杜撰还是事实……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Ultra-Low Power Comparison: MSP430 vs. Microchip XLP Tech Brief

A Case for Ultra-Low Power Microcontroller Performance

Introduction

The MSP430's power consumption is unmatched in the industry

MSP430: World's Lowest-Power MCU

http://focus.ti.com/lit/wp/slay015/slay015.pdf

- 详细阐述了**TI**关于**MSP430**与**PIC24 XLP**之间差别的观点
  - 回顾了MSP430低功耗产品发展历程
  - 声称其CPU和外设具有超低功耗DNA
  - 主要关注MSP430F2xxx
- 针对**XLP**提出了**8**个基本论点
  - 所有MSP430器件具有一致的低功耗性能
  - 质疑1.8V规范
  - MSP430是全球功耗最低的MCU
  - 对LPM4（休眠）与深度休眠进行了比较
  - 声称深度休眠模式是“危险的”模式
  - MSP430在电池工作寿命个案研究中获胜
  - MSP430比XLP具有更快的唤醒速度
  - MSP430的执行速度要比XLP快2倍

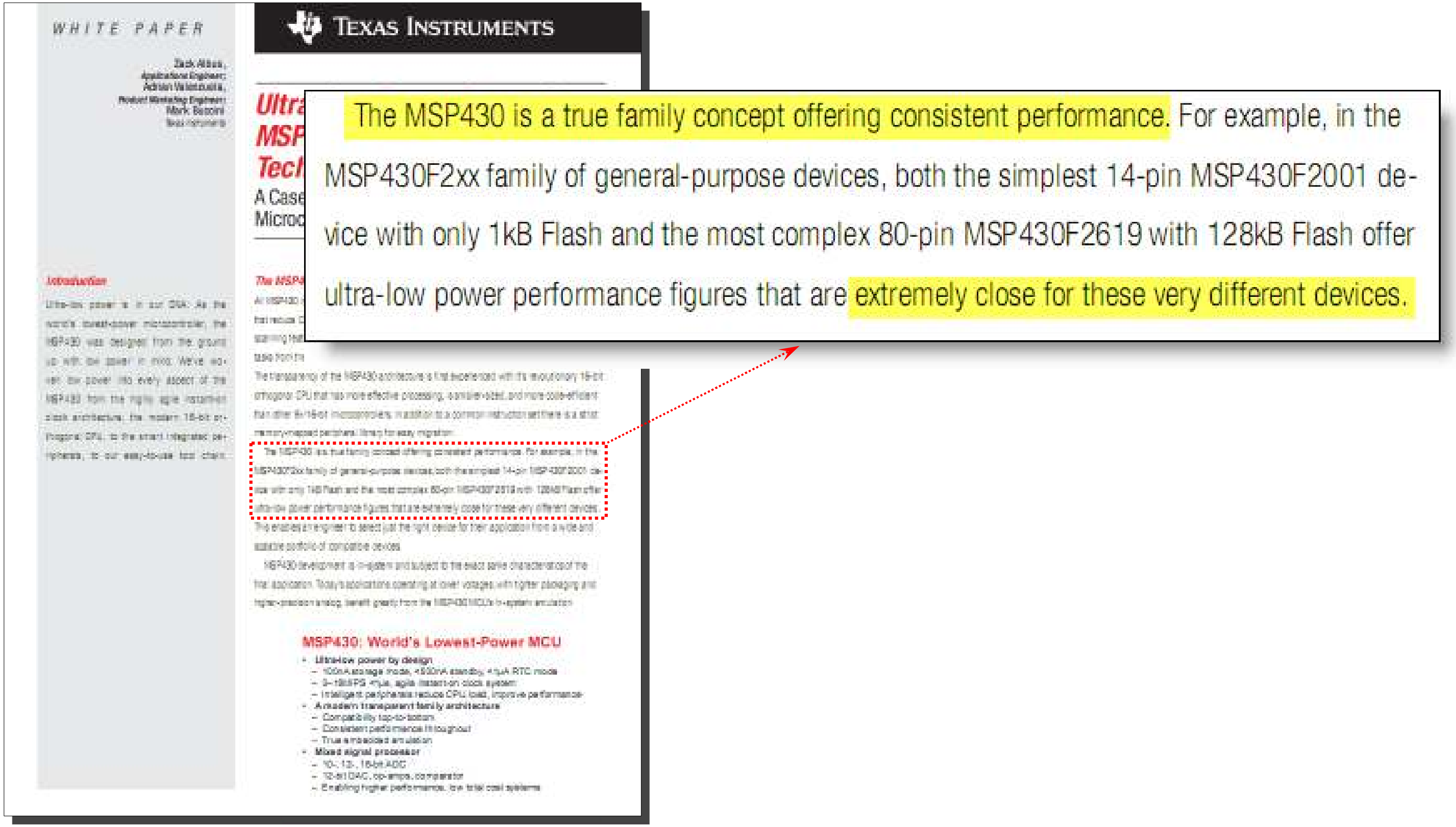
需要了解的事情……

- **XLP**推广活动第一阶段取得成功……
- **XLP**追使**TI**采取防守……

- “白皮书”并不准确！
- **XLP**产品极具竞争力
- 我们的产品具有“全球最低的休眠电流”
- **XLP**产品的电池寿命无可比拟

- 更多**XLP**产品即将推出！

TI论点 #1：
MSP430系列具有始终如一的性能
杜撰还是事实？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The MSP430 is a true family concept offering consistent performance. For example, in the MSP430F2xx family of general-purpose devices, both the simplest 14-pin MSP430F2001 device with only 1kB Flash and the most complex 80-pin MSP430F2619 with 128kB Flash offer ultra-low power performance figures that are extremely close for these very different devices.

MSP430: World's Lowest-Power MCU

- Ultra-low power by design
- A modern transparent family architecture
  - Consistent performance throughout
- Mixed signal processor

TI论点 #1：
系列之间的电流消耗相近
数据手册值

TI器件（3.0V时的典型值，来自数据手册）	闪存与引脚	LPM5（关闭）（nA）	LPM4（存储）（nA）	LPM3 + WDT（nA）	LPM3 + RTC（简单定时器）（nA）	运行模式 8MHz，采用INTOSC/DCO “省电式”（mA）
MSP430F2001	1-2KB 14引脚	n/a	100	[illegible]	900	2.0
MSP430F2252	8-32KB 40引脚	n/a	[illegible]	[illegible]	900	2.8
MSP430F2619	92-120KB 64-80引脚	n/a	[illegible]	600	1100	4.3
MSP430F553x	192-256KB 80-100引脚	100	1690	1800	2600	1.1

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- *LPM4电流变化量为1700%*
- *WDT电流变化量为360%*
- *RTC电流变化量为290%*
- *运行电流变化量为390%*

TI论点 #2：Microchip通过展示XLP 的1.8V数据而非3.0V数据进行“误导”

杜撰还是事实？

Microchip's application report and video compares the PIC24F XLP specifically to the MSP430. The fundamental claim is that the PIC24F XLP is lower power compared to the MSP430F2xx – this is also demonstrated in a video using a special Microchip measurement board. What is misleading and causes error are the unrealistic use-case conditions. For example, testing at 1.8V is unusual with few real-world sources – perhaps two discharged alkaline batteries? Most ultra-low power systems are powered directly from a 3V lithium coin-cell battery for low cost and a long run time because of its very low leakage. Another common battery solution is two fully charged alkaline batteries at 3.3V. The benchmark needs to be shifted closer to a real-world 3V supply. In the report and in the video, modes of operation are shown that disable BOR

Application Report AN1267A?

- 1.8V?
- No BOR?
- RAM?
- Deep Sleep wakeup?
- Crystal included?
- Clock source included?
- Add together what?
- Most ULP systems are 3V battery powered

protection and remove power to RAM – these techniques will reduce power but are both a dangerous and an inconvenient practice. The importance of brown out is clear for any application in which batteries could be replaced or power could be disrupted for any reason. In the example where RAM is de-powered and the content lost, this lost data would likely be stored temporarily into on-chip Flash. With the PIC24F XLP, this would be a Flash program operation that needs 10mA for 2ms for each 96-Byte block – this adds significant power consumption that is never mentioned.

It is important also to note that all XLP modes of operation require summing various adders together to get the total current for any mode – this is confusing and can be misleading. For example, the mentioned 195µA for PIC24F XLP "1MHz run" is just for the CPU with an external square wave clock source. Because of a /2 divider to the CPU, the CPU clock is running at only 500kHz at 1.8V and does not include the internal clock

