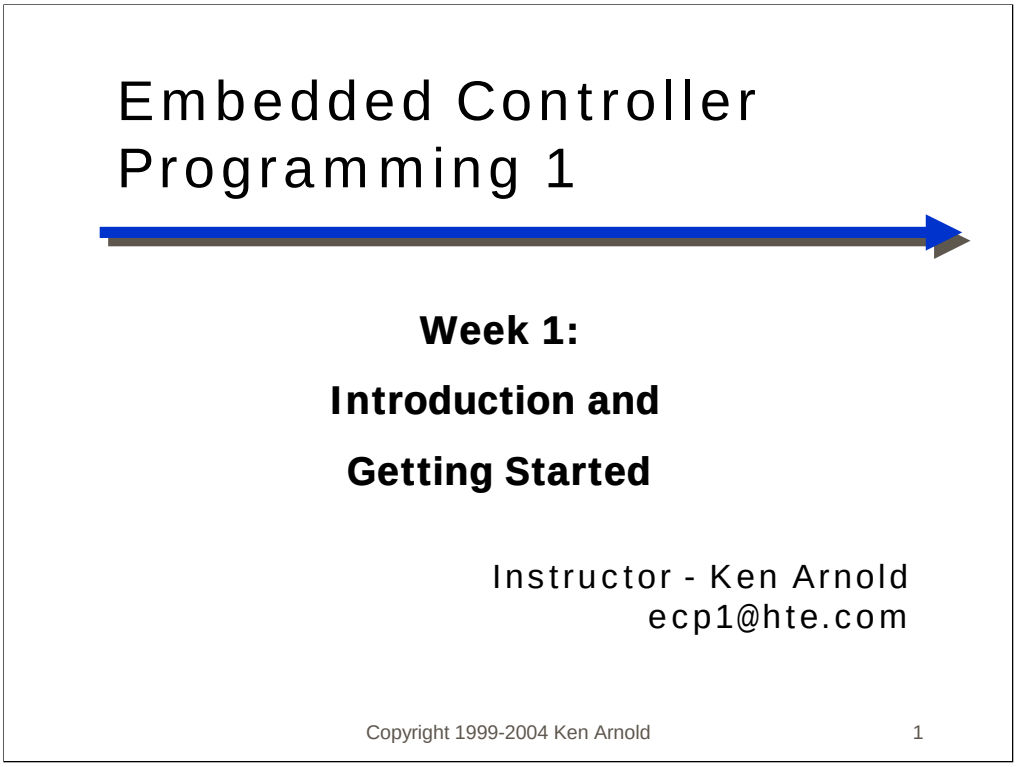


These are the course notes to accompany the UCSD Extension class:
Embedded Controller Programming I: ***Assembly Language Programming***

FIRST send e-mail listing any e-mail addresses you would like to have class notices sent to:

ecp1@hte.com

NEXT send an e-mail message to subscribe to the class discussion group by sending a message to: ucsdecp-request@luisa.hte.com with subject = subscribe

The class e-mail will consist of updates between meetings, Q&A, important notices, and interaction with the instructor and other students between classes.

Course web site: http://www.hte.com/uconline/ecp

programs/other files on the ftp site: ftp://ftp.hte.com/uconline/ecp

Ken Arnold ecp1@hte.com
phone 858-679-1569 or 679-4821 (office)
phone 858-335-9361 (mobile)
fax 858-679-7569
HiTech
14260 Garden Road, Suite 2A
Poway, CA 92064-4972

Welcome to class!

- ECP 1 and 2 Course Overview
- Instructor & Student Introductions
- Processor Architecture
- Basic Instruction Set
- Introduction to the SDK
- Homework #1

 2

Overview - ECP 1

- uC Architecture and Programming
- Assembly Language Programming
- 8051 Memory Model and Memory Usage
- 8051 Instruction Set
- 8051 Hardware Features
- Other Topics

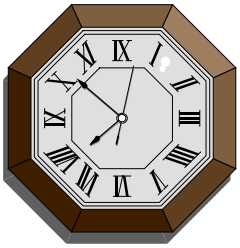
 3

Overview - ECP 2

- Focus on Applications
- Learning to use C for uC Programming
- Adapting C to the uC environment
- Focusing on Modular Programming
- Handling Basic Peripherals
  - Displays
  - Switches/Keypads
  - Motors/Controls
- Student Projects !

