Low Power Case Study #1: Actual Algorithm Execution

Objective: Compare the actual time to execute an algorithm to measure the true energy consumed. For this case study, the C function "memcpy" was used as an example of a common microcontroller function. Comparing examples is the best indicator of true battery life since differences between MCU architectures do not always make it possible to accurately measure power consumption by simply comparing instruction speed or µA/MIPS.

We will compare how long it takes to wake-up from sleep and copy a 32-byte array from one location in memory to another using the standard C function memcpy ( ) and measure the dynamic power consumption to compare the true energy consumed. The following design requirements were assumed, which are typical for many portable applications that need to optimize battery life while using a coin cell.

Design Requirements

- Must operate while battery is between 3V down to 2.5V
- Requires at least 10 MIPS performance across this voltage range
- Program memory ~16 KB Flash
- Average current <10 µA
- Longest battery life using CR2032 coin cell

This engineer has identified the Microchip PIC24F16KA and the TI MSP430F2252 families. Both seem to meet his design requirements. To decide which one will work better, both a data sheet comparison as well as actual benchmarks are taken.

Data Sheet Comparison

	PIC24F16KA	MSP430F2252
Max Frequency at 3V	32 MHz, 16 MIPS	12 MHz, 12 MIPS
Max Frequency at 2.5V	22 MHz, 11 MIPS	8 MHz, 8 MIPS
Lowest Sleep Mode with BOR	36 nA	100 nA
Lowest Sleep Mode with BOR & WDT	448 nA	600 nA

Looking at both Microchip and TI data sheets, the engineer makes the following observations:

- PIC24 has a divide by 2 in the clock module so 32 MHz = 16 MIPS
- However, when the battery drops down to 2.5V, the MSP430 can only operate at 8 MIPS while the PIC24 can operate at 11 MIPS
- CoreMark™ benchmarks show that the PIC24F can execute code faster than the MSP430
- PIC24 deep sleep mode allows much lower sleep currents than the equivalent LPM3 mode from TI
- Deep sleep mode has many wake-up sources ranging from RTC to WDT to POR
- If I need to retain RAM or have faster wake-up time, the regular Sleep mode is also very low power
- With both BOR and WDT for safety, the PIC24 is still lower power than the MSP430

Benchmark Results

Using the sample code shown below, the application will wake-up from sleep every 10 ms and copy a 32-byte array using the memcpy( ) instruction.

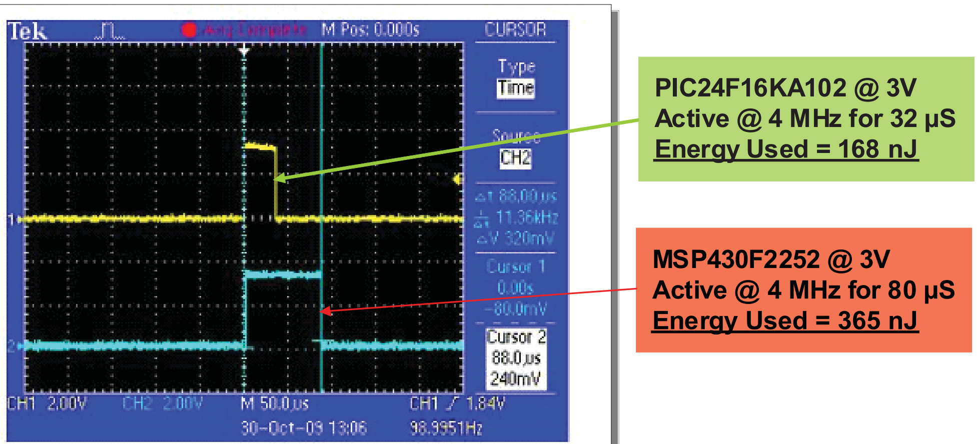
Sample C Code:

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

Low Power Case Study #1: Actual Algorithm Execution (continued)

Here is a snapshot of the scope showing the actual execution time for PIC24 versus MSP430 running at the same frequency and the amount of energy used to execute the above code every 10 ms. You can see the PIC24F16KA executed faster and used less energy.

- MSP430 consumes 117% more energy by running 150% longer
- PIC24 executes faster, sleeps longer & provides longer battery life with lower average current



PIC24F XLP v MSP430 - 32 byte memcpy

Here are the measured results:

	PIC24F16KA	MSP430F2252
Clock Startup	3 µS	1 µS
Instruction Cycles	40	315
Execution Time (at 4 MHz)	32 µS @ 2 MIPS	80 µS @ 4 MIPS
Measured Active Current (I_{DD})	1.6 mA	1.5 mA
Energy Consumed = I_{DD} * (Execution Time + Clock Startup) * 3V	168 nJ	365 nJ
Measured Average Current 10 mS Sleep Time with 32 kHz Clock	5.2 µA	15.4 µA

With this measured average current, the PIC24F16KA provides over 2 times longer battery life.

The PIC24 has more single cycle instructions so the instruction cycles required is dramatically shorter than the MSP430. This corresponds to faster execution time. With both the PIC24 and MSP430 running at 4 MHz the time to complete the algorithm is less than half with the PIC24 even though it is only running at 2 MIPS compared to 4 MIPS for the TI MSP430. (Both are running at 4 MHz). So, it is clear that MIPS are not always the best way to compare execution efficiency. In this case the true execution time is a much more accurate measure of execution efficiency.

Conclusions

- ✓ Microchip's PIC24 meets the performance requirements even at the lowest battery voltage (PIC24 = 11 MIPS at 2.5V compared to MSP430 = 8 MIPS at 2.5V)
- ✓ PIC24 provides the lowest sleep currents with BOR, WDT and RTC
- ✓ PIC24 has faster execution time
- ✓ More time in sleep mode leads to lowest average current and longer battery life

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