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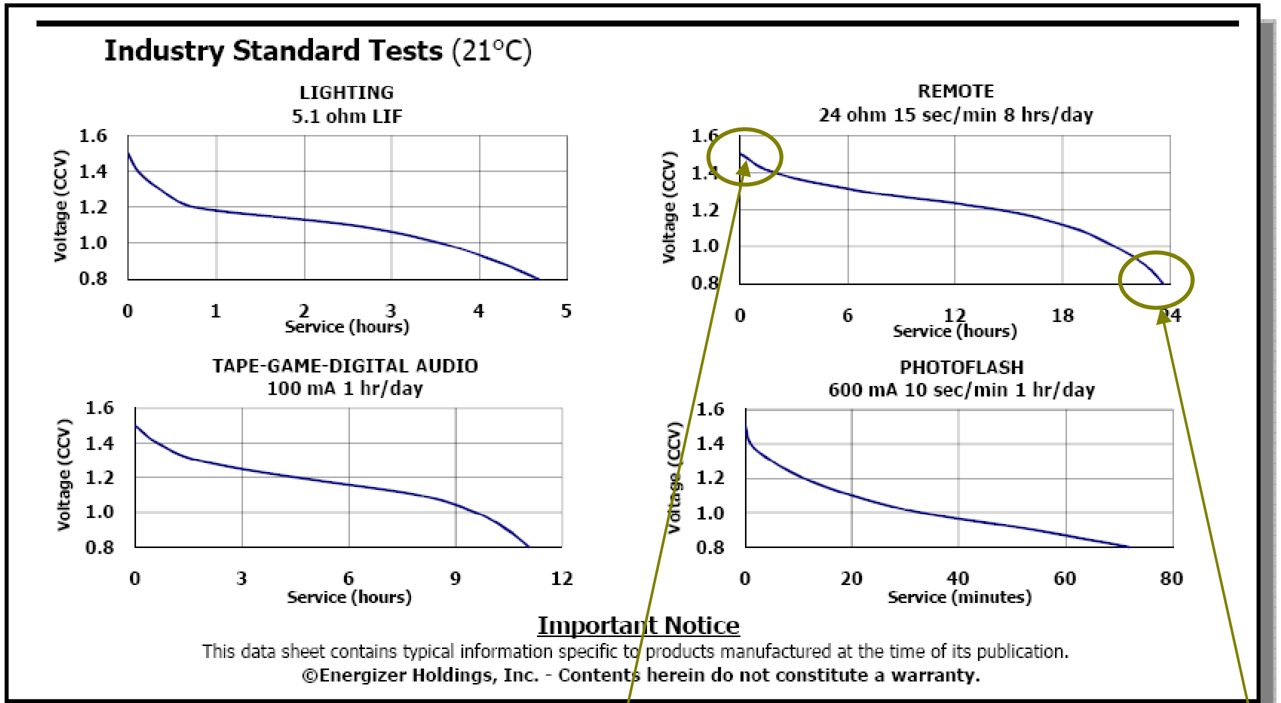
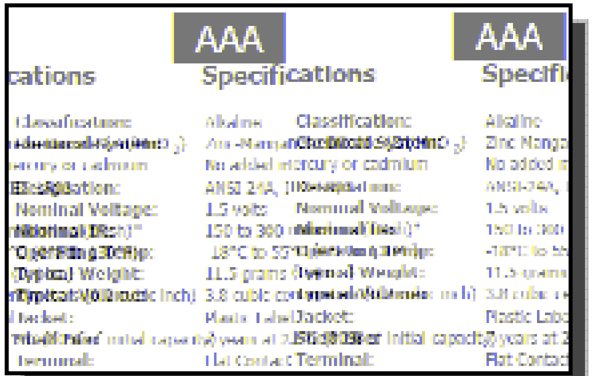
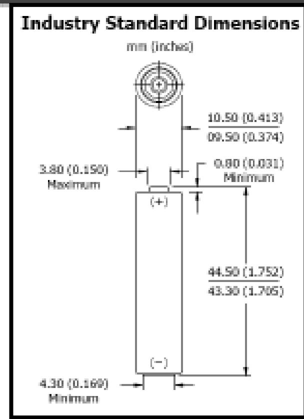
现实中不存在3V电池电源。锂离子钮扣电池和2节碱性电池都会相对快速地降至低于3.0V的标称电压。在其电池寿命期间，它们会分别降至2.5V和1.8V。设计人员必须在他们的应用中考虑这一点，以最大程度延长电池寿命。

碱性AAA电池规范







- 对于在室温（**20-25ºC**）下工作的典型碱性电池应用：
  - MCU需要在低于3V（2 x 1.5V）的电压下工作
  - 最大程度地延长电池寿命意味着需要能够在低至1.8V（2 x 0.9V）的电压下工作
  - 需要在最大电池寿命 = 1.8 – 3.0V这一工作范围内安全工作

来源：http://data.energizer.com/PDFs/E92.pdf

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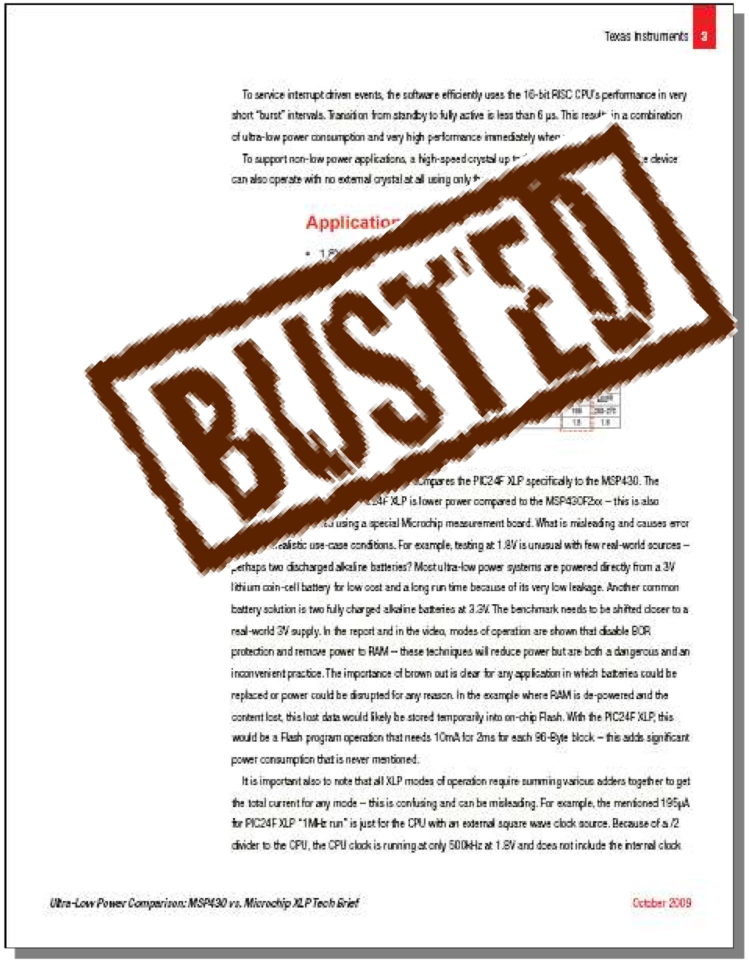
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To service interrupt driven events, the software efficiently uses the 16-bit RISC CPU's performance in very short "burst" intervals. Transition from standby to fully active is less than 6 µs. This results in a combination of ultra-low power consumption and very high performance immediately when

To support non-low power applications, a high-speed crystal up t… device can also operate with no external crystal at all using only th…

Applicatio…

- 1.8…

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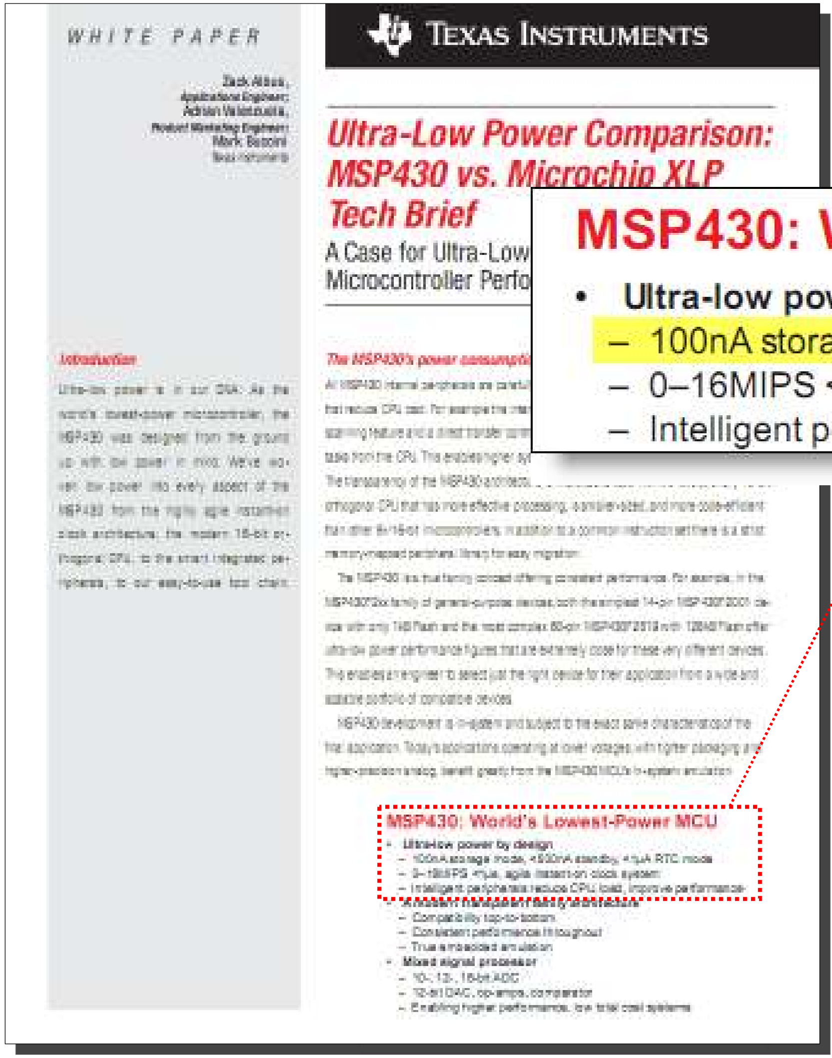
- 对于*超长*电池寿命，实际的**MCU使用的情形是……**
  - 碱性电池（2节）
    - 工作后，从3.0V降至1.8V
  - 锂离子电池
    - 工作后，从3.0V降至2.5V

TI论点 #3
全球功耗最低的MCU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A Case for Ultra-Low ... Microcontroller Perfo...