 4

Administrative Stuff



- Fill Out Student Forms Please !
- Send e-mail to ecp1@hte.com
- Course Format, Policy
  - Lecture, Demo, Homework, Project
- Class Web Page:
  http://www.hte.com/uconline/ecp
- Grading
  - 4 HomeworkProblems - Due Week after Assigned !
  - Programming Project, Comprehensive Final Exam
- Be Here So We Can Start (and Finish) On Time !

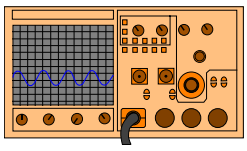
 5

Course Objectives

- Microcontroller vs. Desktop PC
- Familiarity with Hardware
- Familiarity with Tools
- Hands-on Exposure Required
- Low Level Programming, Interfacing
- Microcontroller Applications
- Polite, Invisible computing!

 6

Course Format



- In-class:
  - Lecture and demonstrations
  - 3 hours * 6 meetings
  - Please Ask Questions!!
- Outside of Class:
  - Software Development Kit (SDK),
  - Development Setup:
    - SDK, Prototyping, and Test Equipment

 7

Resources

- Software Tools
  - Assembler
- Hardware
  - SDK, Prototyping Board, Components
- Support Web Sites
  - http://www.hte.com/uconline
- General Information

 8

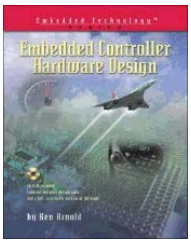
The Toaster Fable

- The King Wants a New Toaster
  - The Pragmatic Solution
  - The Politically Correct Solution
  - The King Resolves the Conflict
- Moral:
  - CS emphasizes most general solution
  - EE emphasizes minimizing complexity

 9

Instructor

- Father of 5, age 6 to 24
  - Preemptive Multi-tasking, Dynamic Priorities!
- Wireless Innovation
  - Product Development and Manufacturing
- UCSD Extended Studies
  - Embedded Certificate Programs



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Student Introduction

- Your Name and Background
- What Do You Do ?
  - *(i.e. - EE at XYZ Corp., etc..)*
- What Do You Want to Get out of This Class ?

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What Is a Microcontroller ?

- What Are They ?
- How Are They Used ?
- Basic Features
- Sizes
- Families
- uC's vs uP's, DSP's, PLD's

 12

µ Controller vs. µProcessor

- µC Chip Includes:
  - Central Processor
  - Program Memory
  - Data Memory
  - I/O
- Highly Integrated
- Low Cost
- Specialized Architectures

- µP Chip Includes:
  - Central Processor
- Separate Chips for:
  - Central Processor
  - Program Memory
  - Data Memory
  - I/O
- Highest Performance
- Highest Cost!

 13

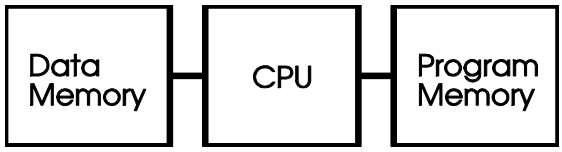
Von Neumann Architecture

- Single Memory for:
  - Programs
  - Data
- Familiar
- Most Flexible
- Used in PCs
- Speed Bottleneck:
  - Memory Interface

 14

Harvard Architecture

- Separate Memory for:
  - Programs
  - Data
- Advantages:
  - Faster
  - Overlap Transfers
    - Instruction Fetch
    - Data Transfer
  - Can't execute Data!



