Welcome to Microchip’s Technical Training Seminar

Simplify • Reduce • Re-Use
What Problems Do You Face During a Design Project?

Have you ever had design requirements change in the middle of a project?

Have you known of a project where Time to Market was NOT a factor?

Have you known of a project where Cost did NOT matter?
Today’s Objectives

Microchip offers solutions to help you quickly adapt a design to new requirements

What You’ll Learn Today

How easy it is to migrate from 8-bit, to 16-bit, to 32-bit MCUs

How a universal tool suite can help reduce development time

How to re-use software as you migrate to more complex devices

Latest technologies in low power, human interface and connectivity

How to create your own application using 8/16/32-bit microcontrollers
Today’s Agenda

Universal Development Tools Overview

Module #1
How to create an entry-level application that uses touch buttons, LEDs, LCD and has a long battery life

Module #2
Using entry-level application: add more performance, better graphics, USB and RF4CE

Module #3
Using mid-tier application: increase performance, add bigger graphics and WiFi

Wrap Up and Summary
Which Tools are Most Important to You?

IDE (Integrated Development Environment)
Compilers/Assemblers
Debuggers
Logic Analyzers
Software Simulators
JTAG
Trace
Software Libraries
Configuration Management
Which of the following are your favorite/most important software/hardware tools?

- Compiler/assembler
- Debugger
- Oscilloscope
- IDE
- JTAG/BDM
- Logic analyzer
- ICE
- Linux tools
- Configuration management tools
- Codevelopment tools
- Software libraries
- Automatic code generation
- Simulation modeling tools
- Source code analysis/timing analysis tools
- Graphical Design tools
- Software testing tools
- Device driver tool
- Trace

Source: Embedded Market Study 2011

2011 (N = 1,752)
2010 (N = 1,422)
2009 (N = 1,446)
MPLAB® X C Compilers
MPLAB Hardware Debuggers
Oscilloscope??
MPLAB X IDE
(Integrated Development Environment)
MPLAB® XC Compilers

MPLAB XC8
PIC10, 12, 16, & 18

MPLAB XC16
PIC24 and dsPIC® DSCs

MPLAB XC32
PIC32

MPLAB XC Suite
All PIC® MCUs and dsPIC DSCs

Runs on Windows®, MAC OSX and Linux
Node-locked and floating licenses

www.microchip.com/MPLABXCcompilers
Compiler Optimization Options

- **Eval**
  - All devices and memory supported
  - Pro Optimization for 60 days then reverts to Free optimizations
  - Commercial Use Permitted

- **Free**
  - All devices and memory supported
  - Minimal Optimization
  - Commercial Use Permitted

- **Standard**
  - All devices and memory supported
  - Optimized 20-25% better than Free
  - Commercial Use Permitted

- **PRO**
  - All devices and memory supported
  - Optimized ~50% better than Free
  - Commercial Use Permitted

---

FREE | FREE | $495 | $995
---|---|---|---
Hardware Development Roadmap

- **PICkit™ 3**
  - Full Speed USB, Run, Halt, SS, Break on Data/Address
  - Stopwatch, Program, Read

- **MPLAB® ICD 3**
  - PICkit™ 3 Functionality +
  - High Speed Custom USB, Complex Trigger/Break, I/O protection, Production programmer

- **MPLAB® REAL ICE™**
  - MPLAB ICD 3 +
  - Real-Time Watch, Dynamic Trace, Logic Probes, 10-ft debug

- **$50**

- **$200**

- **$500**
PICkit™ 3 Debugger

Low Cost Debugger
USB (Full Speed Interface to PC)
Simple Breakpoints
Event Breakpoints
  Stack, Watchdog Timer, Sleep
Programmer-To-Go
Accessories
  Processor Extension Pak
One PIC® Microcontroller Platform Dev Board

- PIC Microcontrollers
  - PIC16LF1939-I/PT
  - PIC24FJ256GA106-I/PT
  - PIC32MX795F512L-80I/PT
- Capacitive Touch Pads
- Segmented LCD
- Colored LEDs
- Single Cell Battery Supply
  - MCP1640T-I/CH
- Real-Time Calendar Clock
  - 1 MCP79410-I/S
- PICkit™ 3 Connector
- PICtail™ Board Connector
MPLAB® ICD 3 Debugger

Most Cost Effective Debugger
Complex Breakpoints
Event Breakpoints
  Stack, WDT, Sleep
USB High Speed Connection
Microchip Standard Connectivity
  RJ-11
Accessories
  Processor Extension Pak
Production Programmer
MPLAB® REAL ICE™
In-Circuit Emulator

Top of the Line Debugger
Complex Breakpoints
Real-Time Data Watch Points
Various Trace Methods
  Native, SPI, PORT, iFlowTrace
Event Breakpoints
  Stack, WDT, Sleep
USB High Speed Connection
Expandable Driver Boards
Logic Probes
Accessories
  Performance Pack
  AC opto isolation
  Processor Extension Pak
Production Programmer
Sorry, Microchip does not make an oscilloscope!

But our MCUs and dsPIC® DSCs are inside many of the best scopes worldwide.
MPLAB® X IDE: Integrated Toolset
MPLAB® X IDE

Universal IDE that support Over 800 Devices
All 8-bit, 16-bit, 32-bit PIC® MCUs, dsPIC® DSCs and memory devices

Runs on Windows®, MAC OS, Linux
Supports Microchip compilers, simulators, emulators, debuggers and starter kits
Supports many third-party tools
Microchip Tools Offer

One development platform under MPLAB® X IDE

Supporting ALL PIC® MCUs and dsPIC® DSCs

Simple selection of hardware debuggers and compilers

ISO-9000, CE and RoHS compliance

Outstanding technical support
Module #1

Create a entry-level application that uses touch buttons, LEDs, LCD and has a long battery life.
Initial Specifications

Universal Remote Control
- Wireless communication
- Low cost display
- Touch keys
- Long battery life

Need it “Yesterday”

Rapid Development
- Use MPLAB® XC
- Microchip application libraries
- Easy to use and universal tools
The Basic Application

- Wireless
  - Unidirectional, short range

- Display
  - Simple but effective

- MCU
  - Modern look and feel

- Power
  - Long battery life

- Keypad
  - Long battery life
Display and MCU

- Simple but effective
- Modern look and feel
- Basic IR
- Long battery life

Diagram:
- Wireless
- Display
- MCU
- Power
- Keypad
# 8-Bit MCU Options

## Baseline
PIC10, PIC12, & PIC16
- **Inst:** 33, 12-bit
- **Pin:** 6-40
- **Features:**
  - Comparator
  - 8-bit ADC
  - Data memory
  - Internal Osc.

