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• General Introduction to AVR
• AVR Standard Products
  – Existing and New General Purpose Microcontrollers
  – JTAG, Self Programming, LCD interface
• LCD Interface - A Closer Look
• AVR ASSPs and AVR ASICs
  – AVR Devices for Specific Applications
• Design with the AVR
  – Low Power Design using AVR Microcontrollers
  – Hardware design tips
  – Efficient C-coding for the AVR
• AVR Development Tools
• AVR Demo
  – AVR Design from Conception to Production
~ General Introduction of AVR ~
AVR – Number One!

- Shortest Time to Market
- Highest System Integration
- Highest CPU Performance
- Smallest Code Size
- Most Secure Program Memory

This makes the AVR the World’s best selling Flash MCU!
AVR microcontrollers sold

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<tr>
<th>Year</th>
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<td>2003 (est)</td>
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• RISC architecture with CISC instruction set
  – Easy to learn and powerful instruction set for C and Assembly

• Single cycle execution
  – One instruction per external clock
  – Low power consumption

• 32 Working Registers
  – All registers are directly connected to ALU!

• Very efficient core
  – New design using new technology
  – Fully scalable for future products
AVR Block Diagram
AVR Benefits with C

- Up to 50% smaller code size compared to other architectures
- No code size penalty over assembly, at a fraction of the development time
- Maintainable code with less engineering cost
- Write code the way code should be written
- Reusable code for coming projects saves even more development time
ANSI C-Code Size Benchmarks

- 13 Customer Code Applications compiled
- Averaged and accumulated indexes from all applications
- All applications count evenly
- Code Size compared in Kbytes

![Bar chart showing code size for different devices]

- AVR: 100
- HC12: 104
- MSP 430: 122
- HC11: 123
- H8/300H Devices: 130
- 78K/O: 139
- 80C51: 156
- COP8: 218
- PIC18: 265
AVR Family Roadmap

1997

AVR
- TINY AVR
- MEGA AVR
- FPGA AVR

2000

AVR
- TINY AVR
- MEGA AVR
- FPGA AVR

2003

AVR
- ASIC AVR
- TINY AVR
- RF AVR
- AVR
- USB AVR
- SECURE AVR
- MEGA AVR
- LCD AVR
- CAN AVR
- FPGA AVR
- DVD AVR
• **TINY AVR**
  – General purpose Microcontroller with up to 2K Bytes Flash program memory 128 Bytes SRAM and EEPROM

• **AVR**
  – General purpose Microcontroller with up to 8K Bytes Flash program memory 512 Bytes SRAM and EEPROM

• **MEGA AVR**
  – Self programming memory enables remote reprogramming without additional circuitry. Up to 128K Bytes Flash, 4K Bytes EEPROM and SRAM

• **LCD AVR**
  – Integrated LCD driver, automatic contrast control. Extended battery life active mode power consumption 32KHz 20uA
AVR Product Family

- **Secure AVR**
  - Smart Card solutions with integrated 16 bit Crypto co processor and Random word generator

- **RF AVR**
  - Integrated Monolithic programmable Micro Transmitter including PLL-stabilized RF transmitter

- **USB AVR**
  - USB 2.0 compliant core supports general purpose or keyboard controllers
• **CAN AVR**
  - AVR with single or dual CAN controllers targeted at industrial or automotive applications

• **DVD AVR**
  - Complete chip set for DVD and CD storage applications including interface and servo system and read channel device.

• **FPGA AVR**
  - Field programmable integrated circuit with up to 40,000 gates of FPGA and 36K Bytes of SRAM

• **ASIC AVR**
  - Synthesizeable AVR embedded Microcontroller core. Can be combined with memory and logic library structures
~ AVR Standard Products ~

tinyAVR
AVR
megaAVR
LCD AVR
The AVR Product Family

- **Family ranges from 1K to 128K devices**
  - All devices based on same AVR architecture

- **One set of development tools**
  - Reduces tools cost
  - Only one user interface to learn

- **Code can be reused on all other devices!**
AVR – Single-Chip Solution

Many uC only give you this

- TWI
- USART
- SPI
- Hardware Multiplier
- OTP Memory
- Analog Comparator
- CPU CORE
- A/D Converter
- SRAM
- Register File
- I/O pins
- Analog Reference
- Temperature Sensor
- Brown Out Detector
- Watchdog
- In-Circuit Emulator
- Test Fixtures
- LCD driver
- Output Driver
- Programming Circuitry
- EEPROM

LCD DISPLAY
AVR – Single-Chip Solution

AVR Integrates Much More!