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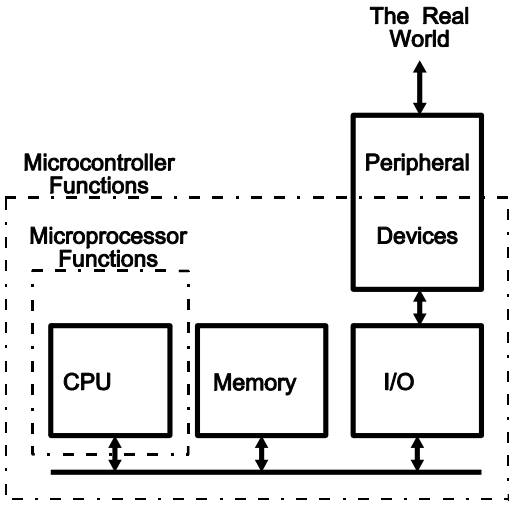
Bus Oriented Microcomputer



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One Chip Microcontrollers

- Advantages:
  - Fewer chips required
  - Lower cost and smaller
  - Lower power
  - Fewer connections
  - More user I/O pins
  - Reliability is higher
  - K.I.S.S.!
- Disadvantages:
  - Reduced flexibility
  - Expansion is limited
  - Limited performance
  - Limited I/O
  - Design compromised to fit everything on one chip

 17

Hierarchy of Computer Design

High Level	Sum := Sum + 1
Assembly	MOV BX,SUM INC (BX)
Machine	1101010100001100 0010001101110101 1111100011001101
Register Transfer	Fetch Instruction, Increment PC, Load ALU with SUM ...
Gate	
Circuit	

Getting Specific...

- In order to get into details, we must look into a specific processor architecture.
- What criteria were used to decide which architecture to use for this course?
  - A real device, in common use
  - Availability from multiple manufacturers
  - Free and very low cost development tools available for student use

The 8051 Microcontroller

- The most widely used microcontroller
- Multiple sources, hundreds of variants
- Free software development tools
  - Assembler
  - Simulator
  - C Compilers
- Low cost hardware components and tools

 20

The 8051 Family

- Originally Designed by Intel
- Introduced in 1980
- PCs Shipped in the Millions per Year
- ***Billions*** of 8051s shipped in one year
  - 1B Sold just by one of the many manufacturers
- New Variants Come out All the Time
- Other Microcontrollers Ship in Billions/Year

 21

Partial List of 8051 Vendors

- **Intel**
  - The Original 8051
  - The 80251 Family
- **Philips**
  - 8051 Family Variants
  - The 8051XA Family
- **Atmel**
  - 20 Pin 89Cxx51 Family
  - 8051 Family Variants
- **Dallas Semiconductor**
  - High Speed Versions
  - Non Volatile SRAM
- **Analog Devices, Cygnal**
- **Temic, ISSI, Matra, OKI, Siemens, SMC, SSI** - and Many Others Too !!!
- **IP Cores for ASICs**
  - Synopsis
  - Mentor

 22

Embedded Memory

- Semiconductor Storage
- Implications of Storage Technology
  - Matching Technology to Application
  - Read-Write, Read-Only, Read-Mostly
- Non-ideal Memory Characteristics
  - Asymmetrical Read, Write

 23

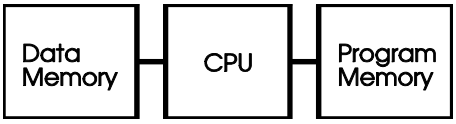
Memory Volatility

- Volatile:
  - Loses contents when power is removed
  - Used for temporary storage of changing values:
    - Variables
    - Stacks
- Non-Volatile:
  - Retains contents after power loss
  - Used for permanent storage of:
    - Programs
    - Constants
    - Look-up Tables