Introduction

MSP430: World's Lowest-Power MCU

MSP430: World's Lowest-Power MCU

- **Ultra-low power by design**
  - 100nA storage mode, <500nA standby, <1µA RTC mode
  - 0–16MIPS <1µs, agile instant-on clock system
  - Intelligent peripherals reduce CPU load, improve performance

- *MSP430F2xx is lower power compared to the PIC24F XLP in all modes of operation, by the datasheet and on the bench*
- *At a measured 700nA in a true 3V standby mode with self-wakeup, PIC24F XLP is 75% higher power compared to MSP430F20xx at 400nA*
- *When evaluating ULP MCUs be cautious of incredibly low marketing numbers such as "20nA deep sleep". These are often under unrealistic conditions such as 1.8V, no BOR, no RAM retention and no self wakeup – this is not a very useful state for a microcontroller.*

MSP430与PIC24F的在3V时的对比

数据手册值与（基准测试值）

MCU系列	闪存与引脚	休眠（nA）	休眠 + BOR（nA）	休眠 + WDT（nA）	休眠 + BOR + WDT（nA）	休眠 + BOR + RTCC（nA）	运行模式 8MHz，采用 INTOSC/DCO “省电式”（mA）
PIC24F16KA102 *深度休眠模式*	4-16KB 14-28引脚	28（40）	36（55）	440（450）	476（464）	676（670）	2.4（2.4）
PIC24F16KA102 *休眠模式*	4-16K[illegible] 14-[illegible]	84（120）	160（150）	780（805）	856（791）	724（848）	2.4（2.4）
MSP430F20[illegible] *休眠[illegible]*	[illegible]	[illegible]a	100	n/a	500	900	2.0
M[illegible]	[illegible]引脚	n/a	100（120）	n/a	600（427）	900（1500）	2.8（2.3）
M[illegible]19 *[illegible]式*	92-120KB 64-80引脚	n/a	200	n/a	600	1100	4.3

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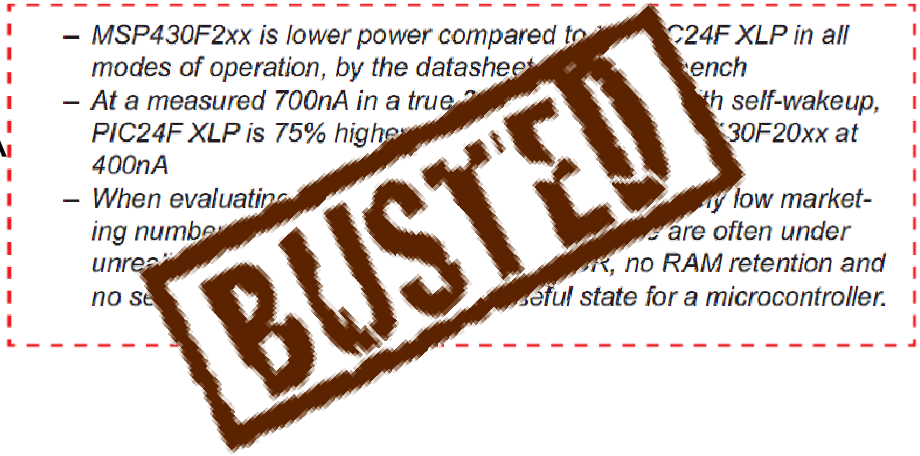
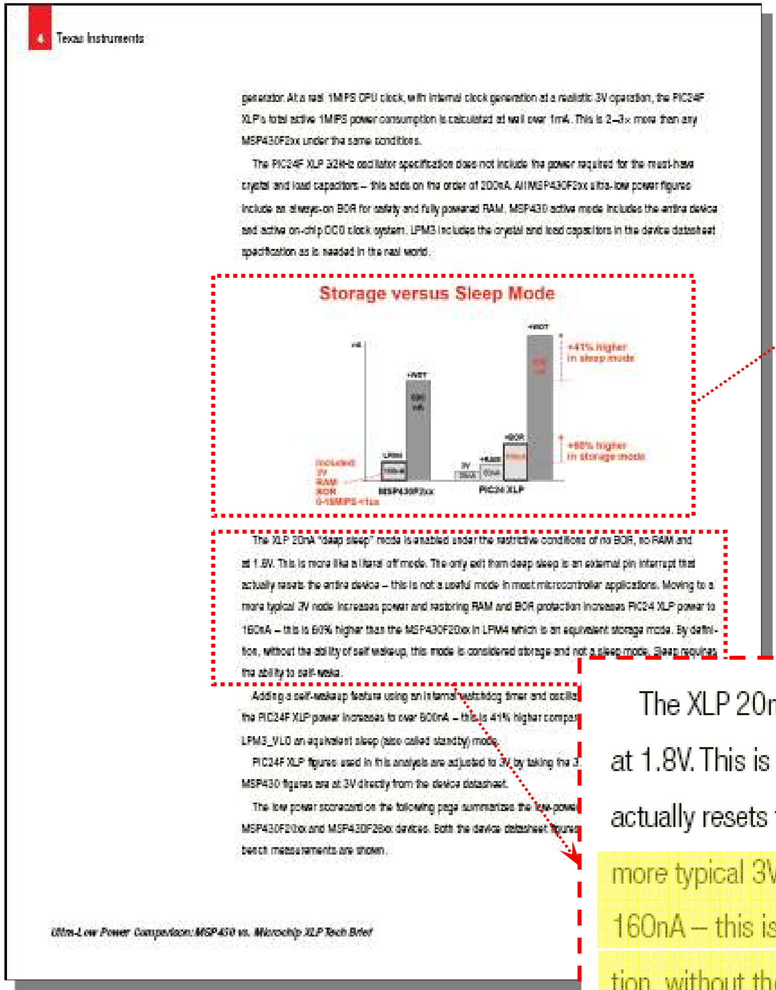
* 所有数据手册数值均为来自数据手册的典型值，根据TI白皮书方法乘以0.8而调整为3.0V时的值。
* 基准测试数值包含在圆括号中（基准测试值），在XLP销售的演示（如果提供的话）上测量得到。
* WDT和/或RTC数值中包含了基本休眠电流。

3.0V、25ºC时的功耗比较

- 采用BOR时的最低电流：
  - ***PIC24F16KA102：36nA*** ✓
  - MSP430F2619：200nA，F2013：100nA
- 采用BOR+WDT时的最低电流：
  - ***PIC24F16KA102：476nA*** ✓
  - MSP430F2619/F2013：600nA
- 采用BOR+32KHz时的最低电流：
  - ***PIC24F16KA102：0.8μA*** ✓
  - MSP430F2619：1.1μA，MSP430F2013：0.9μA
- 1MHz运行模式时的最低电流：
  - ***PIC24F16KA102：292μA/MHz*** ✓
  - MSP430F2619：515μA/MHz，MSP430F2013：300μA/MHz
- 16MHz运行模式时的最低电流：
  - ***PIC24F16KA102：3.0V x 4.4mA = 13.2mW*** ✓
  - *32MHz运行模式：PIC24F16KA102：3.0V x 8.8mA = 26.4mW*
  - MSP430F2619：3.3V* x 9.25mA = 30.5mW（* **以16MHz运行时，要求电压≥3.3V**）
  - MSP430F2013：3.3V* x 4.4mA = 14.5mW （* **以16MHz运行时，要求电压≥3.3V**）



TI论点 #4：
MSP430 LPM4在存储模式下击败XLP
杜撰还是事实？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generator. At a real 1MIPS CPU clock, with internal clock generation at a realistic 3V operation, the PIC24F XLP's total active 1MIPS power consumption is calculated at well over 1mA. This is 2–3× more than any MSP430F2xx under the same conditions.

The PIC24F XLP 32kHz oscillator specification does not include the power required for the must-have crystal and load capacitors – this adds on the order of 200nA. All MSP430F2xx ultra-low power figures include an always-on BOR for safety and fully powered RAM. MSP430 active mode includes the entire device and active on-chip DCO clock system. LPM3 includes the crystal and load capacitors in the device datasheet specification as is needed in the real world.

Adding a self-wakeup feature using an internal watchdog timer and oscilla[...] the PIC24F XLP power increases to over 600nA – this is 41% higher compa[...] LPM3_VLO an equivalent sleep (also called standby) mode.

PIC24F XLP figures used in this analysis are adjusted to 3V by taking the 3[...] MSP430 figures are at 3V directly from the device datasheet.

The low power scorecard on the following page summarizes the low-powe[...] MSP430F20xx and MSP430F28xx devices. Both the device datasheet figure[...] bench measurements are shown.