LCD display

Temperature sensor

- TWI
- USART
- SPI
- Hardware Multiplier
- Analog Comparator
- A/D Converter
- Brown Out Detector
- Reset Circuitry
- Programmable Watchdog
- On-Chip Debug
- JTAG
- Flash
- CPU CORE
- Register File
- Analog Reference
- Pull-Ups On Demand
- SRAM
- EEPROM
- In System Programming
- High Current Outputs
- Calibrated Oscillator
- LCD Interface
- Boundary Scan
- Calibrated Oscillator
- On Demand
- High Current Outputs
- Pull-Ups
- I/O pins
- Register File
- Analog Reference
TinyAVR Product Overview

- Targeted to serve the high volume consumer market
- Standard and application specific versions
- Differentiating features:
  - A/D with Gain Stage
  - High Frequency PWM with PLL
  - Integrated EEPROM
- High integration for system cost reduction
# TinyAVR Products

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<th>Feature</th>
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AVR Product Overview

• **AVR ranging from 2kB to 8kB**

• **Features:**
  – Integrated SRAM & EEPROM
  – UART
  – SRAM interface
  – High pin count
  – Analog to digital converter

• **High integration for system cost reduction**
### AVR Products

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MegaAVR Product Overview

• Complete Family with 8 to 128K Bytes Flash
• Self-Programming Memory
  – Remote Programming or Field Upgrade
• Hardware Multiplier
• IEEE 1149.1 Compliant JTAG Interface
  – On-chip debug support
• High level of integration
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AVR Embedded Flash and EEPROM

- AVR Flash is the Most Flexible Program Storage
  - Last minute programming
  - Shorter time to market
  - Reduced inventory/logistics cost

- AVR Flash enables the highest security

- AVR Embedded EEPROM saves external components!

Atmel is a market leader in Flash and EEPROM technology!
How to program the Flash

The programming channels can be disabled to avoid any further download!

Parallel
- One of the fastest way to download
- Compatible with major programmers

JTAG
- IEEE std. 1149.1 Compliant interface, can program NVMs, fuses and lock bits
- Used also for On-Chip Debugging and to test the PCB (Boundary-Scan)

Self Program using any physical link!
- Program through any interface (e.g. SPI, TWI)
- Allows 100% Secure Encrypted Remote Updates

ISP
- The native 3-wire interface for a quick update in the field
- Easy-to-use and efficient
Self-Programming – The Easy Way

• AVR Microcontrollers are designed to program themselves at your command

• Designed for ease of use
  – Reprogram new code without external components
  – Small 128 byte Sectored Flash
  – Variable Boot Block Size
  – Read-While-Write
  – Reduces programming time
  – Hardware controlled programming

• Opens a world of possibilities
  – Program through any interface
  – Reprogram without external components
  – Allows 100% Secure Encrypted Remote updates
After a Reset the device can start in Application or Boot Loader Mode.

From the Application, it's possible to jump to the Boot Section.

Data to program can be obtained from the application, internal RAM or from outside.

The Boot Section can program:
- The Application Section
- The Boot Section

Boot Section and Application Section can be locked to avoid:
- Read
- Write
- Read and Write
AVR JTAG Interface

• **A 3-in-one solution:**
  – Efficient development
    ▪ On-Chip Debugging in production silicon
    ▪ Debug on finished product
  – Improved final test
    ▪ Boundary-Scan for efficient PCB test
  – Faster production
    ▪ ISP Programming of both Flash and EEPROM during JTAG production test
    ▪ Reduced programming time compared to standard ISP

• **JTAG Tools available from 3rd Party Vendors**
  – Easy to add program and test support for automated test equipment
Minimum Size Package Options

- **AVR Die Sales Program**
  - All AVR devices are available in Die Form or as uncut wafers

- **Micro Lead Frame Packaging**
  - Low cost package technology
  - Very good noise immunity; substrate connected to ground
  - Standard package for all megaAVR and most tinyAVR devices
  - Near chip-scale package size; Save up to 69% of board space

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<th>TQFP size</th>
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<th>MLF area</th>
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<td>81</td>
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Size in millimeters | Area in mm²
Full range of development tools

- **Evaluation tools**
  - STK500
  - AVR Studio (free!)
  - GCC Compiler (free!)
  