## Mid-Range
PIC10, PIC12, & PIC16
- **Inst:** 35, 14-bit
- **Pin:** 6-64
- **Features:**
  - (In addition)
    - 10-bit ADC
    - SPI/I²C
    - UART
    - PWMs
    - LCD
    - Op-Amp

## Enhanced Mid-Range
PIC12F1 & PIC16F1
- **Inst:** 49, 14-bit
- **Pin:** 8-64
- **Features:**
  - (In addition)
    - Multiple Comm
    - PWM with ind. Timers
    - New peripherals…

## PIC18
- **Inst:** 77, 16-bit
- **Pin:** 18-100
- **Features:**
  - 8x8 HW Multi
  - CAN
  - CTMU
  - Ethernet
  - 12-bit ADC
Segmented LCD Portfolio

47 LCD PIC® MCUs
Pin & Code Compatible
For Easy Migration

Performance

Features

- PIC16F190X
  28-40 pins
  Up to 116 segments
  3.5-14 KB Flash

- PIC16F193/4X
  28-64 pins
  Up to 184 segments
  Up to 28 KB Flash

- PIC16F91X
  28-64 pins
  Up to 168 segments

- PIC18FXX9X
  64-80 pins
  Up to 192 segments
  8-128 KB Flash

- PIC16F1939
  47 LCD PIC® MCUs
  Pin & Code Compatible
  For Easy Migration

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PIC16F193X/194X Block Diagram

- Program Memory
  - Up to 28 KB

- CPU
  - PC+16 Level Stack

- Internal Oscillator
  - 32 MHz

- Data EEPROM
  - 256B

- Data Memory
  - Up to 1 KB

- LCD Drive
- 10-bit ADC
- Touch Sensing
- I²C™, SPI, UART
  - (2x, 2x, 2x)
- Comparators
  - (3x)
- Capture/Compare/PWM
  - (5x)

- Extreme Low Power
## Core Enhancements

### HW Stack
- **Basic (2)**
- **Mid-Range (8)**
- **Enhanced (16)**

### Instruction Set
- **Basic (33)**
- **Mid-Range (+2)**
- **Enhanced (up to 2 KB)**
- **Enh. Shifting**
- **Enh. Arithmetic**
- **Fast Banking**
- **Relative Branching**

### SFR (RAM)
- **Basic (up to 64B)**
- **Mid. Range (up to Ind)**
- **Enhanced (up to 2 KB)**
- **Linear Addressing**
- **2 x Indirect Pointers**

### Interrupt
- **Basic (none)**
- **Mid. Range (1 vector)**
- **Fast Save/Restore**

### PC (Flash)
- **Basic (up to 3.5 KB)**
- **Mid-Range (up to 12 KB)**
- **Enhanced (up to 28 KB)**

---

**Improved C Language Support**
Peripheral Enhancements

General Purpose I/O
- Multiple Ports

Timer-based
- (1) 16-bit Timer
- (2) 8-bit Timers
- Capture/Compare/PWM

Up to 10 PWMs

Communication
- 2x SPI/I²C™
- SPI/I²C
- AUSART/EUSART

High Integration
- CLC-Logic Macrocells
- NCO
- SR-Latch (555)
- CWG

Up to 30 Channels

Up to 10 PWMs

Analog
- 10-bit ADC
- Comparator(s)
- Voltage Reference
- FVR
- Op Amp
- Temp

Human Interface
- Capacitive Touch
- LCD

Up to 192 Segments

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All basic 8-bit peripherals are common and compatible with 16 and 32-bit architecture.

New peripherals introduced in the 8-bit families will migrate up as they gain popularity and find new applications.
Programmable Switch Mode Controller

Advanced Features:
- Dead-band control for synchronous switches
- Complimentary waveforms with transient suppression
- Auto shutdown, polarity control

Available on: PIC16F178X and PIC16F176X
**NCO**

**Numerically Controlled Oscillator**

**Key Features:**

- Linear, fine frequency control
- Fixed duty cycle
- Pulse Frequency Modulation

**Available on:** PIC10F32X, PIC16F150X and PIC16F151X
Complementary Waveform Generator

Key Features:
- Multiple Input Sources
- Auto Shutdown & Restart
- Polarity Control
- Dead band control
- Independent rise & fall control

Available on: PIC10F32X, PIC16F150X and PIC16F151X
Configurable Logic Cell

Applications:

- Eliminate glue logic
- Address decoding
- Complex trigger event capture
- Small state machines
- HW assist to reduce CPU workload

Available on: PIC10F32X, PIC16F150X and PIC16F151X
Enhanced Mid-Range Starter Kit

Featuring:
- LCD (segmented) display
- 32 KHz Osc.
- External Temp sensor
- Potentiometer
- Prototyping area

Additional Features:
- Serial to USB interface
- Expansion connector
- Powered from:
  - Single AAA battery (with boost)
  - USB connector
  - External Supply
First Look at MPLAB® X

Quick

Tour of the MPLAB X
Set up Project

Easy

Use MPLAB IDE to rapidly build and debug the application
Blink LED and display message on LCD
Part 1 of Hands-on Section
Wireless Interface

- Wireless
- Display
- MCU
- Power
- Keypad

Wireless Interface

IR (Infrared)

- Protocol handler encoder/decoder
- Optical Transceiver

- MCU
- MCP21XX
- TxIR
- RxIR

RF Sub-GHz

- RF Transmitter or RF Transceiver

- MCU
- MRF89XA
- SPI
- INT

- 434 MHz
- 868 MHz
- 915 MHz
Infrared/IrDA® Offering

**Infrared Products**

- **Infrared Bit Encoder/Decoder**
  - MCP2120
    - HW/SW baud select
  - MCP2122
    - 16x clock req.