 24

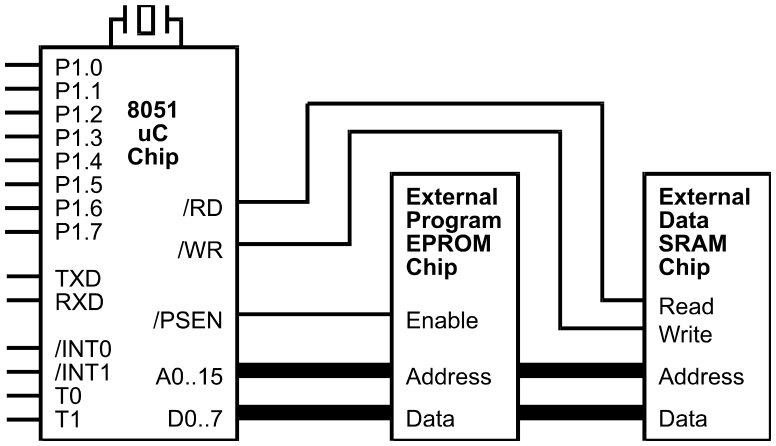
8051 Memory Architecture

- Separate Memory Address Spaces for:
  - Programs - Non-volatile
    - Internal ROM
    - External EPROM
  - Data - Volatile
    - External SRAM
    - Internal RAM
      - General Purpose Registers
      - Bit Addressable Registers
      - Special Function Registers



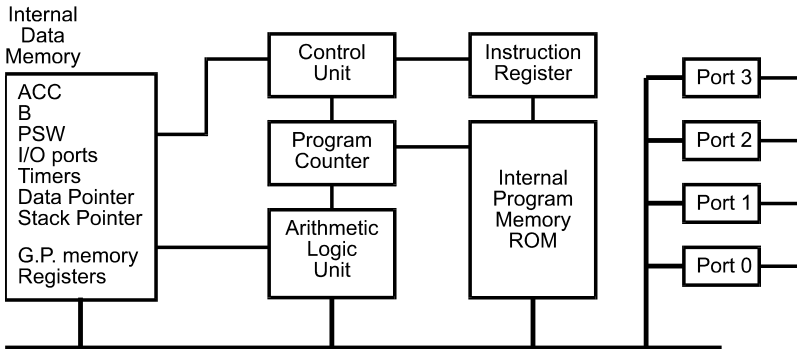
 25

Simple 8051 Block Diagram



 26

8051 uC Chip Block Diagram



 27

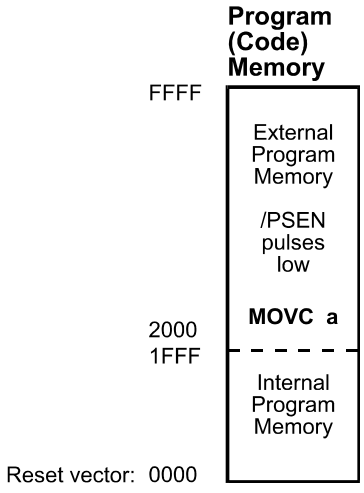
8051 Instruction Set

- Instructions:
  - Data Transfer
  - Arithmetic
  - Logical
  - Control
- Examples:
  - MOV A,90h
  - ADD A,#30h
  - ANL A,#0FEh
  - CALL subroutine
- Address Modes
  - Immediate
  - Direct
  - Indirect
- Examples:
  - MOV A,#30h
  - MOV A,30h
  - MOV A,@R0

 28

8xC52 Program Memory

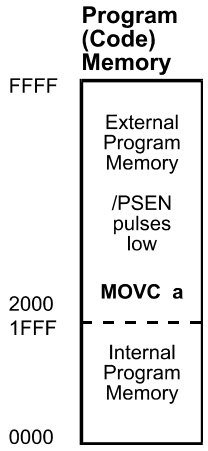
- On-chip Code Memory
  - Non-volatile
  - Different types:
    - 80C52 = Mask ROM
    - 87C52 = EPROM
    - 89C52 = Flash EPROM
- External Code Memory
  - Design Dependent
  - SDK has EPROM & SRAM



 29

Program Memory Usage

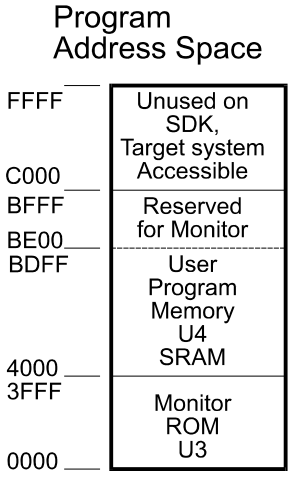
- Processor execution
  - Begins at location 0000h
    - (The “Reset Vector”)
  - Continues with next instruction
- 8x52 has 8K bytes of Internal Code Memory on-chip
- 8x32 has NO code space on chip
- When Processor fetches *external* instructions, /PSEN pulses low