  Total Cost $79

- **Low cost tools**
  - STK500
  - ICE200 or JTAGICE
  - Imagecraft C
  - AVR Studio
  
  Total cost = $377 or $577

- **High Performance tools**
  - STK500
  - ICE50
  - IAR C
  - AVR Studio
  
  Total Cost = $5500
~ LCD Interface ~

A Closer Look
Different Types of LCDs

- **LCD Module**
  - Dot Matrix LCD
  - Single or Multi Line Alphanumerical Display
  - Built-In LCD Driver and Controller
  - Standard 4- or 8-bit Parallel Interface

- **LCD with On-Glass Driver**
  - Segment LCD – Custom Layout
  - Built-In LCD Driver and Controller
  - Serial Interface

- **LCD Glass**
  - Segment LCD – Custom Layout
  - Multiple Connector Access
Liquid Crystal Displays

- **Liquid Crystal Display – LCD**
  - Liquid Crystal used as Polarization Filters
  - Transparent when NOT Energized – Segments NOT Visible
  - Non-Transparent while Energized – Segments Visible
Partly Energized Crystals – Contrast Control

- **LCD Contrast**
  - Partly Energized Crystals cause the Polarization Filters to be Semi-Transparent – Allows Contrast Control
  - Contrast Depending on the Voltage over the LCD Segment
    - Higher Voltage Across the Segment Increases the Contrast
  - Contrast is Adjusted by Increasing/Decreasing VMAX of the LCD Driver

![Contrast vs Voltage Graph](chart.png)
Basic LCD Terminology

• LCD Segment
  – The Smallest Controllable Unit in the LCD Glass
  – The Segment can be any Shape and/or Size
  – Each Segment has Two Terminals – One Segment and One Common

• Segment Terminal
  – The Unique Terminal of a LCD Segment

• Back-Plane or Common Terminal
  – A Terminal that is Connected to Several LCD Segments
Controlling a Simple LCD

- **One Back-Plane – One Segment Line**
  - Alternating Current Obtained by Switching the Polarity of the Back-Plane and the Segment Line
- **One Back-Plane – Multiple Segment Lines**
  - Alternating Current Obtained by Switching Polarity
  - Segment Line Level of Active and Inactive Segments of Opposite Polarity
• **Frame Rate**
  – The Number of Times the LCD is Updated each Second

• **Recommended Frame Rates**
  – Frame Rate Determined by LCD Divider and Prescaler
    ▪ Total Range of Clock Divider is 16 to 32K
  – Above 31 Hz to Avoid Flickering
  – Sufficiently Low Frequency to Avoid Ghosting
    ▪ High Frame Rates can Lead to Problems with Segments Switching Off Correctly
    ▪ Appears as Segments with Less Intensity

• **LCD Clock Options**
  – Asynchronous 32 kHz Timer
  – System Clock
• **Duty Cycle (a.k.a Duty Rate)**
  - The Number of Times the LCD Lines are Toggled within a Frame

  
  \[
  \text{Duty Cycle} = \frac{1}{\text{Number of Common Terminals}}
  \]

• **Bias Voltage**
  - Voltage Levels Required to Activate the Segments Individually

  
  \[
  \text{Bias Voltage} = \frac{1}{\text{Number LCD Driving Voltages} - 1}
  \]
Controlling a Multi Back-Plane LCD

- LCD with more than One Back-Plane is more Complex to Control
  - Several Voltage Levels are Required
  - Polarity of Back-Planes and Segment Lines are Switched more Often
**Duty Cycle and Bias Level**

- **Static Duty, No Bias**
  - One Common Terminal
  - Segment and Common Terminal are Switched Once every Frame
  - 1 Voltage Level

- **½ Duty, ½ Bias**
  - 2 Common Terminals
  - Segment and Common Terminal are Switched Three Times every Frame
  - 2 Voltage Levels
Considering Power Consumption

• Minimizing the Power Consumption of the LCD
  – Special Low Power Driving Waveforms that Minimize Signal Switching should be used
  – To Decrease the Power Consumption of the LCD the Frame Rate should be kept Low

• Sleep Modes that Allow the LCD Module to Operate
  – Synchronous LCD Clock
    ▪ Idle and Power Save Modes
  – Asynchronous LCD Clock
    ▪ Idle, ADC Noise Reduction, and Power Save Modes