- **IrDA® Protocol Handler + Bit Encoder/Decoder**
  - MCP2140A
    - Low speed, Low power
  - MCP2150/5
    - Higher speed, Config ID
Sub-GHz Product Portfolio

Sub-GHz Transmitter
- rfPIC12F675
- PIC12LF1840T48A

Sub-GHz Transceiver
- MRF49XA 433/868/915
- MRF89XA 868/915/950

Sub-GHz Modules
- MRF89XAM8A 868 MHz (EU)
- MRF89XAM9A 915 MHz (US, CA)

MiWi™ Protocol Supports
Keypad

Wireless

Display

MCU

Power

Keypad
Updated Design with mTouch™ Sensing Technology

- Keys
- Proximity Detection
- Slider Control & LED Indicators for Volume
- Gestures for Channel Up/Down
- Sealed Design
Remote Control Example

- Plastic with fixed location and size buttons
- PCB area just for pads
- Rubber keypad
## Cost Analysis

<table>
<thead>
<tr>
<th>What</th>
<th>How</th>
<th>Cost Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce PCB size by 80%</td>
<td>Replace with film solution</td>
<td>10-20%</td>
</tr>
<tr>
<td>Simpler plastic mold</td>
<td>Much cheaper tooling</td>
<td>20-30%</td>
</tr>
<tr>
<td></td>
<td>Faster to manufacture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can be mounted without secondary support</td>
<td></td>
</tr>
<tr>
<td>No stack-up keypad</td>
<td>Easier to manufacture</td>
<td>10%</td>
</tr>
<tr>
<td>No mechanical movement</td>
<td>More reliable</td>
<td>Less return</td>
</tr>
<tr>
<td></td>
<td>High end feeling</td>
<td>Higher perceived value</td>
</tr>
<tr>
<td>Easy to change the look</td>
<td>Just by changing the marking</td>
<td>Reuse of the same plastic cover and electronic</td>
</tr>
</tbody>
</table>

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Additional Advantages

Easy to backlight

Sealed by design

Keys, slider and wheel combination

Gesture implementation
Capacitive Touch Principle

Introduction of a finger produces a parallel capacitance ($C_F$)

$C_P$ is the Parasitic capacitance
$C_F$ is the Finger capacitance
$C_s$ is the total Sensor capacitance
On-chip Capacitive Sensing Methods

**Capacitive Voltage Divider (CVD):** AN1298
- Uses only the on-chip Analog to Digital Converter (ADC)
- ADC Capacitance is used as reference to calculate external capacitance
- Offers high noise immunity as well as low emissions

**Charge Time Measurement Unit (CTMU):** AN1250
- High speed, flexible, analog peripheral; key scanning time ≤ 4 µs
- Measures relative and absolute changes in capacitance
- Uses on-chip adjustable precision current source
- Works in conjunction with ADC

No external components required for either implementation
Thus Reduced BOM Cost
Microchip mTouch™ Technology

Award Winning Technology—mTouch™ Sensing Solutions
Low Power Touch Sensing

Increase battery life
Lower stand by power consumption
<5 µA touch-sensing with PIC® MCUs

Featuring award-winning XLP technology

- MCU Sleep current down to 20 nA
- MCU Active current down to 35 µA/MHz
- MCU Real-time Clock current down to 470 nA
mTouch Solutions Pass:
- IEC61000 Emission and Susceptibility tests
- EFT and BCI tests
- Variety of customers tests

High Signal-to-Noise Ratio (SNR)
Stable over voltage and temperature
AN1334 Techniques for Robust Touch Sensing Design
Metal Over Cap Technology

User Presses Front Panel

Panel Deflects (on the order of microns)

Distance Between Plates Decrease

System Detects the Change in Capacitance

\[ C = \frac{\varepsilon_0 \varepsilon_r A}{d} \]
The only difference is the introduction of a **spacer layer** to allow the deflection of the front panel

- It needs to be non-conductive and non-deformable
- Thickness is between 50 µm and 150 µm
- The most common materials are glue, FR4 or mylar
- It could be part of the molding or etched
mTouch™ Capacitive Evaluation Kit

Featuring:

4 Motherboards
- PIC16F1937 8-bit MCU
- PIC18F46J50 8-bit MCU
- PIC24FJ64GB106 16-bit MCU
- PIC32MX795F512H 32-bit MCU

4 Sensor Daughter Boards
- 2-Channel Slider
- 4-Channel Slider
- 8 Keys Direct Sense
- 12-Key Matrix

PICkit™ Serial Analyzer
- Program & Debug

mTouch Graphical User Interface

Enhanced mTouch™ Capacitive Touch Evaluation Kit
Part # DM163026-2
mTouch™ Code Example

Quick
Use standard templates to assemble the basic application structure
Flash out the basic components
   Initialization
   Main Loop

Easy
Use MPLAB® X to rapidly build and debug the application
Use mTouch Library
Part 2 of Hands-on Section
Selecting the Right Power Source

- Display
- Segmented LCD
- Touch Sensing
- Keypad
- Wireless
- MCU
- Power
- Basic IR
- Long battery life

Wireless

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XLP References

- Using the Microchip Ultra Low-Power Wake-Up Module
  - Authors: Ruan Lourens, Jose Benedek

- nanoWatt and nanoWatt XLP Technologies: An Introduction to Microchip’s Low-Power Devices
  - Author: Brant Ivey

- Design Practices for Low-Power External Oscillators
  - Author: Jonathan Dillon

www.Microchip.com/XLP
Over a 100 XLP devices available.
**eXtreme Low Power**

**Product Performance:**
- **Sleep:** down to 20 nA
- **Watchdog Timer:** down to 300 nA
- **Real-Time Clock:** down to 500 nA

**Improved LP T1 Oscillator** enables Real-Time Clock functionality
**Improved LP Watchdog Timer** ensures proper system activity
**Improved LP Brown Out Reset** monitors system voltage integrity

*With a dramatically reduced in current consumption!*
Beyond XLP
Low Active Currents

<CY09  CY09  CY10  CY11  CY12

30µA/MHZ
Beyond XLP Sleep Currents

Qualifying Microcontrollers must:

