Universidad de Costa Rica

Informe - Laboratorio 4

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1. Resumen

En el cuarto laboratorio se realizó una estación meteorológica con un Atmega2560 (Arduino MEGA), pantalla LCD, sensores de temperatura, humedad, luz, velocidad del viento, lluvia, nivel de batería, potenciómetros, servomotores, LEDs y resistencias. Se un sistema IoT entre un Arduino MEGA y el servidor Thingsboard. Se crea un enlace de comunicación serial a través de un puerto USART para enviar datos del Arduino a la PC, imprimirlos en consola y luego enviarlos a un Dashboard en la plataforma Thingsboard por medio de un script de Python. Se logró implementar lo solicitado en la práctica.

2. Nota teórica

2.1. Detalles técnicos

En esta práctica de laboratorio se utiliza el MCU ATmega2560. Todas las especificaciones se pueden consultar en la hoja de especificaciones completa en el Anexo A. Este MCU viene incrustado en una placa Arduino MEGA.

Se utiliza o recomienda el termistor RTD Pt100 W-EYK. El cual es de platino y depende de la variación de la resistividad en cuanto a la temperatura, es Pt100 por ser de platino y por tener una resistencia de 100 Ω a 0 °C y no posee una curva necesariamente lineal. Tiene un rango de trabajo optimizado entre 0 °C y 100 °C. Todas las especificaciones se pueden consultar en la hoja de especificaciones completa en el Anexo B.

Se utiliza o recomienda el sensor de humedad DHT22. El cual tiene un rango de trabajo de 0 % al 100 % de la humedad relativa. Todas las especificaciones se pueden consultar en la hoja de especificaciones completa en el Anexo C.

Se recomienda el sensor de velocidad de viento WSS100 4-20 mA al no haber encontrado hoja de especificaciones del JL-FSX2 4-20 mA. El cual tiene un rango de trabajo de 0 m/s a 50 m/s. Todas las especificaciones se pueden consultar en la hoja de especificaciones completa en el Anexo D.

Se utiliza o recomienda el sensor de lluvia RG-11. Todas las especificaciones se pueden consultar en la hoja de especificaciones completa en el Anexo E.

2.2. Consideraciones de programación

Es necesario para la manipulación de la pantalla LCD PCD8544 en Arduino incluir la siguiente biblioteca: Pantalla LCD - PCD8544.

Para manejar el servomotor en Arduino se debe incluir la siguiente biblioteca: Servo.

Para el uso de bajo consumo de potencia del Arduino MEGA se utiliza la siguiente biblioteca: Low-Power.

Finalmente, para la comunicación serial en Python y comunicación con Thingsboard se necesitan las siguientes bibliotecas: Serial - Python3 y Paho-mqtt.

2.3. Diseño

2.3.1. Diseño del circuito

- **Sensor de Temperatura RTD:**

  Este corresponde al sensor de temperatura. Se eligió el RTD Pt100 W-EYK similarmente al Laboratorio 3, el cual tiene un rango de operación optimizado entre 0 °C y 100 °C [2], por lo que se maneja en ese rango en el simulador.

  Por la simplificación del componente en el simulador, se caracterizó experimentalmente en una configuración de divisor de tensión con una resistencia de 92 Ω, que al conectar a 5 V se obtiene: 0 °C : 2.6 V. Para el límite superior se caracterizó el componente experimentalmente obteniendo una correspondencia de: 100 °C : 3 V.

  Por ello, todos las entradas analógicas se trabajaron con un nuevo valor de referencia externo Aref: 3 V, para obtener una mejor resolución de los datos.

  Debido a la simplificación de este componente en el simulador, se hace una aproximación lineal para detectar temperaturas intermedias a estos extremos. Teniendo la siguiente ecuación lineal para leer la tensión a través del pin analógico.

$$y = (mx + b)\left(\frac{3\ V}{1023}\right)\ [V] \tag{1}$$

  En donde (mx + b), es lo que se lee del pin A1 en un rango de 0 - 1023. Por lo tanto, la temperatura de la temperatura x se lee como:

$$x = \frac{y - b}{m}\ [^{\circ}C] \tag{2}$$

  Con m:

$$m = \frac{3\ V - 2{,}6\ V}{100\ ^{\circ}C - 0\ ^{\circ}C} = 0{,}004\ [V/^{\circ}C] \tag{3}$$

  Y con b:

$$b = 2{,}6\ [V] \tag{4}$$

- **Sensor de Humedad:**

  El sensor de humedad relativa corresponde al DHT22, el cual tiene un rango de operación de: (0 % - 100 %).

  Como simplificación, se utilizó una fuente variable de tensión que mide la humedad relativa en % con los siguientes rangos: (0 % - 100 %) : (0 V - 3 V). Los 3 V es por la nueva referencia externa de tensión para pines analógicos implementada para el sensor de temperatura. Se hace una lectura de la tensión en el pin A2 en un rango de 0 - 1023 y la humedad se calcula de la siguiente forma.

$$Humedad = A2\left(\frac{100\,\%}{1023}\right)\ [\,\%] \tag{5}$$

- **Sensor de Luz:**

  El sensor de luz corresponde a un LDR, el cual se le asignó un rango de operación de: (1 Lux - 999 Lux).