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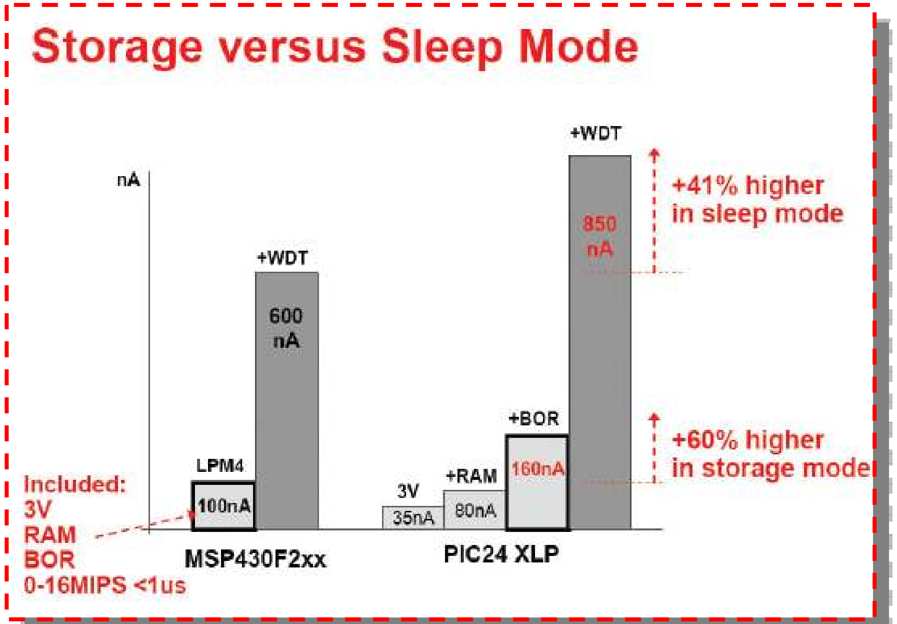
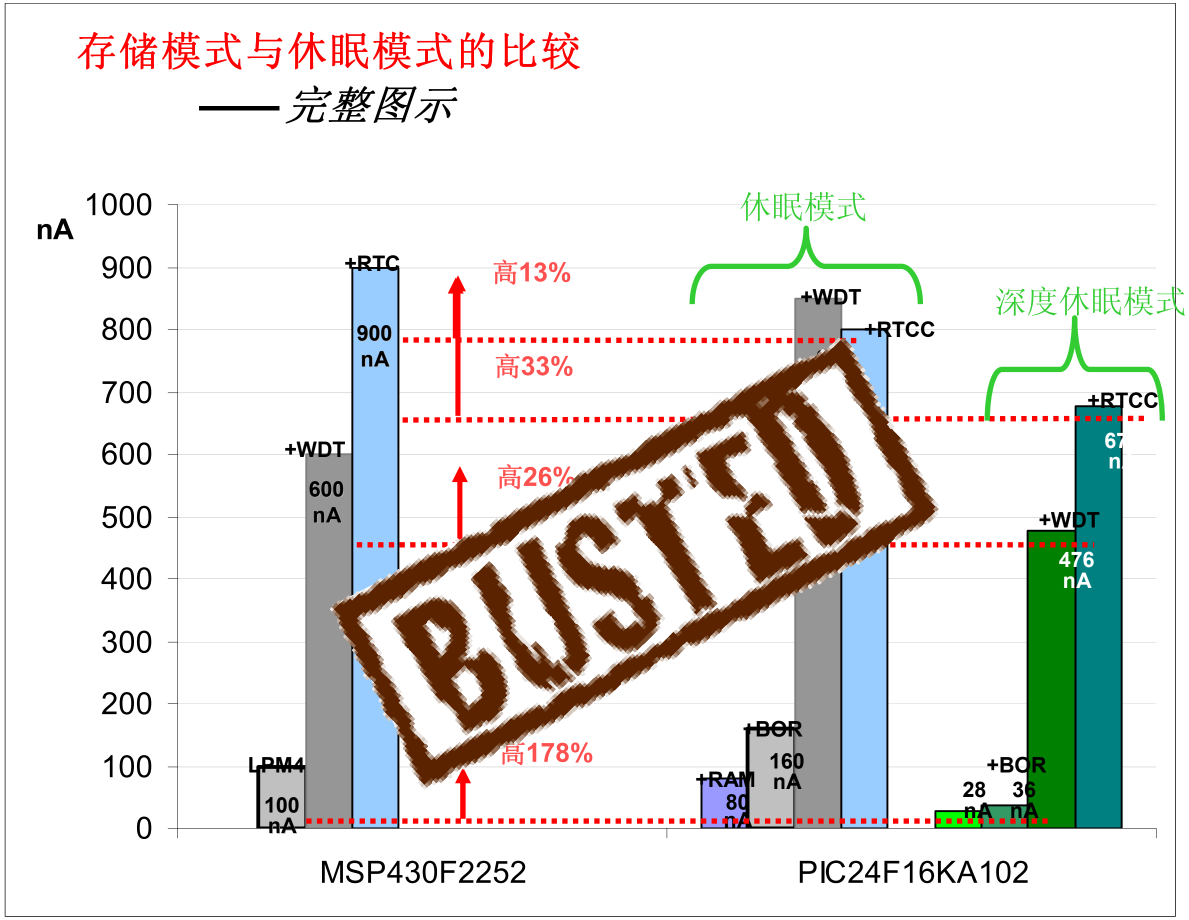


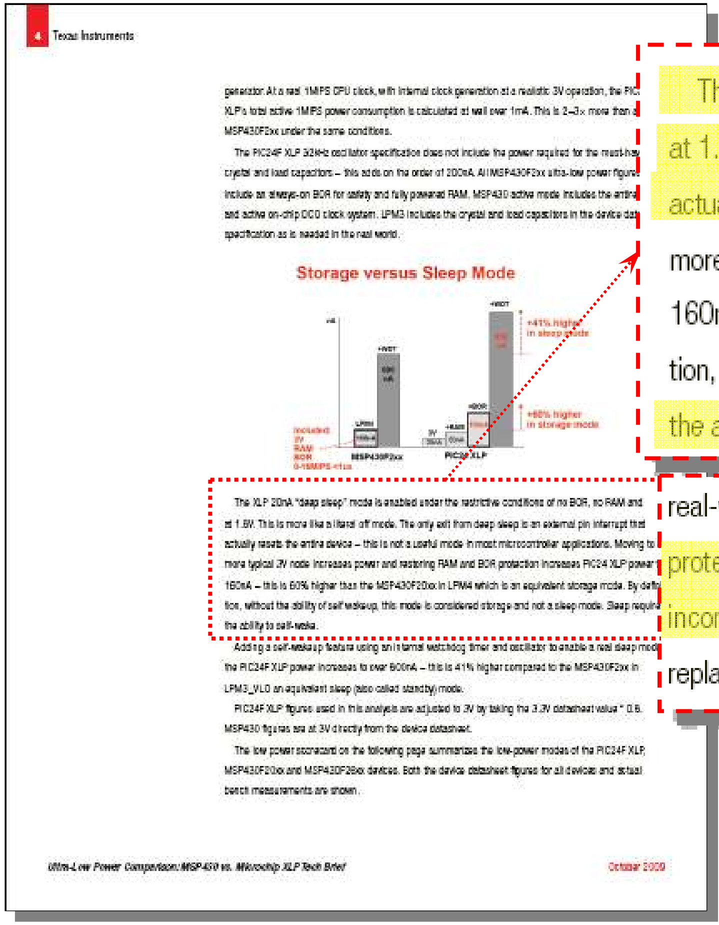
The XLP 20nA "deep sleep" mode is enabled under the restrictive conditions of no BOR, no RAM and at 1.8V. This is more like a literal off mode. The only exit from deep sleep is an external pin interrupt that actually resets the entire device – this is not a useful mode in most microcontroller applications. Moving to a more typical 3V node increases power and restoring RAM and BOR protection increases PIC24 XLP power to 160nA – this is 60% higher than the MSP430F20xx in LPM4 which is an equivalent storage mode. By definition, without the ability of self wakeup, this mode is considered storage and not a sleep mode. Sleep requires the ability to self-wake.

TI论点 #4：
MSP430 LPM4在存储模式下击败XLP
杜撰还是事实？



- ***TI选择不显示处于休眠模式时的RTC数据***
  - *MSP430的数据高出13%*
- ***TI选择不显示带唤醒功能的深度休眠的数据***
  - *MSP430的数据最高可高出33%*
- ***处于深度休眠模式的PIC24F16KA是功耗最低的选择***
  - *即使在3V时采用BOR*
  - *MSP430的数据高出178%*

TI论点 #5：
深度休眠是“危险的”、没用的模式
杜撰还是事实？



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real-world 3V supply. In the report and in the video, modes of operation are shown that disable BOR protection and remove power to RAM – these techniques will reduce power but are both a dangerous and an inconvenient practice. The importance of brown out is clear for any application in which batteries could be replaced or power could be disrupted for any reason. In the example where RAM is de-powered and the

深度休眠唤醒选项

10.2.4 DEEP SLEEP MODE

In PIC24F16KA102 family devices, Deep Sleep mode is intended to provide the lowest levels of power consumption available without requiring the use of external switches to completely remove all power from the device. Entry into Deep Sleep mode is completely under software control. Exit from Deep Sleep mode can be triggered from any of the following events:

- POR event
- $\overline{\text{MCLR}}$ event
- RTCC alarm (If the RTCC is present)
- External Interrupt 0
- Deep Sleep Watchdog Timer (DSWDT) time-out

In Deep Sleep mode, it is possible to keep the device Real-Time Clock and Calendar (RTCC) running without the loss of clock cycles.

The device has a dedicated Deep Sleep Brown-out Reset (DSBOR) and a Deep Sleep Watchdog Timer Reset (DSWDT) for monitoring voltage and time-out events. The DSBOR and DSWDT are independent of the standard BOR and WDT used with other power-managed modes (Sleep, Idle and Doze).

来源：PIC24F16KA102数据手册

- 实际上，深度休眠支持
  - BOR（确保安全性）
  - 自唤醒
- 深度休眠唤醒源
  - *深度休眠欠压*
  - *深度休眠看门狗*
  - *实时时钟/日历*
  - *深度休眠POR*
  - *外部中断*
  - *主复位*

TI有它自己的深度休眠方式

1.4.2 Entering and Exiting Low-Power Mode LPM5

LPM5 entry and exit is handled differently than the other low power modes. LPM5, when used properly, gives the lowest power consumption available on a device. To achieve this, entry to LPM5 disables the LDO of the PMM module, removing the supply voltage from the core of the device. Since the supply voltage is removed from the core, all register contents, as well as, SRAM contents are lost. Exit from LPM5 causes a BOR event, which forces a complete reset of the system. Therefore, it is the application's responsibility to properly reconfigure the device upon exit from LPM5.