 30

SDK Program Memory Map

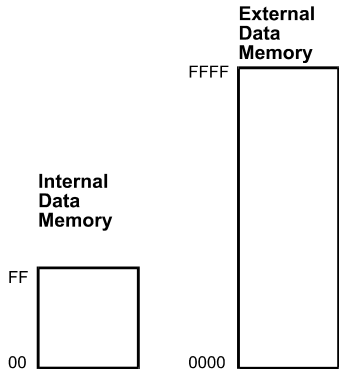
- ROM: 0000-3FFFh
  - Monitor Program
- RAM: 4000-
  - User Program/XData
    - 4000-BDFFh
    - User Programs and Data
  - Monitor Data
    - Reserved: BE00-BFFFh
    - DO NOT Modify!
    - Temporary Storage



 31

Data Memory

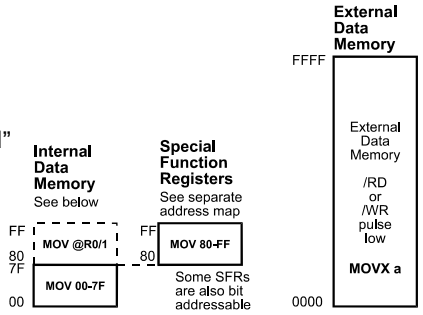
- External SRAM
  - External chip
  - Typically SRAM
- Internal RAM
  - General Purpose Registers
  - Bit Addressable Registers
  - Special Function Registers



 32

Data Memory Addresses

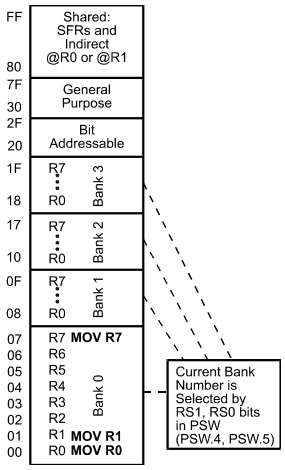
- External Data 0000-FFFFh
- Internal Data 00-FFh
  - General Purpose 00-7Fh
    - G.P. Register Banks
    - Bit Addressable
    - General Purpose “Scratch Pad”
  - Indirect Access 80-FFh
    - Use MOV @R0 or @R1
  - SFRs Direct 80-FFh
    - Overlapped addresses
    - Direct address MOV 00-FFh
    - Special Internal Registers



 33

Internal Data Memory

- Registers R0..7
  - 8 registers per bank
  - 4 Banks available
- Bit Addressable
- General Purpose
- Special Function Registers (SFRs)
  - Accumulator, I/O
  - Timers, misc. registers



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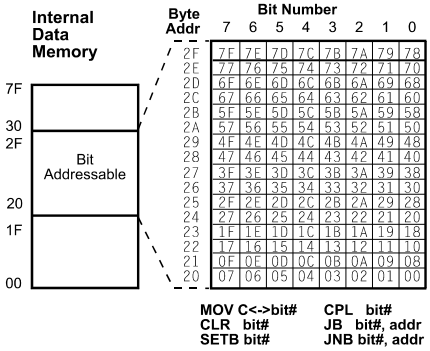
Bit Addressable Memory

- Internal Data Memory
  - Byte Addresses 20-2Fh
  - Bit Addresses 00-7Fh
- Allows individual bit operations:
  - MOV bits to/from Carry
  - SETB sets a bit to 1
  - CLR clears a bit to 0
  - JB conditional jump



 35

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 36

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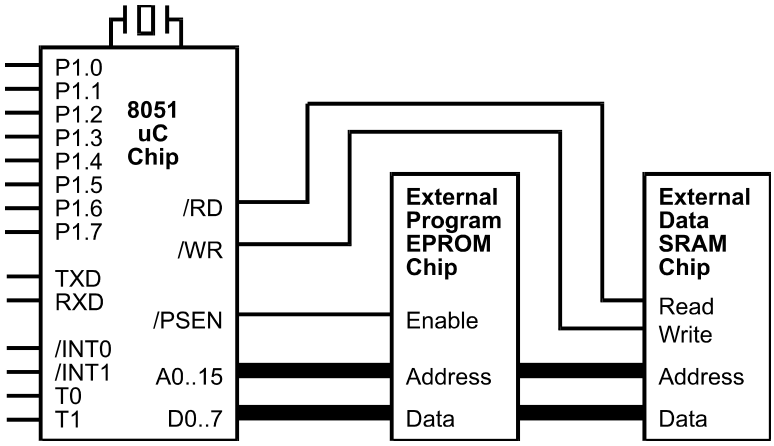