- **Meet or below** nanoWatt XLP current consumption specs
- Contain the following:
  - Low Power Timer 1 Oscillator
  - Low Power/Ultra Low Power Watchdog Timer

Many non-XLP PIC® Microcontrollers are LOW POWER

<table>
<thead>
<tr>
<th>Device</th>
<th>Sleep (nA)</th>
<th>Watchdog Timer (nA)</th>
<th>Active (µA/MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC10F20X/PIC16F51X</td>
<td>100</td>
<td>1000</td>
<td>44</td>
</tr>
<tr>
<td>PIC16F61X/PIC16F690</td>
<td>50</td>
<td>1000</td>
<td>55</td>
</tr>
<tr>
<td>PIC16F88X/PIC16F91X</td>
<td>50</td>
<td>1000</td>
<td>55</td>
</tr>
<tr>
<td>PIC16LF1501/3/7 and PIC10F32X</td>
<td>20</td>
<td>400</td>
<td>30</td>
</tr>
<tr>
<td>PIC12F629/675</td>
<td>1</td>
<td>300</td>
<td>100</td>
</tr>
</tbody>
</table>
XLP 8-Bit Development Board

Demonstrate low power measurements for various modes of operation

- Code examples for low power
  - Online updates available
- Multiple Power Supply Options:
  - External: USB or DC Power Supply
  - Battery: CR2032, 2x AAA or Energy Harvester Power
- PICtail™ Connector:
  - Extendibility for Prototyping

Part # DM240313 $125
Choosing the Right Power Source

Simple functions only
Small form factor
IR data transfer
Power Characteristics of A Basic Remote Control

Average drains 10-50 mA
Average pulses 100-500 mA
Average standby drains in nA
Average “button press” 25-100 ms
  Depends on TV OEM code
Constant resistance device
  Magnitude of pulse will decrease with battery voltage
Constant Resistance Device – As battery voltage decreases, device current consumption decreases and resistance is held relatively constant.

From electronics perspective, think unregulated power demand.

Alkaline batteries tend to perform well in this type of device.

Internal resistance of alkaline batteries increases through discharge.
Rate capability of alkaline batteries decreases through discharge.
Power Characteristics of A Basic Remote Control

Typically powered by CR2032 or AAAA

Pulse capability of the battery is important

CR2032 for low average and peak drains

AAAA or AAA when higher currents needed

Expect years of battery life
Single Cell with MCP1640 Diagram

Output voltage
- 2.0 to 5.5V
- VOUT accuracy ±3%

Low start-up and input voltages
- 0.65V start-up
- 0.35V input

Low-power operation
- Up to 96% efficiency
- 19 µA quiescent current
- <1 µA shutdown current
VDD Stability Over Battery Life

**VBATT**

- **VDD**
- **Battery Voltage**

- 1.5V
- 0.7V
- 0.35V
Module #1 Summary

Created Entry Level Application Using

Modern Look & Feel – Capacitive Touch
Long Battery Life – 25 nA Sleep & 30 µA/MHz
Wireless Comm. – Infrared & Wireless
Design Flexibility – Several options for MCU’s New peripherals
Easy of Design – Unified Development Tools
Module #2

Change in Requirements:
Add more performance, a better graphical interface, USB and RF4CE.
Change in direction...

Universal remote control

Adds

- Graphical display
- More touch keys
- USB
- RF wireless communication
- Form factor up to 3x AAA batteries

Need it “yesterday”

Now what?

- Start over vs. reuse
- Can I use any of my 8-bit code?
- How will I ever have time to write firmware for graphics, USB and RF?
New Remote Requirements

- Graphical display
- More touch keys to allow advanced functions
- Low power consumption
- USB for programming remote
- More memory
- More I/O
- More performance
- RF wireless

Components:
- Wireless
- Display
- MCU
- Power
- Keypad

More touch keys to allow advanced functions
Next, let’s consider the alternatives to meet these requirements.
Find the Right Tool
16-bit PIC® MCUs

- The right mix of performance, peripherals, power and cost for this application
- **Performance**
  - 16-60 MIPS
  - C-efficiency
- **Pins**
  - 14-144
- **Memory**
  - Up to 512 KB Flash
  - Up to 96 KB RAM
## Overview of 16-bit Product Families

<table>
<thead>
<tr>
<th></th>
<th>Performance</th>
<th>Flash (KB)</th>
<th>RAM (KB)</th>
<th>Pins</th>
<th>Highlights</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PIC24F K Families</strong></td>
<td>16 MIPS</td>
<td>4-32</td>
<td>0.5-2</td>
<td>14-48</td>
<td>Lowest Cost, Lowest Power, 5V options</td>
</tr>
<tr>
<td><strong>PIC24F G Families</strong></td>
<td>16 MIPS</td>
<td>16-256</td>
<td>4-96</td>
<td>28-100</td>
<td>Low Cost, Lowest Power, USB</td>
</tr>
<tr>
<td><strong>PIC24F D Families</strong></td>
<td>16 MIPS</td>
<td>128-256</td>
<td>24-96</td>
<td>64-100</td>
<td>Graphics Controller, USB</td>
</tr>
<tr>
<td><strong>PIC24H GP Families</strong></td>
<td>40 MIPS</td>
<td>12-256</td>
<td>1-16</td>
<td>18-100</td>
<td>CAN, 150⁰ C options</td>
</tr>
<tr>
<td><strong>PIC24E GP Family</strong></td>
<td>60 MIPS</td>
<td>280-536</td>
<td>28-52</td>
<td>100-144</td>
<td>USB, CAN</td>
</tr>
<tr>
<td><strong>dsPIC33E GP Family</strong></td>
<td>60 MIPS</td>
<td>280-536</td>
<td>28-52</td>
<td>100-144</td>
<td>USB, CAN</td>
</tr>
<tr>
<td><strong>dsPIC33E MC Family</strong></td>
<td>60 MIPS</td>
<td>280-536</td>
<td>28-52</td>
<td>100-144</td>
<td>USB, CAN, Motor Control PWMs</td>
</tr>
</tbody>
</table>
PIC24 MCU & dsPIC33 DSC Family Features

High Performance

- Efficient C Code
- Integrated Peripherals
- Integrated DSP Engine for Control Applications

Efficient C Code

16-bit Applications (~ 40KB code)

100% 110% 115% 169%

dsPIC33E dsPIC32F dsPIC33HC

Integrated DSP Engine
for Control Applications
16-bit MCU Development Platform

Explorer 16 Development Board (DM240001/2)
A cost-effective development board for Microchip’s 16-bit products. The PICtail™ Plus connector works with PICtail Plus daughter cards.