The wakeup time from LPM5 is significantly longer than the wakeup tim ther power modes (please see the device specific datasheet). This is primarily due to exit from LPM5, time is required for the core voltage supply to be regenerated, as w ion before the application code can start. Therefore, the usage of LPM5 is ycle events.

If the application has l aximizing time in LPM5 can further reduce power co

来源：MSP430x5xx Users Guide slau208d

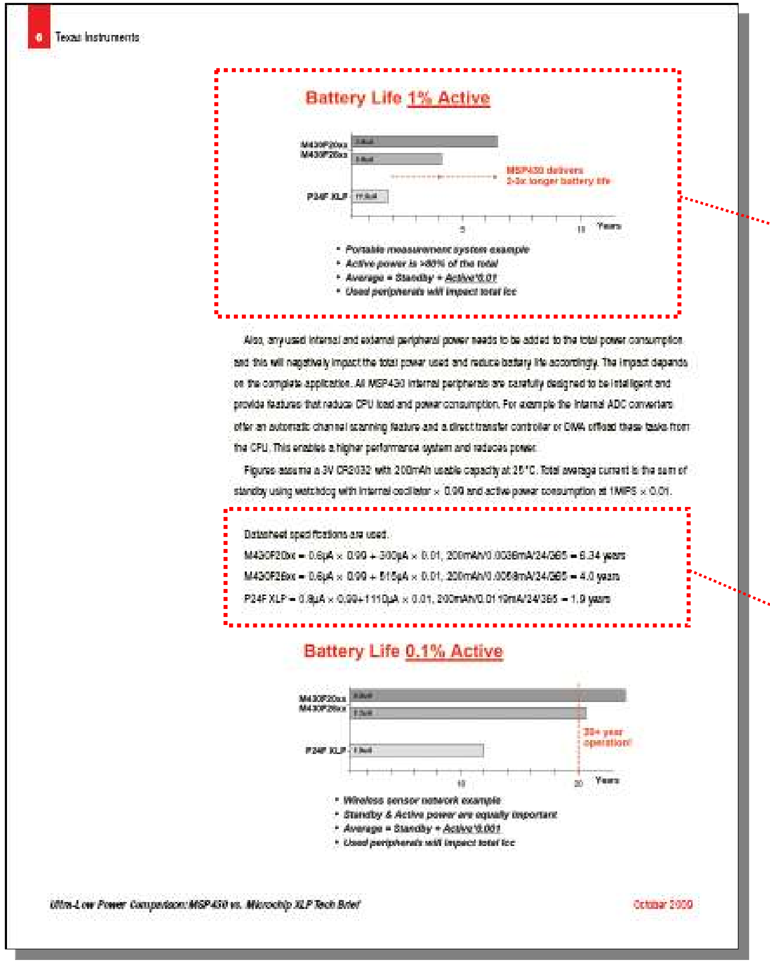
- **LPM5**是"危 没有自唤醒功能，也没有**BOR**功能
  - 仅有的唤醒源 SET或INT

I_{LPM5}	Low-power mode 5 (LPM5) current(7)	$f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz, $f_{ACLK} = 0$ Hz, PMMREGOFF = 1	$V_{CC} = 3$ V A versions only	–40°C	0.1	µA
				25°C	0.1	
				55°C	0.2	
				85°C	0.5	

(6) Current for brownout included.
(7) Internal regulator disabled. No data retention.

- *并且……其功耗比深度休眠高5倍！*

TI论点 #6：
在电池寿命方面，MSP430击败了PIC24F
杜撰还是事实？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Battery Life 1% Active

- Portable measurement system example
- Active power is >80% of the total
- Average = Standby + Active*0.01
- Used peripherals will impact total Icc

Also, any used internal and external peripheral power needs to be added to the total power consumption and this will negatively impact the total power used and reduce battery life accordingly. The impact depends on the complete application. All MSP430 internal peripherals are carefully designed to be intelligent and provide features that reduce CPU load and power consumption. For example the internal ADC converters offer an automatic channel scanning feature and a direct transfer controller or DMA offload these tasks from the CPU. This enables a higher performance system and reduces power.

Figures assume a 3V CR2032 with 200mAh usable capacity at 25°C. Total average current is the sum of standby using watchdog with internal oscillator × 0.99 and active power consumption at 1MIPS × 0.01.

Datasheet specifications are used.
M430F20xx = 0.6μA × 0.99 + 300μA × 0.01, 200mAh/0.0036mA/24/365 = 6.34 years
M430F26xx = 0.6μA × 0.99 + 515μA × 0.01, 200mAh/0.0058mA/24/365 = 4.0 years
P24F XLP = 0.8μA × 0.99+1110μA × 0.01, 200mAh/0.0119mA/24/365 = 1.9 years

Battery Life 0.1% Active

- Wireless sensor network example
- Standby & Active power are equally important
- Average = Standby + Active*0.001
- Used peripherals will impact total Icc

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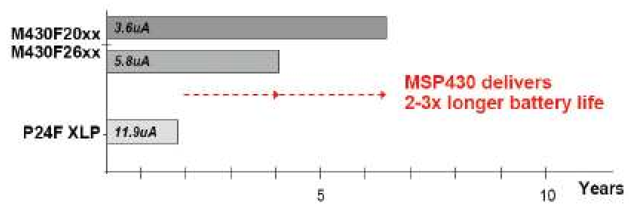

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- Average = Standby + Active*0.01
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Datasheet specifications are used.

M430F20xx = 0.6μA × 0.99 + 300μA × 0.01, 200mAh/0.0036mA/24/365 = 6.34 years

M430F26xx = 0.6μA × 0.99 + 515μA × 0.01, 200mAh/0.0058mA/24/365 = 4.0 years

P24F XLP = 0.8μA × 0.99+1110μA × 0.01, 200mAh/0.0119mA/24/365 = 1.9 years

- 对于**MSP430**，**TI**使用了典型值数据
- 对于**PIC24**，**TI**使用了最大值数据
- 未使用深度休眠数据

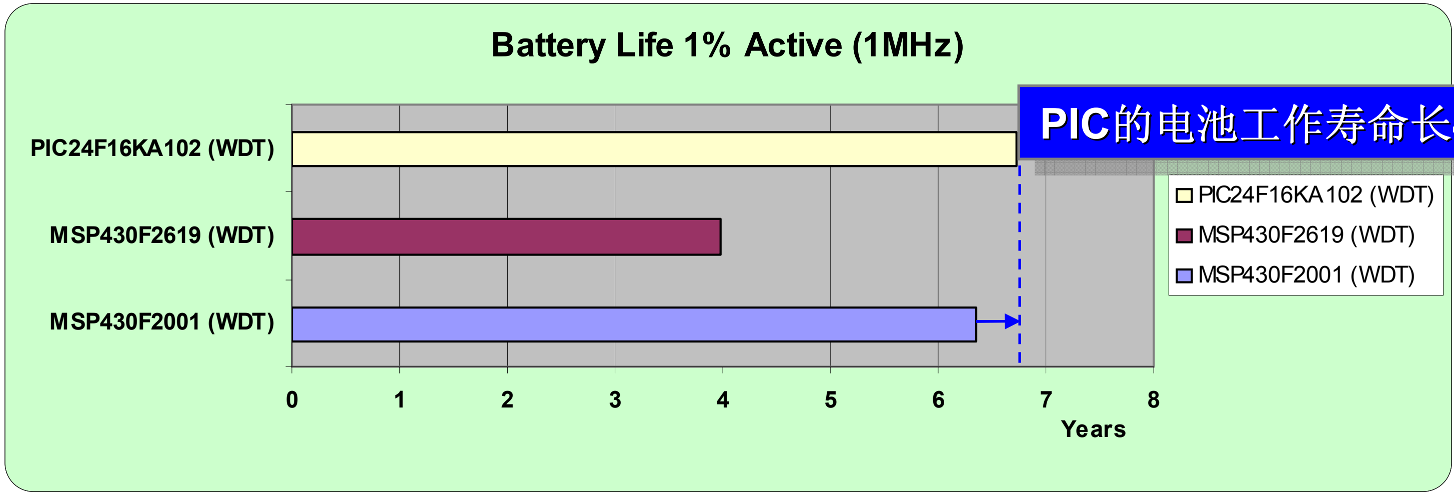
应用示例论点

杜撰还是事实？

PIC24模式：
3.0V、25ºC时的数据手册典型值
深度休眠（BOR+WDT）：99%
1MHz工作模式：1%

Profile	Time (%)	Capacity (mAh)
Time in Sleep (%)	99%	200
Time in Active (%)	1%	
Part	**Ave. Current uA**	**Years**
MSP430F2001 (WDT)	3.594	6.4
MSP430F2619 (WDT)	5.744	4.0
PIC24F16KA102 (WDT)	**3.391**	**6.7**