• Sleep Modes that does NOT Allow the LCD to Operate
  – Power Down and Standby Modes
    ▪ And ADC Noise Reduction Mode with Synchronous LCD Clock
  – Blank and Disable the LCD before Entering these Modes
Other Considerations

- **LCD Module Highly Flexible**
  - Between 13 and 100 Segments can be Controlled
    - Use 1 to 4 Back-Planes (Depending on Duty Cycle)
    - Use 13 to 25 Segment Lines
  - Unused LCD Pins can be used as General I/O

- **Start of Frame Interrupt used for LCD Update Timing**
  - Ensure that the LCD Data Registers are Latched during Update

- **An External Capacitor must be Applied**
  - LCDCAP – Power Reservoir
A Job for the LCD Module

- The ATmega169 LCD Module is in Control…
  - ‘Set and Forget’ Parameters
    - Frame Rate
    - Duty Cycle
    - Bias Voltage
  - Activate and De-Activate LCD Segments
    - Bits in I/O Registers Control Activation of LCD Segments
    - Contrast Controlled by 4 bits in I/O Register – 16 Levels between 2.60 and 3.35 Volts
  - Automatically Handled by the LCD Module
    - Driving Waveforms (Depending on Duty and Bias)
    - Driving Level (Contrast) Regulated – Not Dependent on Supply Voltage
    - Low Power Waveforms
LCD Module Overview
Where Do I Find More Information?

- ATmega169 Datasheet

- Application Notes
  - AVR064 – “A Temperature Monitoring System with LCD”
  - AVR065 – “LCD Driver for STK502”
  - STK502 Users Guide

- Websites and data sheets from LCD display manufacturers
~ AVR ASSPs and AVR ASICs ~

Secure AVR
RF AVR
USB AVR
CAN AVR
DVD AVR
FPGA AVR
AVR ASICs
SecureAVR Architecture
Secure AVR

- 16-bit Crypto-Processor with pre-programmed functions for cryptography
  - RSA 512- to 2048-bit, DSA, CRT, Key Generation, ECC
- One or Two ISO7816 external interfaces
- USB interface for some devices
- Security Features
  - Obtained security certification under ISO15408 standard, also known as EAL4+
  - AT90SC6464C: capable of VISA Smart Card based payment products up to level 3
- Applications
  - Banking and Financial, Mobile Phone, Pay TV, Internet Transaction
## Secure AVR Line Card

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<thead>
<tr>
<th>Devices</th>
<th>Flash (KB)</th>
<th>Mask ROM (KB)</th>
<th>EEPROM(Bytes)</th>
<th>RAM(Bytes)</th>
<th>SPI</th>
<th>TWI</th>
<th>Hardware Multiplier</th>
<th>8-bit Timer</th>
<th>16-bit Timer</th>
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<th>Vcc(V)</th>
<th>Crypto Engine</th>
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<td>3.3</td>
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<td>RSA 2048-bit now</td>
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</table>
• Smart card applications require high performance, to perform encryption functions in real time.

• **AVR is a High performance core**
  – Harvard RISC architecture
    ▪ Speed benefit of 16-bit core or better….
  – 32 internal registers
  – Most instruction done in one clock cycle

• **AVR: the best choice for JavaCards implementations**
  – AVR is a fast architecture
    ▪ JVM is stack based ; AVR has 4 stack pointers

• **Atmel has developed a SecureAVR architecture**
  – High Security Level Visa Level 3 and C.C. EAL4+ certifications
• The Smart Card market is now a commodity market
• AVR is Cost effective
  – 8-bit complexity
  – Data space efficiency of 8-bit μC
• Most of Smart Card applications are developed in C language
• AVR is Optimized for C
  – Efficient Compiler and development tools
• The main Smart Card application is GSM SIM card
  – AVR is a Low Power architecture
**Atmel: Your Smart RF Solution!**

- **Single chip RF transmitter & microcontroller**
  - RF-part fully under AVR-control
  - One package saves PCB area
- **Minimal external component count**
- **Non-Volatile program & data memory**
  - Flash-part for flexible application
  - EEPROM allows unique ID-coding and data storage
- **Uses standard AVR programming tools**
- **Ideal for battery powered applications**
  - Remote controls, garages, doors, air cons, toys
- **Telemetry**
  - Temperature
- **Alarms**
• AT86RF401 Wireless Data Transmitter
  – Phase-Locked Loop (PLL) -stabilized RF transmitter
  – AVR with 2KB of in-system programmable flash memory
• Watchdog timer and brown-out protection
• 2V operation from a CR2032/CR2016 battery
• Ideal for low-cost, short-haul, battery-operated wireless data transmission applications
AT86RF401 System Block Diagram
AT43USB325/326 Keyboard Solution