PICtail Plus Daughter Cards
Daughter cards provide easy expansion capability for a range of technologies including:
- Graphics
- Ethernet
- USB
- WiFi
- ZigBee
- CAN/LIN
- Speech Playback
16-bit MCU Starter Kits

All include integrated programmer/debugger.

- PIC24F Starter Kit (DM240011)
- PIC24H Starter Kit (DM240021)
- PIC24E Starter Kit (DM240012)

Microstick II for dsPIC® DSCs and PIC24 (DM330013-2)
Easy connection to breadboard
Basic Block Diagram
Choosing a Display Solution

<table>
<thead>
<tr>
<th></th>
<th>Segmented Display</th>
<th>Graphical Display</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>Lower</td>
<td>Typically higher</td>
</tr>
<tr>
<td><strong>Complexity</strong></td>
<td>Easy</td>
<td>More software required</td>
</tr>
<tr>
<td><strong>Appearance</strong></td>
<td>Static</td>
<td>Dynamic</td>
</tr>
<tr>
<td><strong>Ideal for</strong></td>
<td>Simple functionality</td>
<td>Complex functionality made simple with a good user interface</td>
</tr>
</tbody>
</table>
Lowest Cost Graphics – PIC24FJ DA Family

Directly Drive Colorful Display using integrated Display Controller

Hardware Graphics Acceleration
- Enables scrolling and animation
- Image Decompression – show compressed graphical images
- Character Processing – render text

256 Entry Color Lookup Table Enables 16-bit Color Depth
- Huge variety of color choices using less memory

Cost savings using internal 96 KB RAM for QVGA 8 bpp
Graphics Library
For 16-bit & 32-bit PIC® MCUs

Render graphics objects, fonts and languages

Static text, multiple fonts
Supports touch screen
Button
Images
Graphics Display Designer

Visual Design Tool
Provides GUI Design Wizard
Works with Graphics Library

Reduce development time using design tools to generate screens.
PIC24FJ256DA210 Development Board

- Supports QVGA (8 bpp) with on-chip memory
- Supports WQVGA with external SRAM Frame buffer

Connect to one of our available TFT displays or choose your own

PICtail™ Plus daughter board expansion slot

Additional Flash and RAM to store more objects and fonts

Part # DM240312
Advantages of RF over IR
- No need for line of site
- Bi-directional secure communication
- Longer battery life

ZigBee® RF4CE
- ZigBee Alliance Compliant Platform
- 2.4 GHz IEEE 802.15.4 standard based technology
- Radio Frequency for Consumer Electronics
- Interoperability
- No interference
- Supports Star topology
ZigBee® RF4CE Features

Supports the following features and functions:

- Frequency agility – ability to automatically change channels
- Target and controller device types
- Easy implementation of pairing devices
- Secure link communication AES-128 encryption
- Stack size is very small ~16 KB
IEEE 802.15.4 ZigBee® Portfolio

802.15.4 Transceiver IC

MRF24J40

802.15.4 Modules

MRF24J40MA
+0 dBm

MRF24J40MB
+20 dBm, PCB Ant

MRF24J40MC
+20 dBm, Ext Ant
Development Platforms

Add RF to Existing MCHP Dev Boards

MRF24J40MA
Part # AC164134-1

MRF24J40MB
Part # AC164134-2

MRF24J40MC
Part # AC164143

Explorer 16 Dev Board
Part # DM240002

PIC18 Explorer Dev Board
Part # DM183032
mTouch™ Sensing

On-screen menus using analog resistive touch screen
Integrate display with touch interfaces

Control buttons using capacitive touch
Charge Time Measurement Unit (CTMU)
Eliminate external touch controller
Includes plastic overlay
AR1000 Resistive Controller

- Turnkey touch controller
- On-chip calibration
- Supports all 4, 5 or 8 wire sensors
- Highly accurate touch for small button pressing by delivering advanced, filtered touch coordinates

Development Kit

- 7” four-wire resistive touch screen sensor
- PICkit™ Serial Analyzer
- All necessary cables
- Easy-to-use AR1000 configuration utility with (GUI)
Basic Block Diagram

- Wireless
- MCU
- Power
- Keypad
- Display
Run Modes

Run
Doze
Idle
Sleep
Deep Sleep

8-bit, 12 MIPS Core
- 8-bit ALU
- Register File 8-bit
- 8 x 8 MPY
- 2 MB Address Space

16-64 KB Flash
RAM Retention Mode
Memory Bus
Peripheral Bus

Interrupt Control

Peripheral Pin Select

USB 2.0
A/D, 10-bit, 13 ch.
Comparators - 2
Watchdog
Capture/Compare/PWM - 2
8-bit Timers - 2
16-bit Timers - 3
UART - 2
SPI/PCI™ - 2
PMP/PSP
CTMU
RTCC
DSBOR
DSWDT
ULPW

µA
nA
mA
The Middle Tier Remote

Universal remote
Full assortment of functions
Update over USB
Small LCD display or backlight
Power Characteristics of A Mid-Range Remote Control

**Same as Basic Remote**
- Average drains 10-50 mA
- Average pulses 100-500 mA

**Difference in Mid-Range Remote**
- Average standby drains in microamps
- Average “button press” 20-30 seconds
- Various minimum operating voltages depending on peripherals
- Constant current device
  - Effect of backlight compared to pulse only
**Power Characteristics of A Mid-Range Remote Control**

<table>
<thead>
<tr>
<th>P.S.</th>
<th>No Backlight</th>
<th>Stand By</th>
<th>Backlight</th>
<th>TV Mode</th>
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</tbody>
</table>

**Constant Current Device** – As battery voltage decreases, device current consumption stays relatively the same

From electronics perspective, think regulated power demand or DC-DC

Lithium and NiMH batteries tend to perform well in this type of device

- Good rate capability throughout life
- Higher voltage for lithium ion disulfide
Power Characteristics of A Mid-Range Remote Control