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Development Tools

- Software
  - Translators
    - Assemblers
    - Compilers
  - Linkers
  - Debug Monitor
    - SDK Monitor ROM
  - Performance Analyzers
    - Find Execution Bottlenecks
- Hardware
  - In-Circuit Emulators
    - Substitutes for CPU chip
    - Allows seeing “inside” uC
  - Logic Analyzer
    - View Timing and Bus Cycles
  - Logic Probe
  - Oscilloscope
  - Lights and Beepers

 38

Hardware Handling Issues

- Precautions Regarding:
  - Take Precautions against ESD
  - Avoid Touching Contacts: Metal Oxidation
  - Power = heat and smoke
- But Don’t Be Afraid!!
  - SDKs are easy to fix and connect to probes
  - Sockets for all ICs, and are easily replaced
  - Unlike surface mounted components!

 39

Introduction to the SDK

- Software Development Kit Connections
  - Power, Serial Port, ICE Cable
  - Documentation available at: ftp://ftp.hte.com/uconline/ecp/sdkstuff/
  - SDK Users manual: sdk31man.pdf
  - SDK Schematic: sdk31sch.pdf
- PC Setup, Software Setup
- Common Problems

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PC Software for SDK

- Hyperterminal, MTTTY, or Procomm
  - Terminal Emulator to connect to SDK
  - Command line monitor ROM on SDK
- asm51 8051 Cross assembler translates
  - Input, 8051 source: *.asm
  - Output, Intel Hex object format: *.hex
  - and listing file: *.lst

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SDK Introduction

- Demonstrate System Setup
- Introduce SDK Operation
- Code Development Cycle
- Download and Test

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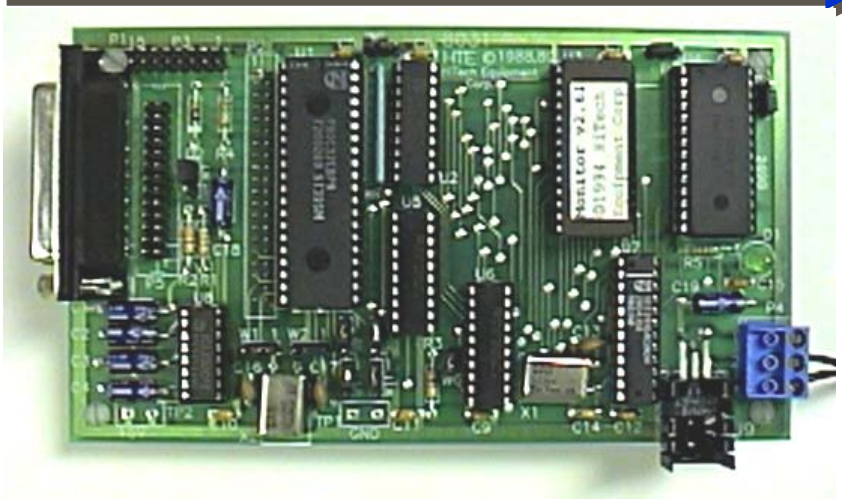
SDK - Top View



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Demonstration of SDK

- Connecting the SDK
- Editing “Hello World” program
- Assembling program
- Downloading Hex file to SDK
- Running the modified SDK program