- **Minimal development effort**
  - USB 2.0 Compliant keyboard firmware
  - Large memory for multiple keyboard matrices/features
  - Minimal external components
  - Available with Atmel firmware for customization

- **Suitable for large and small volumes**

- **Basic platform for the emerging secure computing applications**
AT43USB35X Family Features

- Single chip solution for a whole range of applications
  - 12 and 24 MIPS AVR
  - Low speed and full speed
  - A-to-D Converters and PWM
  - 100% binary compatible
  - Shared applications and tools with AVRs

- Solid USB Compliance
  - USBIF Integrators List
  - XBOX® Qualified
• **AT43USB320A**
  - AVR with USB hub and embedded function controller

• **AT43USB325/326**
  - Optimized for multimedia keyboard applications
  - Drop-in multimedia keyboard solution with customizable keyboard matrices

• **AT43USB35x**
  - Support for low-/full- speed applications
  - Special peripherals optimized for analog inputs and outputs with USB connectivity

• **AT76C711**
  - Compound USB device designed to provide a high-speed USB interface to devices that need to communicate with a host through fast serial links, like UARTs and IrDA interface.
## USB AVR Line Card

<table>
<thead>
<tr>
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<th>16-bit Timer</th>
<th>16-bit A/D Channels</th>
<th>ISP(I)+Self-Prog.(S)</th>
<th>Vcc(V)</th>
<th>Clock speed(MHz)</th>
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<th># of Function Endpoints</th>
<th>HUB Ports</th>
<th>LED Driver</th>
<th>Packages (Pin)</th>
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</table>
• **Single and Dual CAN Controllers**
  – 2.0A and 2.0B
  – 1Mbits/s maximum transfer rate at 8MHz

• **Memories**
  – 64K-128K Bytes In-System Reprogrammable Flash
  – Optional Boot Code Section with Independent Lock Bits
    ▪ In-system programming by on-chip boot program (CAN, SPI, JTAG)
    ▪ True Read-While-Write operation

• **Peripherals including:**
  – Two 8-bit and two 16-bit timers
  – 8 channels of 10-bit ADC, and PWM
  – TWI, USARTs, SPI
• **AT78C1501: DVD/CD ATAPI Interface Controller**
  - Error Correction Code (ECC)
  - Encoder/Decoder (ENDEC) for DVD and CD

• **AT78C1502: DVD/CD Servo Controller**
  - 3 parallel programmable AVRs in Servo Processing Unit
  - On-Chip Debugger Monitor (OCDM)
  - 3 fast 10-bit DACs for Real Time Control

<table>
<thead>
<tr>
<th>Devices</th>
<th>Flash, KB</th>
<th>Mask ROM, KB</th>
<th>RAM, Bytes</th>
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• 5,000 to 40,000 gates of SRAM-based AT40K FPGA with FreeRAM
• Up to 36K bytes of dynamically allocated instruction and data SRAM
  – Two programmable serial UARTs
  – Two-wire interface
  – Two 8-bit and one 16-bit timers and PWM
• Low static and dynamic power consumption
  – Ideal for portable and handheld applications (<100 uA standby)
• Support for FPGA custom peripherals
  – FPGA macro library of custom peripherals
### FPGA AVR Line Card

<table>
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<th>EEPROM, Bytes</th>
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• **A Cell-Based Library Element**
  - can be combined with memories and user defined hardware blocks to build ASICs.

• **Speed Grade**
  - up to 60 MIPS at 70 MHz on 0.18µm process technology

• **Plug-compatible AVR peripherals available**
  - including SPI, UART, CAN/USB/TWI interfaces, and analog functions like A/D converter, DSP, PLLs oscillator or CODEC

• **Industry-standard CAD tools can be used to define and develop these custom solutions.**
What does AVR mean?

- Shortest Time to Market
- Highest System Integration
- Highest CPU Performance
- Smallest Code Size
- Most Secure Program Memory

This makes the AVR the World’s best selling Flash MCU!