Typically powered by AAA, AA or lithium ion
Capacity of the battery is important when needing to power a backlight
Lithium and Nickel-Metal Hydride will give the most
Expect months of battery life
Basic Block Diagram

- Wireless
- Display
- MCU
- Power
- Keypad
Integrated USB

Connectivity with remote control

TV or Set-top box
- Program the remote
- Synchronize with Set-top box

PC
- Download software upgrades
- Configure the remote

Simple, configurable, ubiquitous solution
Wide Range of USB Solutions

- **PIC32**
  - USB Device, Embedded Host, OTG
  - Highest Performance CAN, Ethernet, RTCC

- **PIC24**
  - USB Device, Embedded Host, OTG
  - eXtreme Low Power, Deep Sleep Mode, CTMU, RTCC, Graphics

- **PIC18F**
  - USB Device Support
  - Small, Low Cost, eXtreme Low Power, Deep Sleep Mode, 12-bit ADC, CTMU, RTCC

- **MCP2200**
  - USB to UART
- **MCP 2210**
  - USB to SPI
  - 8 Programmable I/O
  - 256 Bytes EEPROM
USB Software

Free USB Stacks and Drivers

Stacks:
- Embedded Host Stack
- On-The-Go Stack
- Device Stack

Class Drivers & Demo Code:
- Human Interface Device (HID) – for remote control
  - Custom Demos
  - Joystick, Keyboard
  - Digitizers
  - Multi-Touch Digitizer
  - Uninterruptible Power Supply
  - Pen Digitizer
  - Mouse

Other drivers: MSD, CDC, Custom, Audio, Printer

Use Microchip’s USB VID/PID
USB Tools

Explorer 16 Development Board
Part # DM240001

USB PICtail™ Plus Daughter Board
Part # AC164131

PIC24FJ64GB004 Plug-In-Module
Part # MA240019
Using One PIC® MCU demo board

Let’s migrate the code from the 8-bit MCU to 16-bit MCU

- Blink LED
- Drive LCD
- Touch

Additional Functionality

- RF4CE Wireless

Part 3 of Hands-on Section
Microchip Application Libraries

MPLAB® IDE, C Compilers

Microchip Application Libraries

Application/Demo Projects
Such as: Remote Control, Google Map, …

USB  TCPIP  Graphics  …  Other libraries

PIC16  PIC18  PIC24  dsPIC®  DSC  PIC32

Free Download from – www.microchip.com/MLA
Remote Control Demo

PIC24 “DA” MCU running:
- Graphics Library
- mTouch™ Library
- USB Library
- RF4CE Library

3.5” TFT QVGA Display with Resistive Touch Screen

MRF24J40
2.4 GHz IEEE 802.15.4 Transceiver (RF4CE)
Remote Control Demo Board

Cap touch buttons with plastic overlay

3.5” TFT QVGA Color Display With Resistive Touch Screen

USB Connection

3x Energizer Ultimate Lithium AAA batteries

RF4CE Communication

Remote Control Demonstration Board
(Part # DM240315)
In this case, our target is not a TV, but the Wireless/USB PC Adapter which will run a GUI on your computer to acknowledge buttons have been pressed and sent.
Wireless Remote Video
Summary

Seamless migration from 8-bit
Free software libraries
Integration of USB, touch, graphics and more

For more details on the tools, libraries, documentation and products covered in this module, visit: www.microchip.com/16bit
Module #3

More Marketing Demands:
Increase performance, support for larger displays add WiFi®.
Change in Direction Again…

Marketing wants to add advanced features to the remote

- WiFi® Connectivity
- Large Display
- High Quality Graphics
- Real-Time Clock

Microchip’s 32-bit PIC32 microcontroller is the perfect fit for high end applications

- Highest performance 32-bit core
- Multiple connectivity options
- Industry leading graphics control
New Remote Requirements

- High End Graphical Display
- WiFi® wireless
- More memory
  - More I/O
  - More performance
- USB for programming remote
- More touch keys to allow advanced functions
- Real-Time Clock/Calendar
- Accurate Time keeping
- More I/O
- More performance
PIC32 Overview

First introduced in 2007 and now 7 families strong

PIC32 brings a new level of processing performance to low cost MCUs

Key software stacks available in source code form and royalty free

Easy to migrate amongst our 600+ MCUs making for a common platform across multiple products
PIC32 Microcontroller
Key Features


High Throughput Bus Matrix, which Supports High Speed Concurrent Access to Memories and Peripherals

128-bit wide, 30 MHz Self-programmable Flash, Predictive Instruction Pre-fetch 256 Byte Lockable Cache

16-bit Parallel Master Port, Connect SRAM, Flash, QVGA LCDs or other Peripherals

Direct Memory Access Controller, With Integrated CRC Module…Operates in Idle Mode

Compatible with Microchip Development Tools MPLAB® ICD 2, REAL ICE™, PICkit™ 2, PM3

USB On-The-Go (Host, Device, Dual Role) Controller with Dedicated DMA Channel and Integrated Transceivers

Single 2.3 to 3.6V Supply Power On-Reset, Brown Out Reset, Low Voltage Detection

Analog and Digital Peripherals Compatible with 16-bit PIC® Microcontrollers

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Performance

COREMARK™/MHz

PIC®32 MIPS M4K @ 80 MHz

Competitor R @ 100 MHz

Competitor S @ 120 MHz

Competitor F @ 100 MHz

Competitor T @ 50 MHz

Competitor N @ 72 MHz

Competitor S @ 72 MHz

www.coremark.org

CoreMark is an independent/public benchmark for core performance
CoreMark is a trademark of The Embedded Microprocessor Benchmark Consortium (EMBC®)
New Remote Requirements: High End Graphics

- Wireless
- VGA/WVGA Display
- MCU
- Power
- Keypad
- Real-Time Clock/Calendar
Graphical Interface with the PIC32MX Family

The Traditional Approach

32-bit Core Performance – 1.56 DMIPS/MHz
Large Memory – Multiple stacks & data buffering
Multimedia Expansion Board (MEB)