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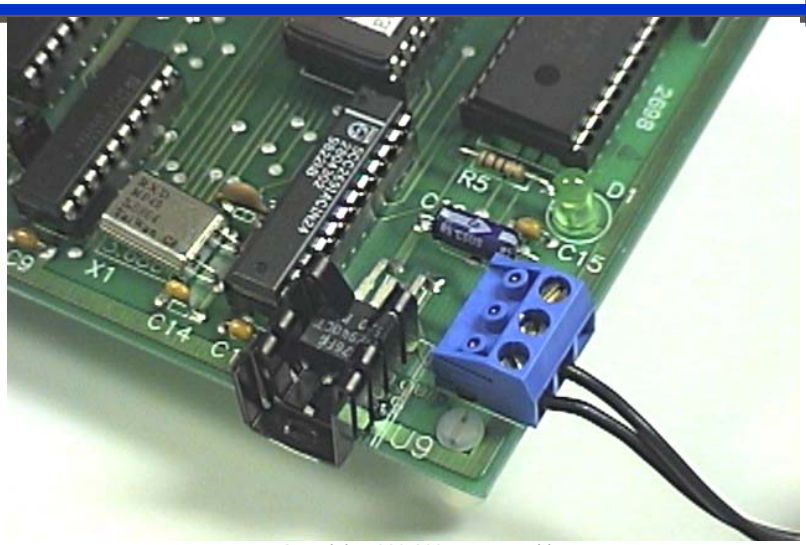
SDK Power Connection



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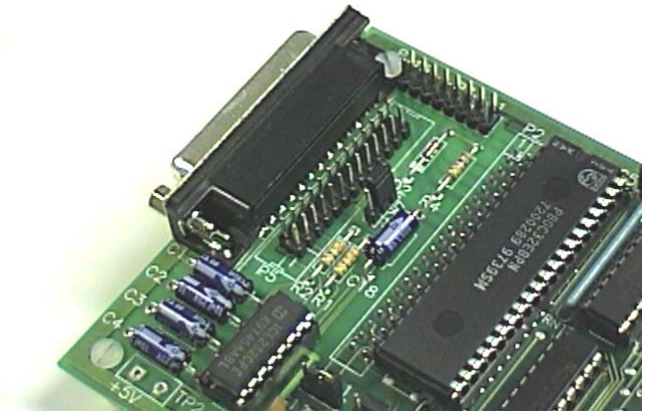
SDK Serial Connector



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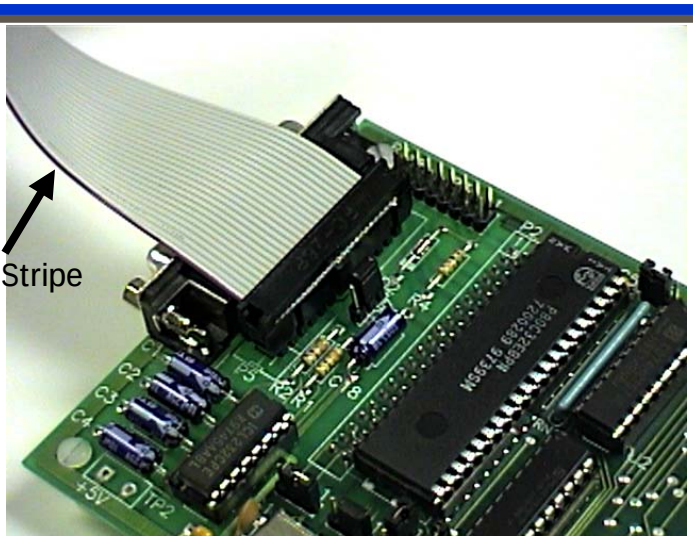
SDK Serial Cable



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Summary

- Introduction
- Microcontroller Architecture
- Memory
- Instruction Set Intro
- Development Tools
- SDK Intro

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Homework Assignment

- Setup SDK and Software
- Modify “Hello World” Program
  - Change output string to Hello <your name>
  - Optional: Try other changes…
    - Increment Port 1 Outputs
    - Blink an LED!
    - Echo characters
    - Play!!!

 49

References

- SDK User's Manual
- Arnold, "Embedded Controller Hardware Design"
- Ayala, "The 8051 Microcontroller"
- Cook, "A First Course in Digital Electronics"
- Foster, "Real Time Programming"
- Gonick, "The Cartoon Guide to Physics"
- Horowitz & Hill, "The Art of Electronics"
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- Schultz, "C and the 8051" vol I and II

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