  Se caracterizó experimentalmente para obtener un rango de tensión de 0 V a 3 V por lo que se utiliza un resistor de 510 Ω. Se obtuvieron los rangos: (1 Lux - 999 Lux) : (0 V - 3 V). Los 3 V es por la nueva referencia externa de tensión para pines analógicos implementada para el sensor de temperatura. Se hace una lectura de la tensión en el pin A3 en un rango de 0 - 1023 y la intensidad luminosa se calcula de la siguiente forma.

$$Humedad = A3\left(\frac{999Lux}{1023}\right)\ [Lux] \tag{6}$$

- **Sensor de Viento:**

  El sensor de velocidad del viento corresponde al WSS100 4-20 mA (a falta de hoja de especificaciones del JL-FSX2 4-20 mA). Como simplificación, se utilizó una fuente variable de tensión que mide la velocidad del viento con los siguientes rangos: (0 m/s - 50 m/s) : (0 V - 3 V). Los 3 V es por la nueva referencia externa de tensión para pines analógicos implementada para el sensor de temperatura. Se hace una lectura de la tensión en el pin A4 en un rango de 0 - 1023 y la velocidad se calcula de la siguiente forma.

$$Humedad = A3\left(\frac{50m/s}{1023}\right)\ [m/s] \tag{7}$$

- **Sensor de Lluvia:**

  El sensor de lluvia corresponde al Hydreon RG-11. Como simplificación, se utilizó un relé bajo la configuración mencionada en el enunciado el cual es activo en bajo pero corregido en el código para que en alto se indique que está lloviendo. Se conecta al pin digital 9.

- **Sensor de Nivel de Batería:**

  Como la batería es de 12 V y no se puede conectar directamente a un pin, se hace un divisor de tensión con 4 resistencias de 100 Ω cada una y se conecta a la última al pin analógico A0. Se tiene como recomendado trabajar a con una tensión de 7 V para un Arduino MEGA y como límite 6 V. Por lo tanto, se estableció como 8 V la tensión de indicación de batería baja. Esto corresponde a una lectura de la última resistencia de 2 V o menos para encender el LED correspondiente y enviar el mensaje. Aquí se entra a un nivel de consumo bajo por medio de la biblioteca correspondiente.

- **Servomotor - Potenciómetro:**

  Se utilizará dos potenciómetros de 1 kΩ, uno para controlar por PWM el servomotor del panel horizontal (pin 11) y el otro vertical (pin 10), conectado como divisor de tensión de resistencia cada uno y conectado a 5 V. Se busca una tensión máxima del potenciómetro de 3 V (Aref) cuando el potenciómetro vale 1 kΩ. Esto se logró con una resistencia de 665 Ω calculada de la siguiente forma.

$$Vpot = Vin\frac{Rpot}{Rpot + R} \tag{8}$$

Despejando R:

$$\begin{aligned} R &= Vin\frac{Rpot}{Vpot} - Rpot \\ R &= 5\ V\frac{1\ k\Omega}{3\ V} - 1\ k\Omega \\ R &= 665\ \Omega \end{aligned} \tag{9}$$

Los servomotores se controlan por medio de la biblioteca ya mencionada con un rango de ángulo de 0° - 180°.

- **LED - Resistor:**

  Se conecta un LED rojo al pin digital 13 que se encenderá intermitentemente cuando la batería de 12 V alcance un 67 % de su carga, lo que corresponde a 8 V. Esto debido a que se recomiendan 7 V para un funcionamiento óptimo del Arduino MEGA y 6 V como tensión límite de funcionamiento, por lo tanto al alcanzar 8 V se tiene como en caso extremo 2 V para realizar un cambio en la pila, recordando que los paneles solares también cubren cierta carga de consumo del equipo. Además, se conecta un LED verde al pin digital 12 que se encenderá intermitentemente cuando esté habilitada la comunicación USART entre el Arduino MEGA y la PC/Thingsboard.

  Los LEDs tienen una tensión de polarización directa de 2.4 V y soportan una corriente máxima de 30 mA. Teóricamente se toma como la tensión que coloca en el pin el Arduino para encender el LED como 5 V.

  Se calcula la corriente teórica, utilizando un R = 100 Ω.

$$I_{LED} = \frac{5\ V - 2{,}4\ V}{100\ \Omega} = 26\ mA \tag{10}$$

  Se cumple teóricamente que la corriente que pasa por los LEDs, está por debajo de la corriente máxima que resisten estos LEDs: 30 mA.

- **Pantalla LCD:**

  Para la pantalla se hace uso de la biblioteca del siguiente enlace: Pantalla LCD - PCD8544

  Se sigue el procedimiento que señala la biblioteca para su implementación. Se coloca un switch con una resistencia de 100 Ω en configuración pull down, para que cuando el switch está abierto no se imprima ningún dato en la pantalla LCD. Cuando el switch se cierra, pone en alto el pin 2 y es aquí cuando se imprimen los valores de los sensores de temperatura, humedad, luminosidad, velocidad del viento y si está lloviendo.