Use with any PIC32 Starter Kit

Front

1. 3.2 inch QVGA touch screen
2. Four-way joystick (S2) and fire button
3. PICtail™ expansion connector
4. Headphone, line out, microphone jacks
5. Integrated WiFi Module

Back

6. Graphics controller (SSD1926)
7. Micro SD card slot
8. Accelerometer/temp sensor (BMA150)
9. SPI Flash 2 Mbytes
10. 24-bit audio codec (WM8731)

Part # DM320005
MEB Compatible Starter Kits

Plug directly into the Multimedia Expansion Board

Includes an integrated programmer/debugger

USB Powered

- General Purpose
  - 32 Kbytes RAM
  - DM320001

- USB
  - 128 Kbytes RAM
  - DM320003-2

- Ethernet + USB
  - 128 Kbytes RAM
  - DM320004

- dsPIC® Digital Signal Controller
Graphical Interface with the PIC32MX Family

The Controller-less Approach

- Directly Drive the Display
- QVGA (320x240) or WVGA (800x480) resolution

Using PIC32 MCU’s high performance up to a 65K (16 bpp) Color WQVGA can be directly driven

Eliminates the costly graphics controller chip

High performance PIC32 core provides enough MIPS for other tasks beyond driving the display
Controllerless Graphics: Software Advantages

Low MIPs usage (<5 MIPS)

Ample MIPs remain for other features:

- USB
- Ethernet
- Touch
- Wi-Fi®
LCC (Low-Cost Controllerless) Graphics Board

Driving Graphics Displays Without a Graphics Controller

- Interfaces to Microchip Explorer 16
- On Board 256 KB SRAM
  Can be “Jumpered” in or out
- Interfacing to Microchip display modules

- Powered by any PIC32 starter kit
  - 80 MIPS 32-bit performance
  - 128 KB of on-chip SRAM
  - High speed 16-bit PMP
  - High performance DMA keeps core loading to less than 5%!

- Support for up to WQVGA @ 16 bpp color
- PIC32 alone can drive QVGA @ 8 bpp color

Part # AC164144
Graphics Development Boards & Displays

Low Cost Solutions
No External Graphics Controller

- PIC32 Low-Cost Controllerless Graphics PICtail™ (AC164144)

Solutions with External Graphics Controllers

- Graphics LCD Controller PICtail™ Plus SSD1926 Board (AC164127-5)
- Graphics Controller PICtail Plus Epson S1D13517 Board (AC164127-7)

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Display Type</th>
<th>Board Code</th>
<th>Display Type</th>
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<td>WQVGA</td>
<td>4.3” Graphics Display Powertip</td>
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<td>VGA</td>
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<td>WVGA</td>
<td>7” Graphics Display Truly 800x480 Board</td>
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<td>Prototype Boards</td>
<td>Connect Your Glass</td>
<td>AC164139</td>
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</tbody>
</table>
Graphics Software Tools

**Graphics Library**
Pre-made graphics objects
buttons, sliders, etc
Multiple fonts and languages
Compatible with 16-/32-bit PIC MCUs

**Graphics Display Designer**
Visual Design Tool
Provides GUI design wizard
Works with Graphics Library
Graphics Video
New Remote Requirements: WiFi® and Connectivity

- Wireless
- Display
- Keypad
- Real-Time Clock/Calendar
- Power
- MCU
Wired Connectivity Options

- Ethernet
- Serial
- CANbus
- USB OTG
Available serial interfaces

2 to 6 UARTs
- RS-232, RS-485 and LIN support
- IrDA® with on-chip hardware encoder/decoder

2 to 4 SPI modules

2 to 5 \( \text{I}^2\text{C} \)™ modules
PIC32 – CANbus

Robust communication for Automotive and Industrial applications

Industry-standard 1 Mbps CAN2.0b

2 dedicated DMA channels

32 message FIFOs
  Each FIFO can have up to 32 messages, for a total of 1024 messages

Advanced filtering to simplify message processing

DeviceNet™ addressing support
PIC32 – USB

Full speed USB functionality
- Separate PLL – USB clock independent from core clock
- Integrated transceiver
- 2 dedicated DMA channels

Modes supported
- Embedded host
- Device
- On-the-Go
- Dual role: Switch between host and device

Complete USB Software Library available
Integrated 10/100 Mbps Ethernet MAC

2 channel dedicated DMA creates less burden on the CPU

Supports max data rate of 100 Mbps
  Typical 80 Mbps stream consumes only 5 MIPS

Industry standard interface to PHY chips
  Commodity PHYs are readily available from a range of vendors such as
    National DP83848 PHY
    SMSC LAN 8700 PHY

PIC32MX6/7 series support both RMII and MII interface
  See “PIC32 PHY Support” at www.microchip.com for more information
Microchip’s TCP/IP Protocol Stack

FREE!! Royalty-free, no license fees

Modular design

No lower layer design required within the TCP/IP protocol

Optimized for PIC18, PIC24, dsPIC® DSCs and PIC32
  Includes BSD RTOS support via a wrapper

Source code provided

Support documentation
  Compiled HTML page distributed with the stack
On-line Design Centers

USB

www.microchip.com/USB

Ethernet

www.microchip.com/Ethernet
www.microchip.com/TCPIP

CANbus

www.microchip.com/CAN
External modules for wireless connectivity
Through SPI or parallel interface

Wireless Solutions

SPI

802.15.4

WI-FI®
Wi-Fi® Module Overview

Microchip Wi-Fi module

Wi-Fi and Agency Certified – FCC/ ETSI/ IC
No need for RF knowledge
21x31 mm size

Features

Low-power, low data-rate Wi-Fi
Over-the-air data rate: 1 & 2 Mbps (802.11b)
Standard Wi-Fi range expectation
Supports 802.11 Infrastructure and Ad Hoc modes
Connects to standard wireless access points
On-chip encryption support – WEP, WPA and WPA2
Embedded Wi-Fi® Solution

Driver incorporated into Microchip TCP/IP stack

Free download of the stack from www.microchip.com/WiFi

Compatibility across every major Microchip MCU family with a SPI module

PIC18 (8-bit), PIC24 (16-bit), dsPIC33, PIC32 (32-bit)