MSP430模式：
3.0V、25ºC时的数据手册典型值
LPM3（BOR+WDT）：99%
1MHz工作模式：1%



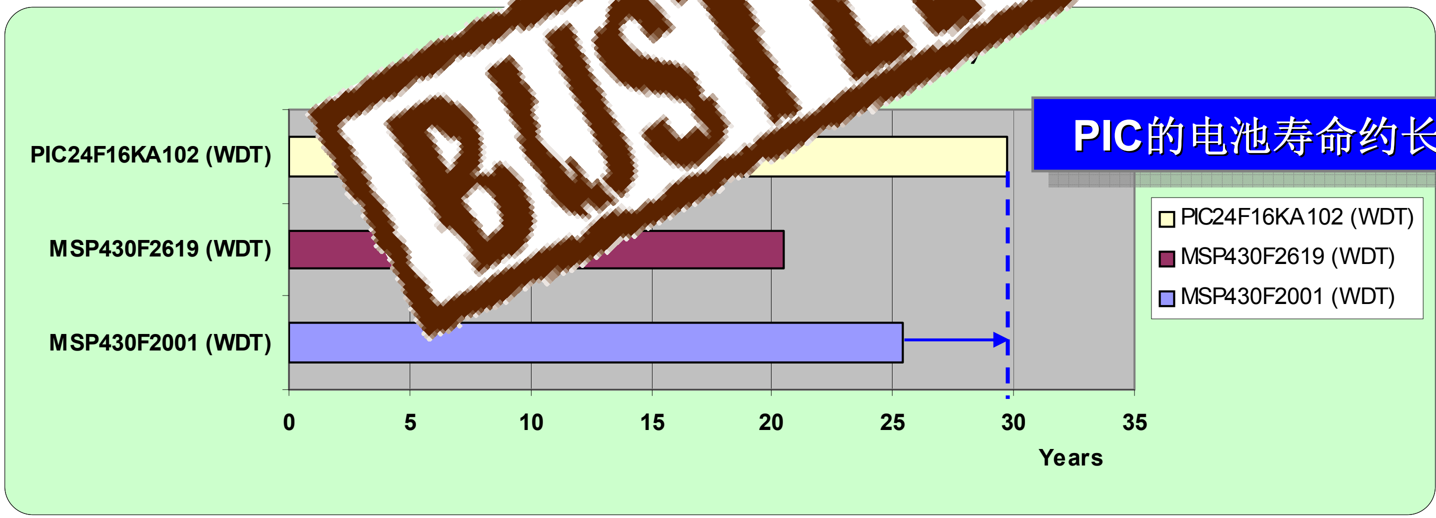
PIC的电池工作寿命长4个月！

应用示例观点
杜撰还是事实?

PIC24模式:
3.0V、25ºC时的数据手册典型值
深度休眠模式（BOR+WDT）：99.9%
1MHz工作模式：0.1%

Profile	Time (%)	Capacity (mAh)
Time in Sleep (%)	99.9%	200
Time in Active (%)	0.1%	
Part	**Ave. Current uA**	**Years**
MSP430F2001 (WDT)	0.899	25.4
MSP430F2619 (WDT)	[illegible]	20.5
PIC24F16KA102 (WDT)	[illegible]	[illegible]

MSP430模式：
3.0V、25ºC时的数据手册典型值
LPM3（BOR+WDT）：99.9%
1MHz工作模式：0.1%



MSP430F2xxx规范

- 以16MHz运行时，MSP430F2xxx要求电压≥**3.3V**
  - 并不是很省电
- **3.0V时，MSP430F2xxx的最大速度 = 12MHz**

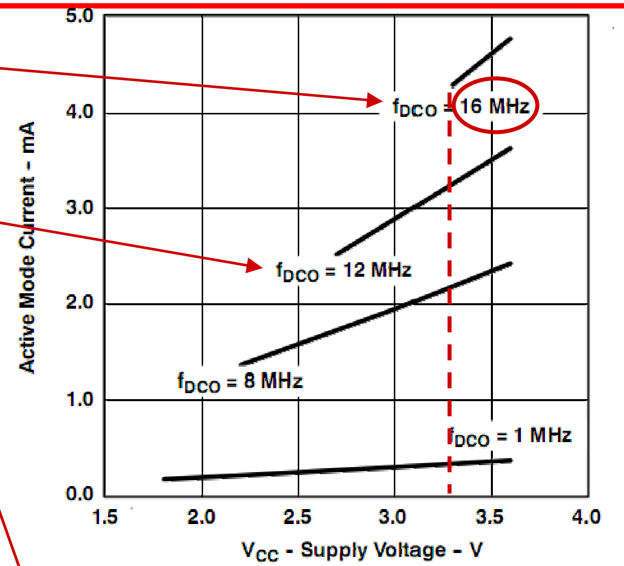
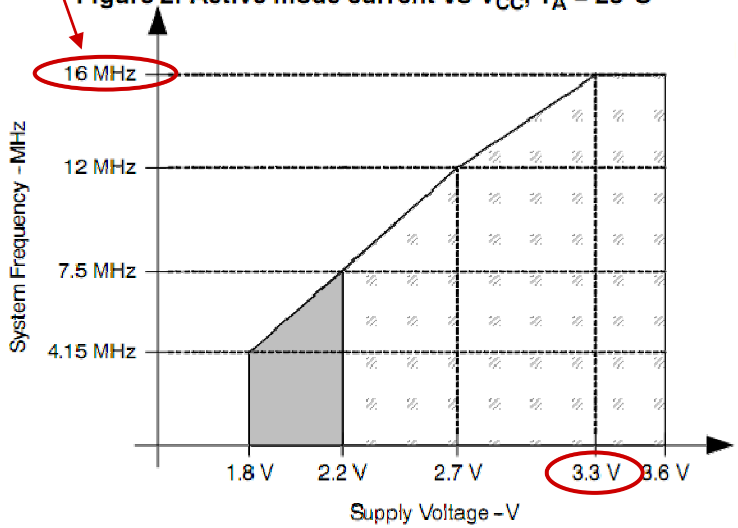


Figure 2. Active mode current vs V_{CC}, T_A = 25°C

recommended operating conditions

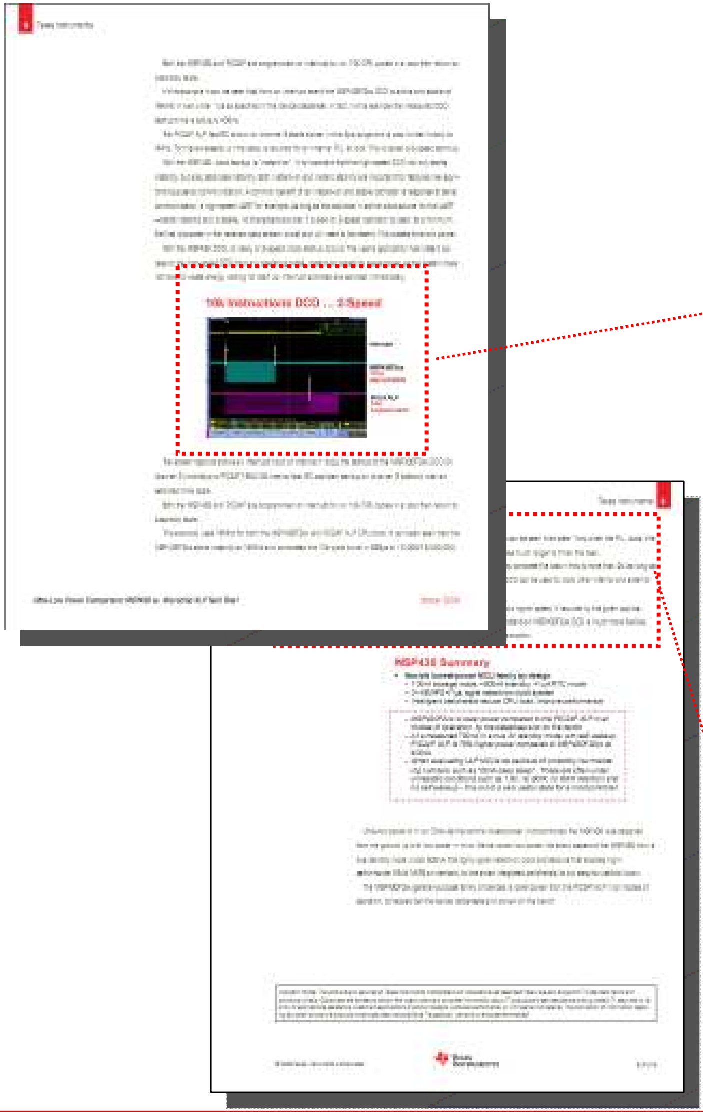
PARAMETER		MIN	MAX	UNIT
Supply voltage during program execution, V_{CC}	$AV_{CC} = DV_{CC} = V_{CC}$ (see Note 1)	1.8	3.6	V
Supply voltage during flash memory programming, V_{CC}	$AV_{CC} = DV_{CC} = V_{CC}$ (see Note 1)	2.2	3.6	V
Supply voltage, V_{SS}	$AV_{SS} = DV_{SS} = V_{SS}$	0.0	0.0	V
Operating free-air temperature, T_A	I version	-40	85	°C
	T version	-40	105	
Processor frequency f_{SYSTEM} (maximum MCLK frequency) (see Notes 2 and 3 and Figure 1)	V_{CC} = 1.8 V, Duty cycle = 50% ± 10%	dc	4.15	MHz
	V_{CC} = 2.7 V, Duty cycle = 50% ± 10%	dc	12	
	V_{CC} ≥ 3.3 V, Duty cycle = 50% ± 10%	dc	16	

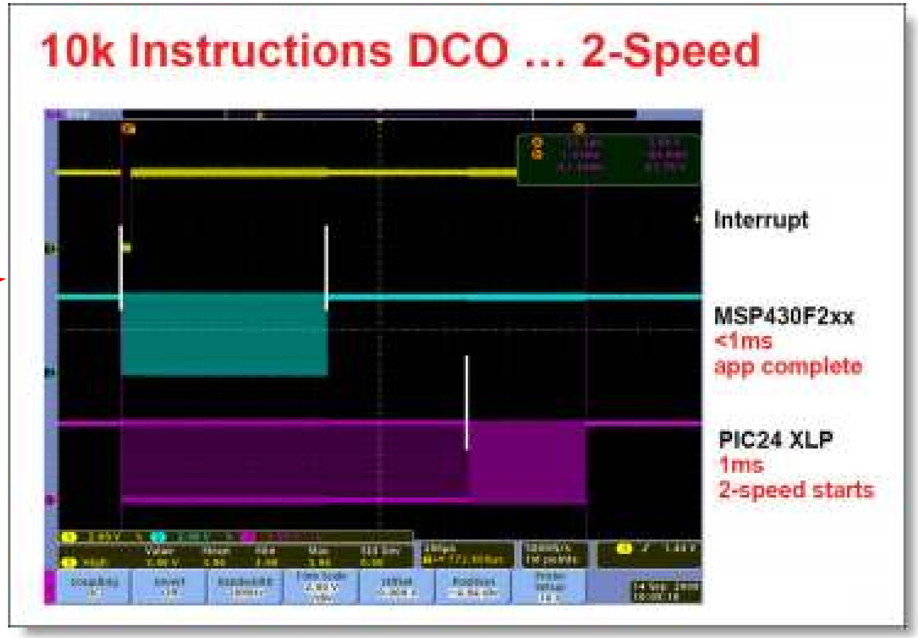
NOTES: 1. It is recommended to power AV_{CC} and DV_{CC} from the same source. A maximum difference of 0.3 V between AV_{CC} and DV_{CC} can be tolerated during power-up.
2. The MSP430 CPU is clocked directly with MCLK. Both the high and low phase of MCLK must not exceed the pulse width of the specified maximum frequency.
3. Modules might have a different maximum input clock specification. See the specification of the respective module in this data sheet.