- **Comunicación USART - Switch**

  Se coloca un switch con una resistencia de 100 Ω en configuración pull down, para que cuando el switch está abierto no se imprima ningún dato en el monitor serial. Cuando el switch se cierra, pone en alto el pin 8 y es aquí cuando se imprimen los valores de los sensores más el estado de la batería en el monitor serial del simulador, que luego son tomados por un script de Python e impresos en terminal en formato JSON y enviados al servidor Thingsboard para ser impresos en un Dashboard.

- **Conexiones a pines:**

  En la tabla 1, se muestran las conexiones de los componentes al Arduino MEGA del circuito a implementar.

  Tabla 1: Correspondencia de conexión entre pines del Arduino MEGA y componentes.

Pin	**Modo**	**Tipo**	**Componente**
A0	Entrada	Analógica	Sensor de Batería
A1	Entrada	Analógica	Sensor de Temperatura
A2	Entrada	Analógica	Sensor de Humedad
A3	Entrada	Analógica	Sensor de Luz
A4	Entrada	Analógica	Sensor de Viento
A5	Entrada	Analógica	Potenciómetro Vertical - Panel solar
A6	Entrada	Analógica	Potenciómetro Horizontal - Panel solar
2	Entrada	Digital	Switch - Pantalla
8	Entrada	Digital	Switch - USART
9	Entrada	Digital	Sendor de Lluvia
10	Salida	Digital - PWM	Servomotor Vertical - Panel solar
11	Salida	Digital - PWM	Servomotor Horizontal - Panel solar
12	Salida	Digital	LED: Verde - USART ON
13	Salida	Digital	LED: Rojo - Batería Baja

2.3.2. Componentes necesarios

Tabla 2: Componentes necesarios, consultados el 12 de junio del 2022 en MJPM [6].

Cantidad	Componente	Precio Unidad	Precio Subtotal
1	Arduino MEGA	$ 35.95	$ 35.95
1	Pantalla LCD PCD8544	$ 8.95	$ 8.95
1	LED Rojo	$ 0.14	$ 0.14
1	LED Azul	$ 0.14	$ 0.14
1	Resistor 92 Ω	$ 0.06	$ 0.06
9	Resistor 100 Ω	$ 0.06	$ 0.54
1	Resistor 510 Ω	$ 0.06	$ 0.06
2	Resistor 665 Ω	$ 0.06	$ 0.12
1	Resistor 10 kΩ	$ 0.06	$ 0.06
1	Resistor 100 kΩ	$ 0.06	$ 0.06
1	Resistor RTD Pt100 W-EYK	$ 12.95	$ 12.95
1	Sensor Humedad DHT22	$ 11.95	$ 11.95
1	Sensor Luz LDR	$ 1.00	$ 1.00
1	Sensor Velocidad Viento WSS100	$ 300.00	$ 300.00
1	Sensor de Lluvia RG-11	$ 60.00	$ 60.00
2	Servomotor	$ 6.00	$ 12.00
2	Potenciómetro 1 kΩ	$ 1.00	$ 2.00
2	Switch	$ 0.65	$ 1.30
Precio Total			**$ 447.28**

Nota: Se muestran precios de los componentes, aunque las características eléctricas se mantienen las que vienen por defecto con los componentes del simulador. No son las mismas características eléctricas de los componentes referenciados, ya que solo se buscaba un precio aproximado.

3. Análisis de resultados

En esta sección se exponen los resultados obtenidos en la práctica cuatro del curso Laboratorio de Microcontroladores. Puede acceder a los archivos en el repositorio: Laboratorio 4 - GitHub. En el repositorio están las instrucciones básicas de la ejecución del código fuente.

3.1. Circuito implementado

En la figura 1, se muestra el circuito implementado completo según el diseño presentado en la nota teórica.