Wi-Fi solution works with many existing development tools

Explorer 16 Development Board
Part # DM240001

MRF24WB0MA Wi-Fi PICtail/PICtail Plus Daughter Board
Part # AC164136-4

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Wireless Software Stacks

Wi-Fi® support in TCP/IP stack

802.15.4 based stacks

- ZigBee® Protocol
- MiWi™ P2P Protocol
- MiWi Mesh Protocol

More information available

Access wireless design centers at:

www.microchip.com/wireless
PIC32 Connectivity

Free software support and includes:
- Firmware libraries
- Source code for custom modifications
- Turn key solutions

Full set of connectivity development boards and kits online design centers:
- [www.microchip.com/USB](http://www.microchip.com/USB)
- [www.microchip.com/ethernet](http://www.microchip.com/ethernet)
- [www.microchip.com/TCPIP](http://www.microchip.com/TCPIP)
- [www.microchip.com/wireless](http://www.microchip.com/wireless)
- [www.microchip.com/CAN](http://www.microchip.com/CAN)
New Remote Requirements: Power Requirements

- Wireless
- Display
- Keypad
- Power
- Real-Time Clock/Calendar
Selecting the Right Power Source – High End Remote

All features of middle tier remotes and more
Large, bright, full-color touchscreens
WiFi®, RF or Bluetooth® data transfer
Charging cradle
The High End Remote

**Same as Middle Tier Remote**
- Constant current device
- Average pulses 100-500 mA
- Average “button press” 20-30 seconds

**Different in High End Remote**
- Average drains 150-300 mA
  - Much higher due to “key illumination”
- Average standby drains in milliamps
- Wireless control of devices in other rooms

Diagram: Current mA vs Time (Seconds)

- Key Illumination
- Backlight
The High End Remote

Typically powered by lithium ion rechargeable
Expect weeks of battery life
Charging pads for convenience:
  Unique, proprietary design
  Universal standard – Qi

*Energizer has introduced a line of wireless inductive chargers based on the Qi platform which can charge any Qi-enabled device.
Rechargeable Solutions: Li-ion/Li Polymer

Li-ion/Li-polymer batteries

3.6V nominal voltage easy to use with many MCUs
Can be molded to specific cavity

Require battery charge controllers

A good battery charger maximizes battery capacity, extends battery life and monitors the charging process
Microchip’s Battery Charging Solutions

Integrated chargers for Li-Ion/Li-Polymer/LiFePO4 batteries
  Variety of charging currents: 15 mA to 1.1A
  Adjustable to meet specific battery needs
  Internal/External FET
  Dual-Input for AC/DC and USB
  Load sharing solutions
  Overvoltage Protection

PIC® MCU + MCP1630/1
  Multi-chemistry, multi-cell advanced solutions
Energizer and Microchip

Microchip & Energizer are working together to provide solutions for primary battery powered embedded applications

www.Microchip.com/BatteryGuide
New Remote Requirements: Real-Time Clock Solutions

Diagram:
- Wireless
- Display
- MCU
- Power
- Keypad
- Real-Time Clock/Calendar
Real-Time Clock
“Three Solutions from MCHP”

RTCC Integrated in MCU

- SRAM
- EEPROM
- Timers
- RTCC

32 KHz Crystal

PIC® MCU

Stand-Alone RTCC
(Used in this module)

- SRAM
- EEPROM
- Timers

I²C™

32 KHz Crystal

CM7V-T1A (Micro Crystal)

Battery or Capacitor

RTCC Simulated with a Timer

- SRAM
- EEPROM
- Timer 1

32 KHz Crystal

PIC® MCU

Which design best fits the final application?
Accurate Timekeeping Over Temperature

- ALL crystals drift in frequency over temperature
  - Digital trimming in RTCC compensates for drift
  - MCP79410 adjustment range from -127 to +127 ppm
  - From -35°C to +80°C maximum error is approx -127 ppm
  - \((127 \text{ ppm})(86 \text{ msec/day}) \approx 10.9 \text{ sec/day error}\)

NOTE:
The higher quality CM7V-T1A crystal drifts less than lower quality devices!
Software Migration Example

Quick

Using EDF Demo Board
Show code migration from 16- to 32-bits
  Blink LED
  Drive LCD
  Touch

Easy

Additional Functionality
  WiFi and Graphics
Part 4 of Hands-on Section
Summary

Seamless migration from 16-bit to 32-bit

High performance 32-bit PIC32 offers

More processing power

High quality graphics

Broad range of connectivity

For more details on the tools, libraries, documentation and products covered in this module, visit www.microchip.com/pic32
Wrap Up
One PIC® Microcontroller Platform

Microchip Tools offer One Development Platform

MPLAB® X IDE
Universal device support
Seamless integration
Hardware debuggers and compilers
Simple migration from 8-bit, 16-bit and 32-bit MCU & dsPIC® DSCs

Microchip Products
8/16/32-bit MCUs and dsPIC DSCs to meet your needs
  Low power, high performance, high integration
Wireless support that ranges from Sub-GHz to WiFi®
Choices of analog and memory components

Design Support
Software libraries that port across 8/16/32-bit MCU’s
Development boards for prototyping and hardware design needs
One Design Platform with unified IDE, debuggers and programmers
Recommended Follow-Ups

Take your “One Platform Board” to the next level
Complete component kit PN: AC164035
Available through participating distributors

Download MPLAB® X IDE and view webinars at:
   www.microchip.com/mplab

Download Free version of MPLAB XC Compilers
   at: www.microchip.com/mplabxc

Need a Tool?
Use the 20% off coupon to get what you need
Recommended Technical Training Classes

TLS0101 – Getting Started with Microchip Development Tools

MCU1101 – Getting Started with Mid-Range Microcontroller Family Architecture

MCU2101 – Getting Started with PIC18 Architecture

MCU3101 – Getting Started with 16 bit Microcontroller Architecture

MCU4101 – Introduction to PIC32
Recommended Technical Training Classes

COM3101 – Introduction to Full Speed USB

COM4201 – Designing Embedded TCP/IP Monitor and Control Applications

HIF3121 – Designing with Microchip’s Graphics Library

PWR0110 - Low Power System Design with nanoWatt XLP
Thank you!