TI论点 #7：
更快的唤醒速度和快速的运行速度意味着更低的功耗！

杜撰还是事实？





The PIC24F XLP oscillator is initially limited to 4MHz as can be seen, then after 1ms, when the PLL locks, the clock moves to 16MHz. This means the PIC24F XLP takes much longer to finish the task.

In this 10k burst example the PIC24F takes 1.44ms to complete the task – this is more than 2× as long as the MSP430F2xx. Additionally the instant-on MSP430 DCO can be used to clock other internal and external peripherals.

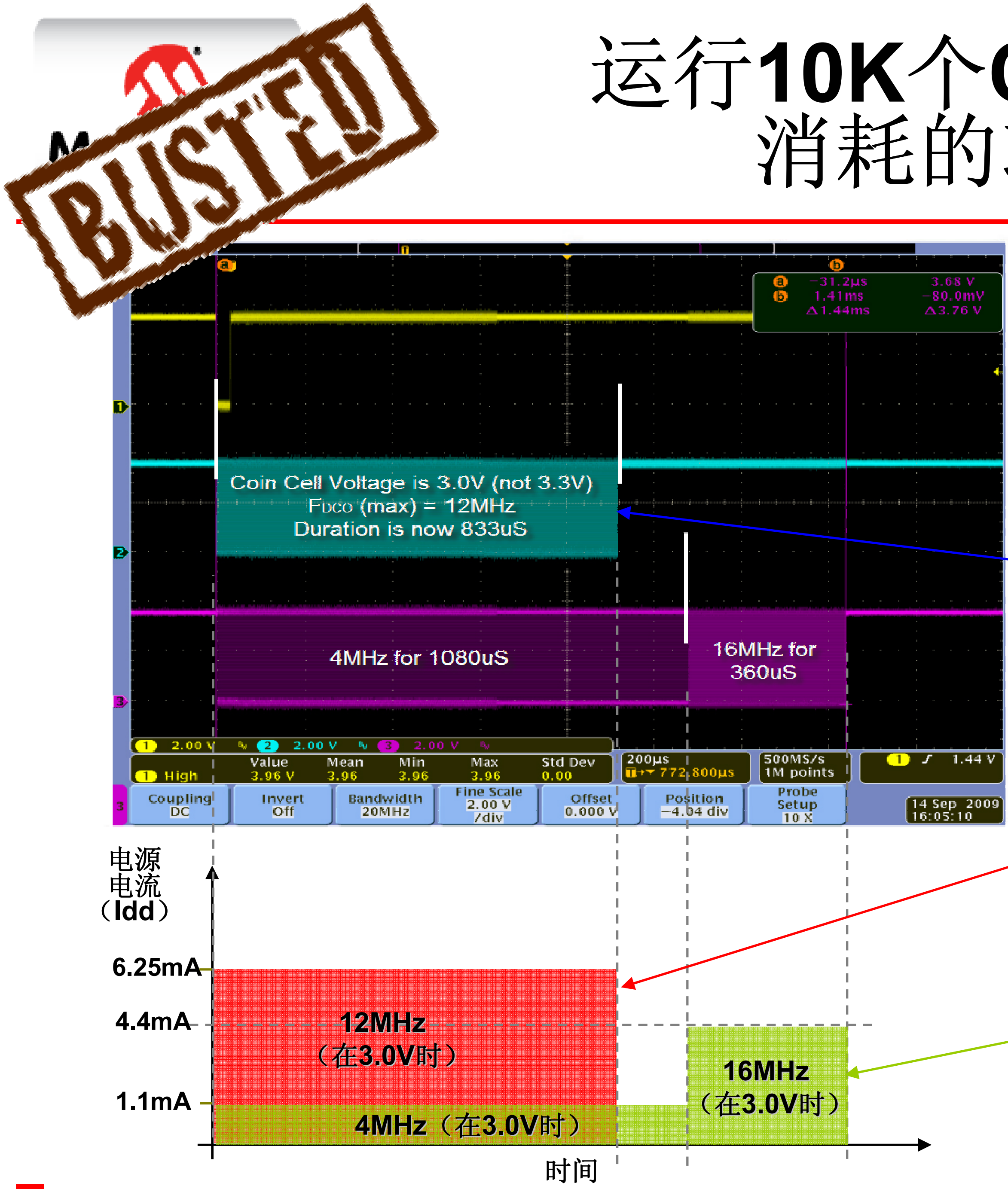
With the MSP430 DCO the device starts faster and at a higher speed, if required by the given application, to finish the task fast and shut down sooner. The instant-on MSP430F2xx DCO is much more flexible, improves performance and reduces system power consumption.

TI论点 #7：更快的唤醒速度和快速的运行速度意味着更低的功耗！

杜撰还是事实？

- 部分真实：
  - 使用它们的DCO技术，它们的唤醒速度确实较快……但是
- ……**MSP430**在运行时的功耗更高，并且……
  - *它们未使用我们速度最快的8MHz唤醒模式*
  - *它们未使用我们32MHz的最高速度*
  - *它们**无法在3.0V时以16MHz运行MSP430F2xx***
    - *不利于要求高性能的电池应用*
      - *PIC24F16KA102可以在3.0V时以32MHz运行*
- 在**3.3V**时以**16MHz**运行时会消耗多少电能？
  - 请记住，客户关心的是电池寿命……

运行10K个CPU周期消耗的功耗



Interrupt

MSP430F2xx
<1ms
app complete

PIC24 XLP
1ms
2-speed starts

将它应用于使用钮扣电池的3.0V应用：
FDCO（最大值） = 12MHz
MSP430消耗的电能是PIC24F的187%！

MSP430F2619（在3.0V时）
工作时间：12MHz时为833uS
电能 = 15.6µJ

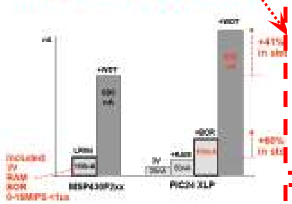
PIC24F16KA102（在3.0V时）
工作时间：4MHz时为1080uS
工作时间：16MHz时为360uS
电能 = 8.4µJ

TI论点 #8：
MSP430的速度比PIC快2倍

杜撰还是事实？

4 Texas Instruments

Storage versus Sleep Mode



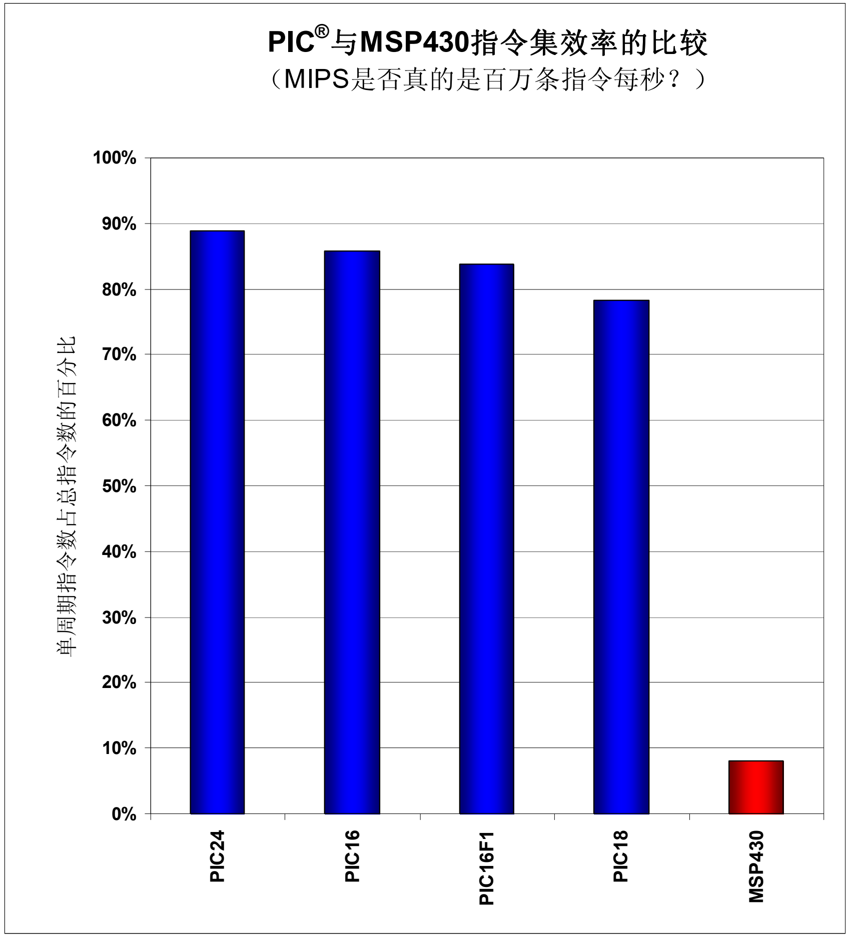
Ultra-Low Power Comparison: MSP430 vs. Microchip XLP Tech Brief — October 2009

> It is important also to note that all XLP modes of operation require summing various adders together to get the total current for any mode – this is confusing and can be misleading. For example, the mentioned 195µA for PIC24F XLP "1MHz run" is just for the CPU with an external square wave clock source. Because of a /2 divider to the CPU, the CPU clock is running at only 500kHz at 1.8V and does not include the internal clock

> generator. At a real 1MIPS CPU clock, with internal clock generation at a realistic 3V operation, the PIC24F XLP's total active 1MIPS power consumption is calculated at well over 1mA. This is 2–3× more than any MSP430F2xx under the same conditions.