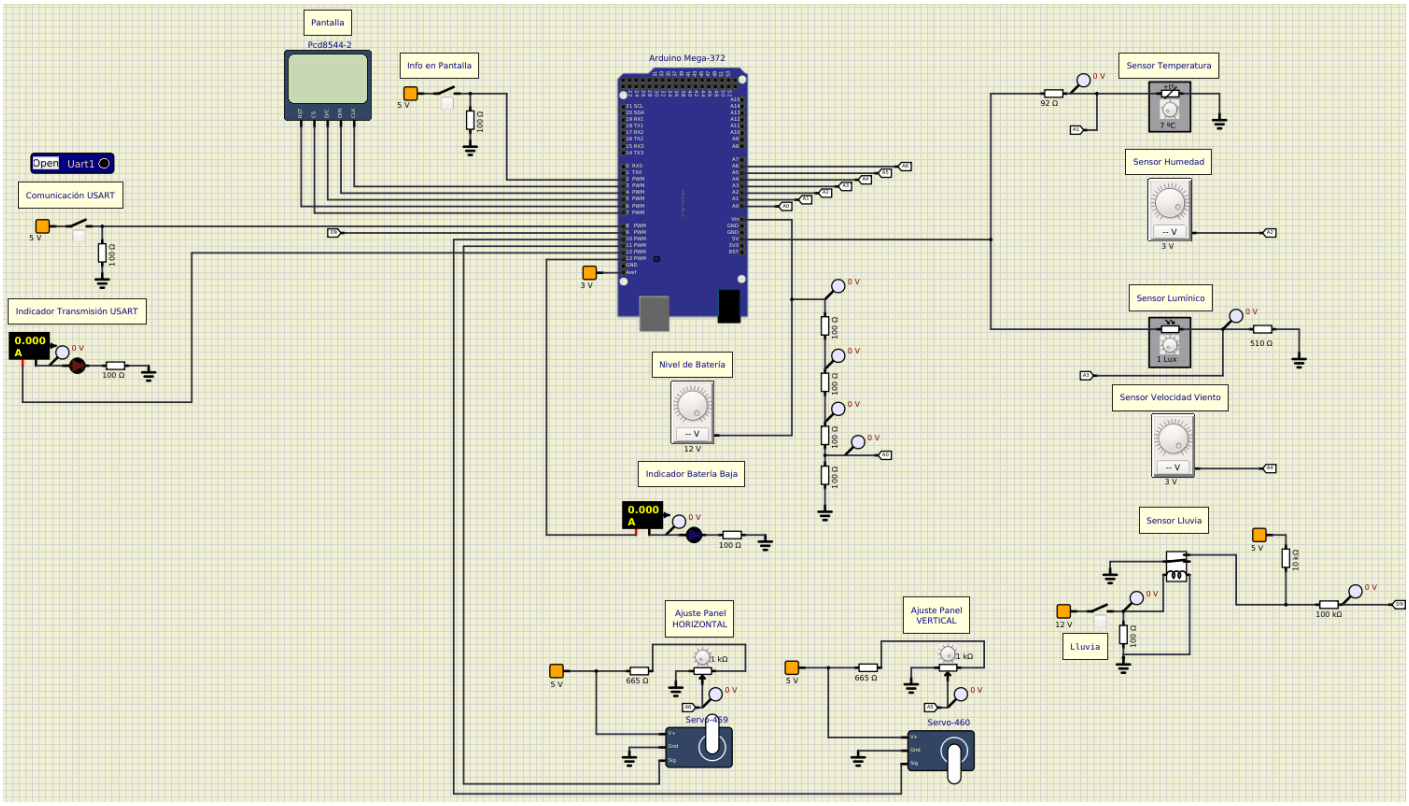


Figura 1: Circuito implementado.

3.2. Funcionamiento del circuito: Estación Meteorológica

En la figura 2, se muestra el mismo circuito siendo simulado. Experimentalmente, se obtiene que a través de cada uno de los LEDs pasan 18.49 mA, lo que está casi a una tercera parte de alcanzar la corriente máxima admitida por uno de estos componentes: 30 mA. El LED verde se enciende intermitentemente al transmitir los datos USART y el rojo se enciende intermitentemente cuando la batería es igual a 8 V o menos. Teóricamente se había calculado para los LEDs una corriente máxima de 26 mA, resultando menor a esta experimentalmente.

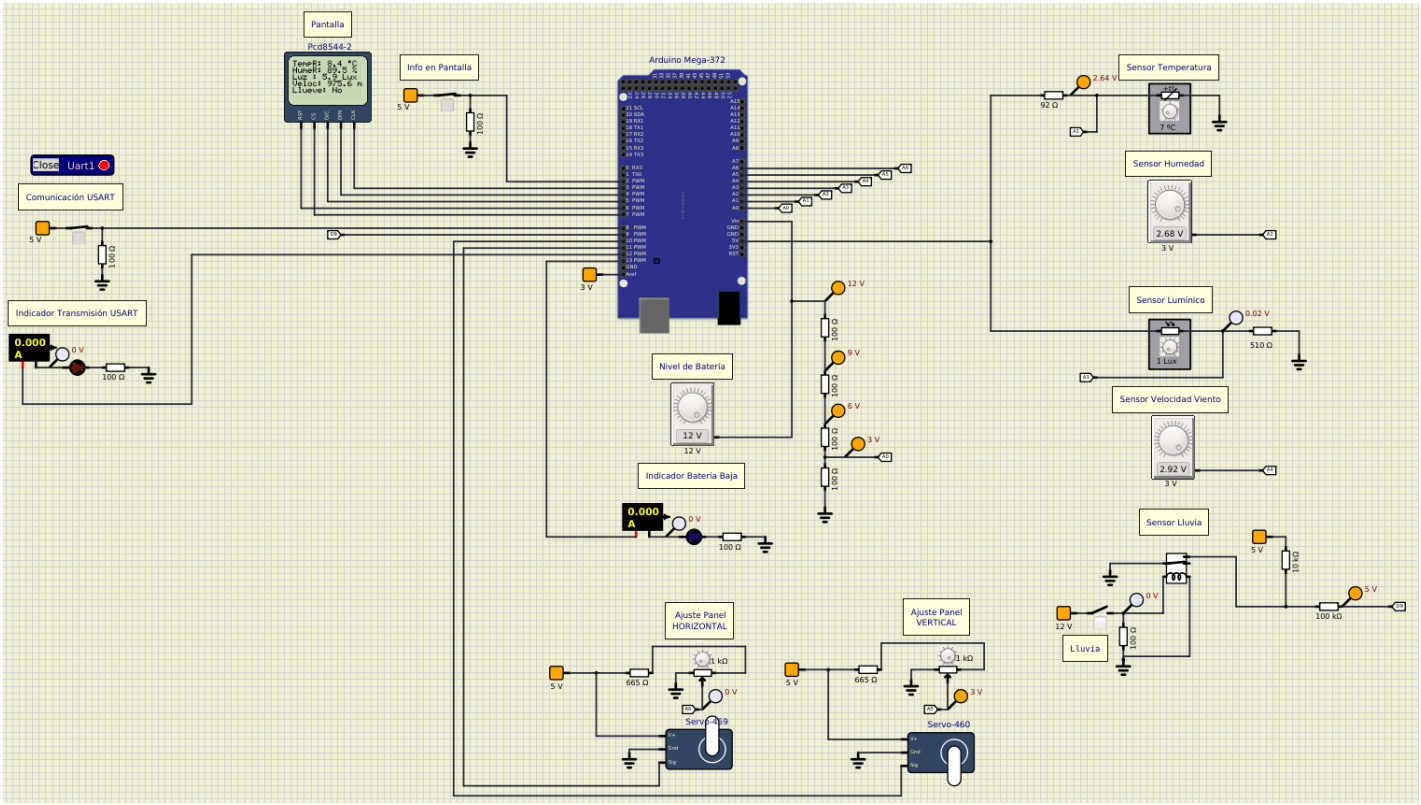


Figura 2: Circuito implementado en funcionamiento.

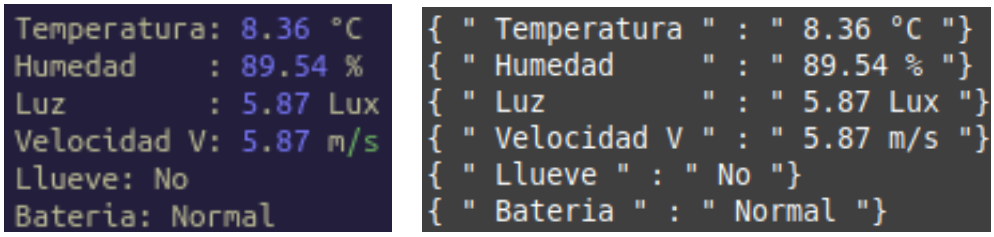
En la figura 3, se muestran los datos impresos en pantalla de forma correcta. Se demuestra la correcta lectura de los sensores de temperatura, humedad, luz, velocidad del viento y de lluvia. La batería no se incluye en esta pantalla LCD pues está el indicador LED, pero se envían los datos serialmente a la PC por medio del script de Python y este al servidor Thingsboard. Cuando se apaga el switch de la pantalla se queda en blanco, se tuvo que hacer por software que imprima strings vacíos porque el simulador no contempla el pin de la alimentación de la pantalla como para deconectarla directamente con el switch (limitación del simulador).

Figura 3: Datos obtenidos en la pantalla LCD PCD8544.

Además, se hace correctamente el control de los servomotores que controlan la dirección del panel solar por medio de potenciómetros.

3.2.1. Comunicación Serial con PC-ThingsBoard

En la figura 4a, se muestran los datos impresos en el monitor serial del simulador al estar el switch USART cerrado. Por lo tanto, el script de Python toma los datos y los imprime en consola (figura 4b) y los envía en formato JSON al servidor de Thingsboard para ser impresos en el Dashboard de nombre Lab4_B41546 (figura 5).



(a) Monitor Serial (b) Terminal-Python

Figura 4: Comunicación Serial: Arduino MEGA - PC - Terminal

Figura 5: Comunicación Serial: Dashboard - ThingsBoard

Nota: No se implementó la escritura en memoria EEPROM de estos datos por cuestiones de tiempo. Además, la impresión o envío de datos al Dashboard se hace con cada lectura de los sensores y no cada 10 minutos como se planteó en el enunciado. Solo estos dos requerimientos no fueron implementados porque se le dio prioridad de completar la conexión IoT entre el Arduino y el servidor de Thingsboard.

4. Conclusiones y recomendaciones

- Se realizó una estación meteorológica con un Arduino MEGA, pantalla LCD, sensores de temperatura, humedad, de luz, velocidad de viento, lluvia, nivel de batería, servomotores, potenciómetros, LEDs y resistencias.
- Se hace la conversión de Analógico a Digital de señales de distintos sensores y potenciómetros.
- Se utilizan actuadores como servomotores controlados por señales PWM en un rango de 180°.
- Se implementó una comunicación serial a través de un puerto USART para enviar datos a la PC, imprimirlos en consola y luego enviarlos a un servidor por medio de Python y Arduino.
- Se hizo una conexión entre un Arduino MEGA y Thingsboard, implementando con éxito el IoT.
- Para una fuente de alimentación baja se hizo trabajar el Arduino MEGA con un bajo consumo de potencia.
- Se recomienda verificar los resultados con componentes reales.
- Se recomienda trabajar de la mano con la hoja de especificaciones de los componentes, en especial los sensores para conocer sus rangos de operación.
- Se recomienda implementar la escritura a la memoria EEPROM que por cuestión de tiempo no se puedo implementar porque se le dio prioridad a la interfaz IoT con Thingsboard. Además, de enviar datos cada 10 minutos para no saturar el envío de datos innecesariamente.