TI论点 #8：MSP430的速度比PIC快2倍

杜撰还是事实？



指令集效率

- 与**MSP430**相比，**PIC24**哈佛架构与指令集架构支持更快的指令执行速度
  - *在工作模式下，通过缩短指令执行时间，PIC24消耗的功耗更低*
  - *PIC24可以在较低频率下运行，节省功耗*
  - MSP430 CPU没有乘法器，所以需要更长的时间执行数学运算

注：
图表给出了单周期指令在每种架构的指令集中的百分比。单周期指令越多，意味着代码执行速度越快，这最终会转化为较低的工作功耗/电能。

TI论点 #8：MSP430的速度比PIC快2倍
杜撰还是事实？

示例：从休眠唤醒和使用memcpy()将32字节数组从存储器中的一个表复制到另一个表所需时间的对比。

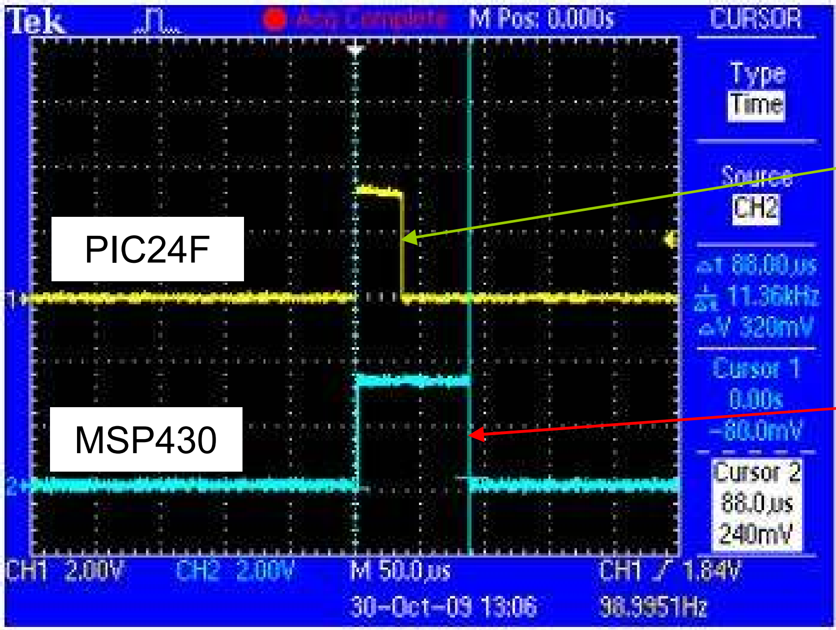
度量指标	PIC24F16KA102	MSP430F2252
时钟启动	**3uS**	**1.5uS**
指令周期	**40**	**316**
4MHz时的执行时间	**32uS**	**80uS**
4MHz时的I_{DD}	**1.64mA**	**1.51mA**
消耗的电能（I_{DD} * 执行时间 * 3V）	**157.4uJ**	**362.4uJ**
平均电流 休眠时间为10mS，采用32kHz时钟	**5.2uA**	**15.4uA**

大致的C语言代码：

```
Sleep();
LATBbits.LATB2 = 1;
memcpy(testArr1,testArr2,sizeof(testArr1));
LATBbits.LATB2 = 0;
```

MSP430F2252比PIC24F16KA102消耗高出230%的电能。平均电流是从电池流出的电流，PIC24F16KA102的平均电流比MSP430F2252低66%，这让PIC24更加省电！

基准测试结果：
32字节存储器复制示波器图



PIC24F XLP v MSP430 - 32 byte memcpy

PIC24F16KA102（在3V时）
4MHz时的工作时间为32uS
消耗的电能 = 157nJ

MSP430F2252（在3V时）
4MHz时的工作时间为80uS
消耗的电能 = 362nJ

- 对于该简单操作
  - *MSP430F2252花费的时间多**250%***
  - *并且……消耗的电能高**230%**！*

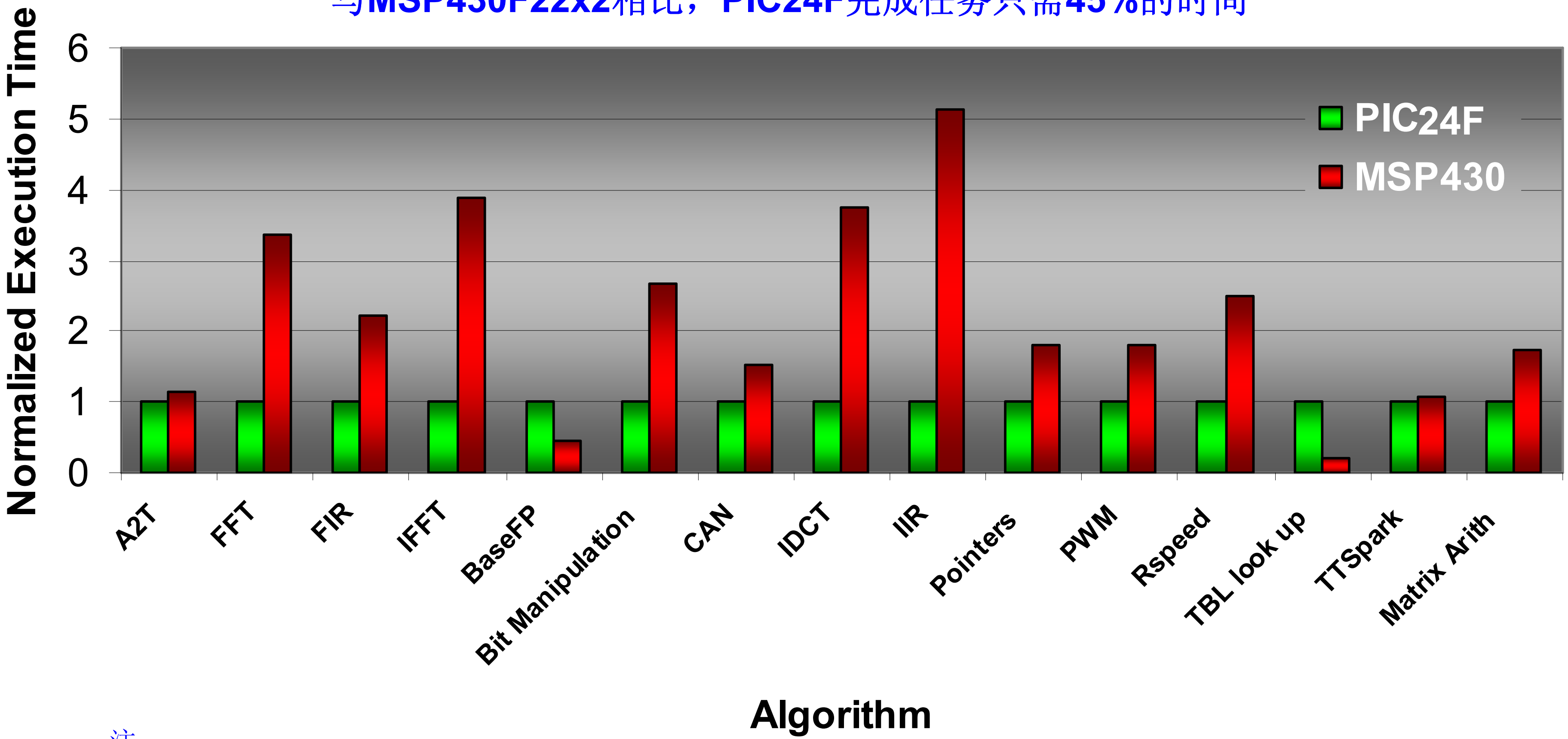
TI论点 #8：MSP430的速度比PIC快2倍

杜撰还是事实？

MSP430F22x2相对于PIC24F16KA102：行业标准基准测试

MSP430F22x2平均需要**220%**的时间来完成基准测试

与**MSP430F22x2**相比，**PIC24F**完成任务只需**45%**的时间



注：

1. MSP430F2xxx系列以16 MIPS运行，使用了Code Composer v3.1，优化级别3，速度与代码长度折衷值 = 5
2. PIC24F系列以16 MIPS运行，使用了用于PIC24F的MPLAB® C编译器，优化级别O3


BUSTED

总结

- **XLP迫使TI采取防守……**
  - “白皮书” 并不准确！
  - XLP产品极具竞争力
  - 我们的产品具有“全球最低的休眠电流”
  - XLP产品在电池寿命方面表现更佳
  - 更多XLP产品即将推出！
- 附属资料：
  - 详细的反驳演示稿，约含60张幻灯片
  - 更新后的XLP客户演示稿即将推出
  - XLP应用笔记、文章、视频以及更多资料……