Bibliografía

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5. Anexos

5.1. Anexo A: Hoja de Especificaciones ATmega2560 [1]

Features

- High Performance, Low Power Atmel® AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 135 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 × 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16MHz
  - On-Chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 64K/128K/256KBytes of In-System Self-Programmable Flash
  - 4Kbytes EEPROM
  - 8Kbytes Internal SRAM
  - Write/Erase Cycles:10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/ 100 years at 25°C
  - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
  - Programming Lock for Software Security
    - Endurance: Up to 64Kbytes Optional External Memory Space
- Atmel® QTouch® library support
  - Capacitive touch buttons, sliders and wheels
  - QTouch and QMatrix® acquisition
  - Up to 64 sense channels
- JTAG (IEEE std. 1149.1 compliant) Interface
  - Boundary-scan Capabilities According to the JTAG Standard
  - Extensive On-chip Debug Support
  - Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - Four 16-bit Timer/Counter with Separate Prescaler, Compare- and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Four 8-bit PWM Channels
  - Six/Twelve PWM Channels with Programmable Resolution from 2 to 16 Bits (ATmega1281/2561, ATmega640/1280/2560)
  - Output Compare Modulator
  - 8/16-channel, 10-bit ADC (ATmega1281/2561, ATmega640/1280/2560)
  - Two/Four Programmable Serial USART (ATmega1281/2561, ATmega640/1280/2560)
  - Master/Slave SPI Serial Interface
  - Byte Oriented 2-wire Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 54/86 Programmable I/O Lines (ATmega1281/2561, ATmega640/1280/2560)
  - 64-pad QFN/MLF, 64-lead TQFP (ATmega1281/2561)
  - 100-lead TQFP, 100-ball CBGA (ATmega640/1280/2560)
  - RoHS/Fully Green
- Temperature Range:
  - -40°C to 85°C Industrial
- Ultra-Low Power Consumption
  - Active Mode: 1MHz, 1.8V: 500µA
  - Power-down Mode: 0.1µA at 1.8V
- Speed Grade:
  - ATmega640V/ATmega1280V/ATmega1281V:
    - 0 - 4MHz @ 1.8V - 5.5V, 0 - 8MHz @ 2.7V - 5.5V
  - ATmega2560V/ATmega2561V:
    - 0 - 2MHz @ 1.8V - 5.5V, 0 - 8MHz @ 2.7V - 5.5V
  - ATmega640/ATmega1280/ATmega1281:
    - 0 - 8MHz @ 2.7V - 5.5V, 0 - 16MHz @ 4.5V - 5.5V
  - ATmega2560/ATmega2561:
    - 0 - 16MHz @ 4.5V - 5.5V

8-bit Atmel Microcontroller with 64K/128K/256K Bytes In-System Programmable Flash

ATmega640/V
ATmega1280/V
ATmega1281/V
ATmega2560/V
ATmega2561/V

Preliminary Summary

2549NS–AVR–05/11

ATmega640/1280/1281/2560/2561

1. Pin Configurations

Figure 1-1. TQFP-pinout ATmega640/1280/2560

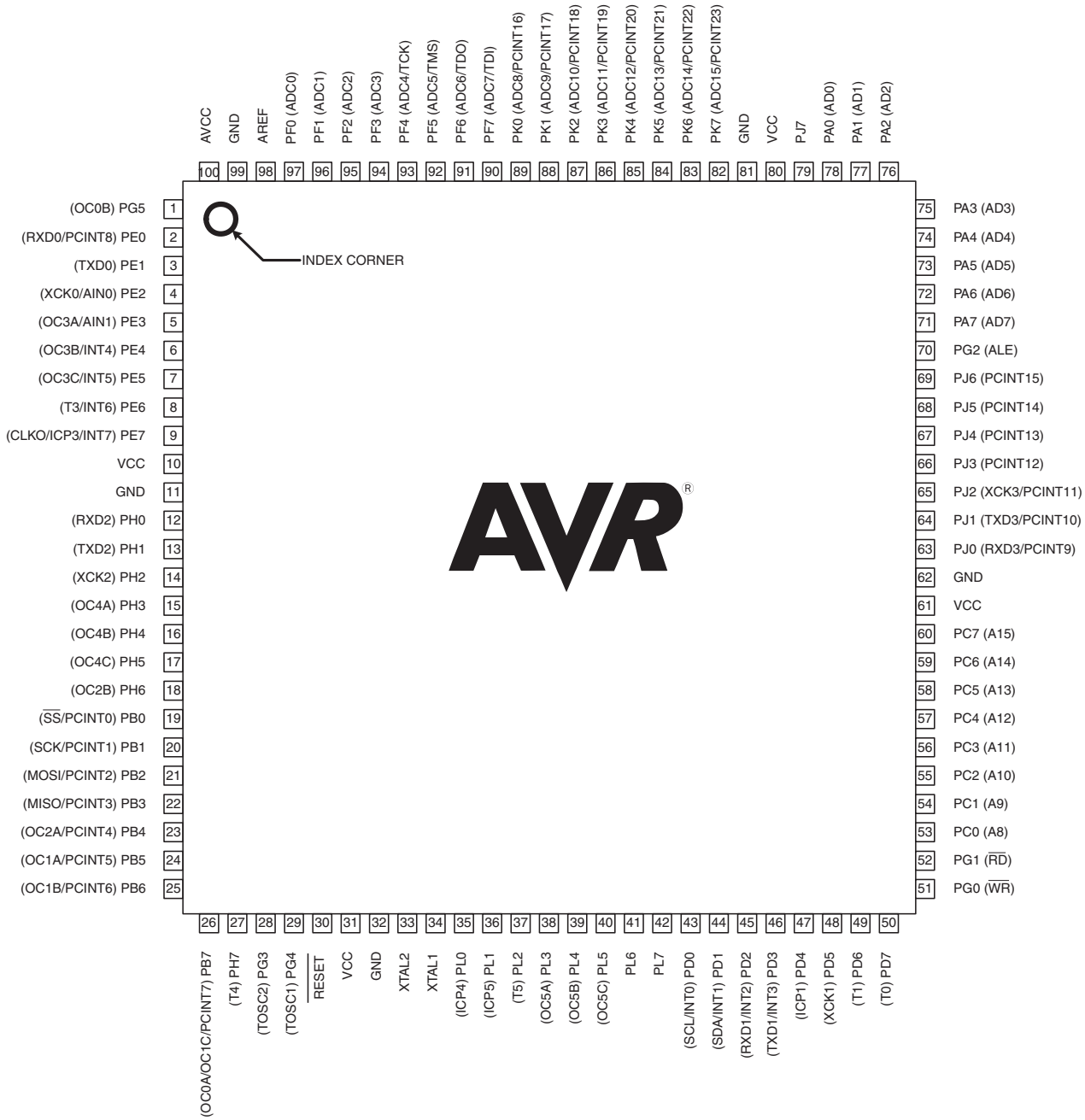


Figure 1-2. CBGA-pinout ATmega640/1280/2560

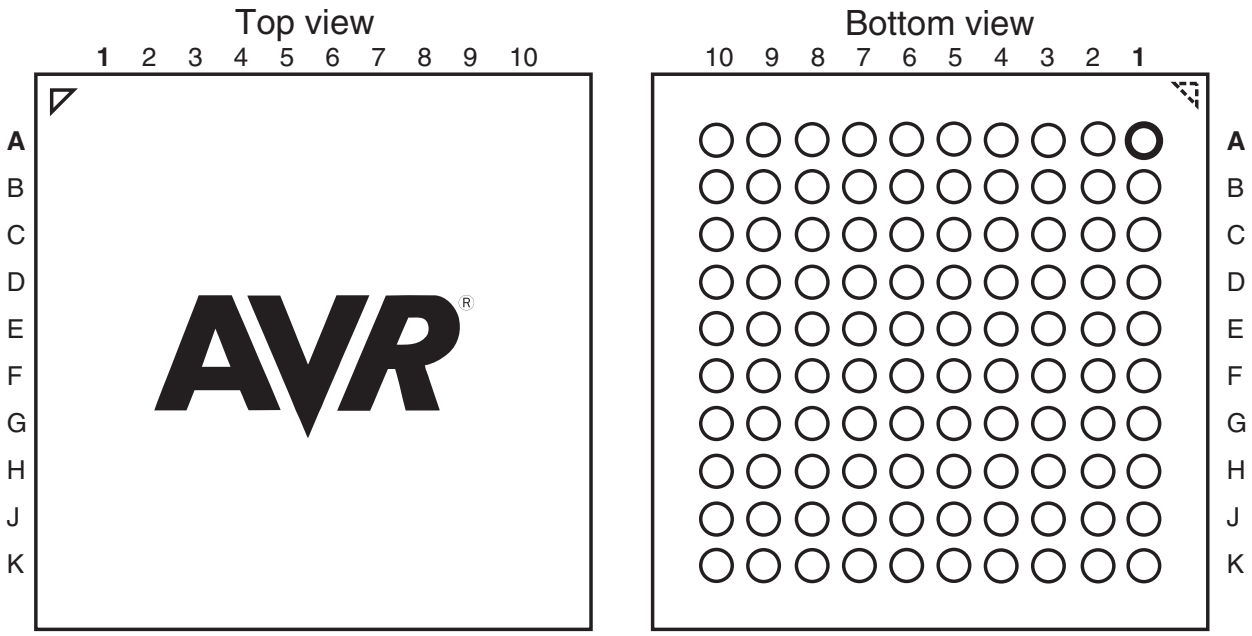
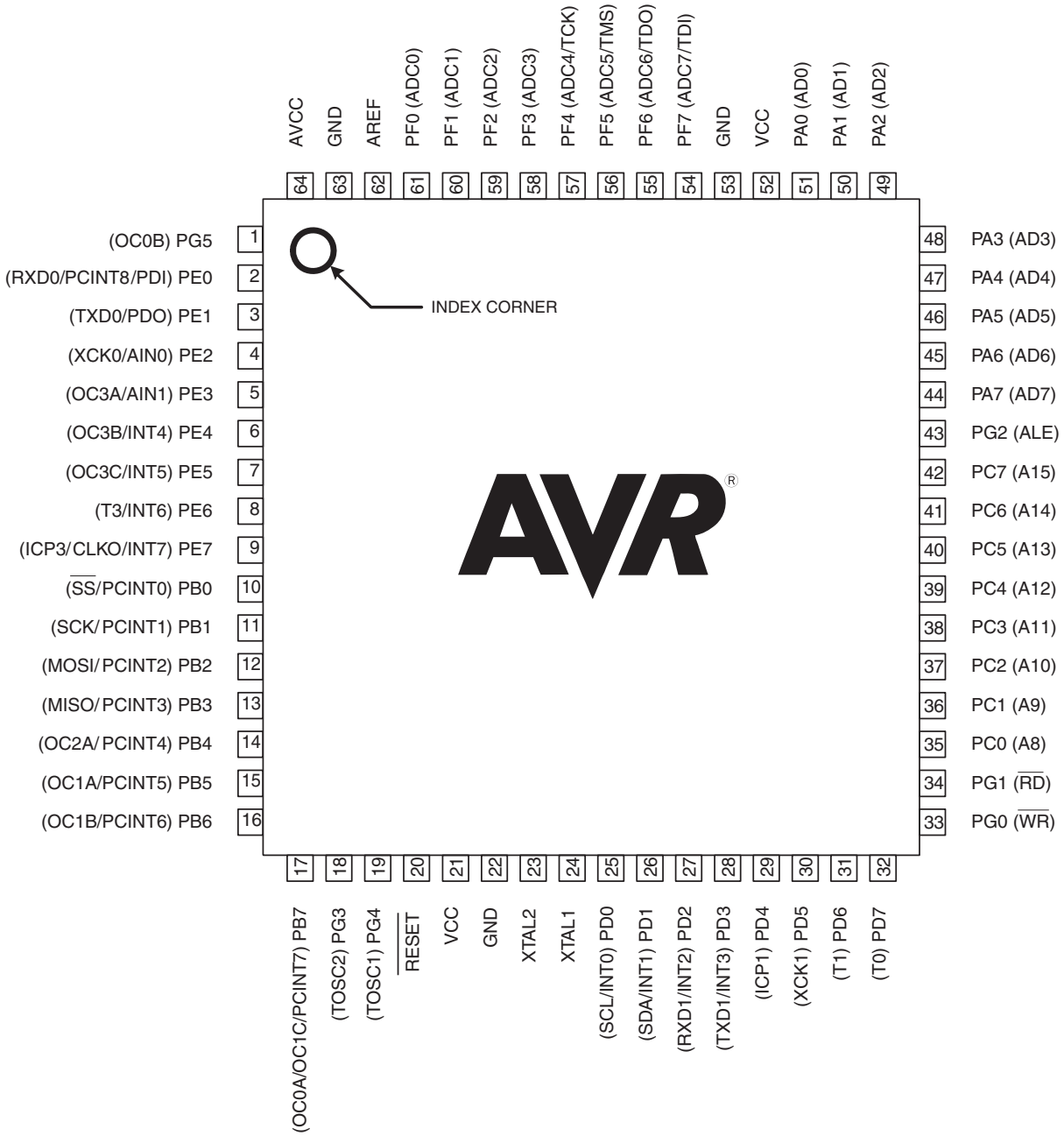


Table 1-1. CBGA-pinout ATmega640/1280/2560

	1	2	3	4	5	6	7	8	9	10
A	GND	AREF	PF0	PF2	PF5	PK0	PK3	PK6	GND	VCC
B	AVCC	PG5	PF1	PF3	PF6	PK1	PK4	PK7	PA0	PA2
C	PE2	PE0	PE1	PF4	PF7	PK2	PK5	PJ7	PA1	PA3
D	PE3	PE4	PE5	PE6	PH2	PA4	PA5	PA6	PA7	PG2
E	PE7	PH0	PH1	PH3	PH5	PJ6	PJ5	PJ4	PJ3	PJ2
F	VCC	PH4	PH6	PB0	PL4	PD1	PJ1	PJ0	PC7	GND
G	GND	PB1	PB2	PB5	PL2	PD0	PD5	PC5	PC6	VCC
H	PB3	PB4	RESET	PL1	PL3	PL7	PD4	PC4	PC3	PC2
J	PH7	PG3	PB6	PL0	XTAL2	PL6	PD3	PC1	PC0	PG1
K	PB7	PG4	VCC	GND	XTAL1	PL5	PD2	PD6	PD7	PG0

Note: The functions for each pin is the same as for the 100 pin packages shown in Figure 1-1 on page 2.

Figure 1-3. Pinout ATmega1281/2561



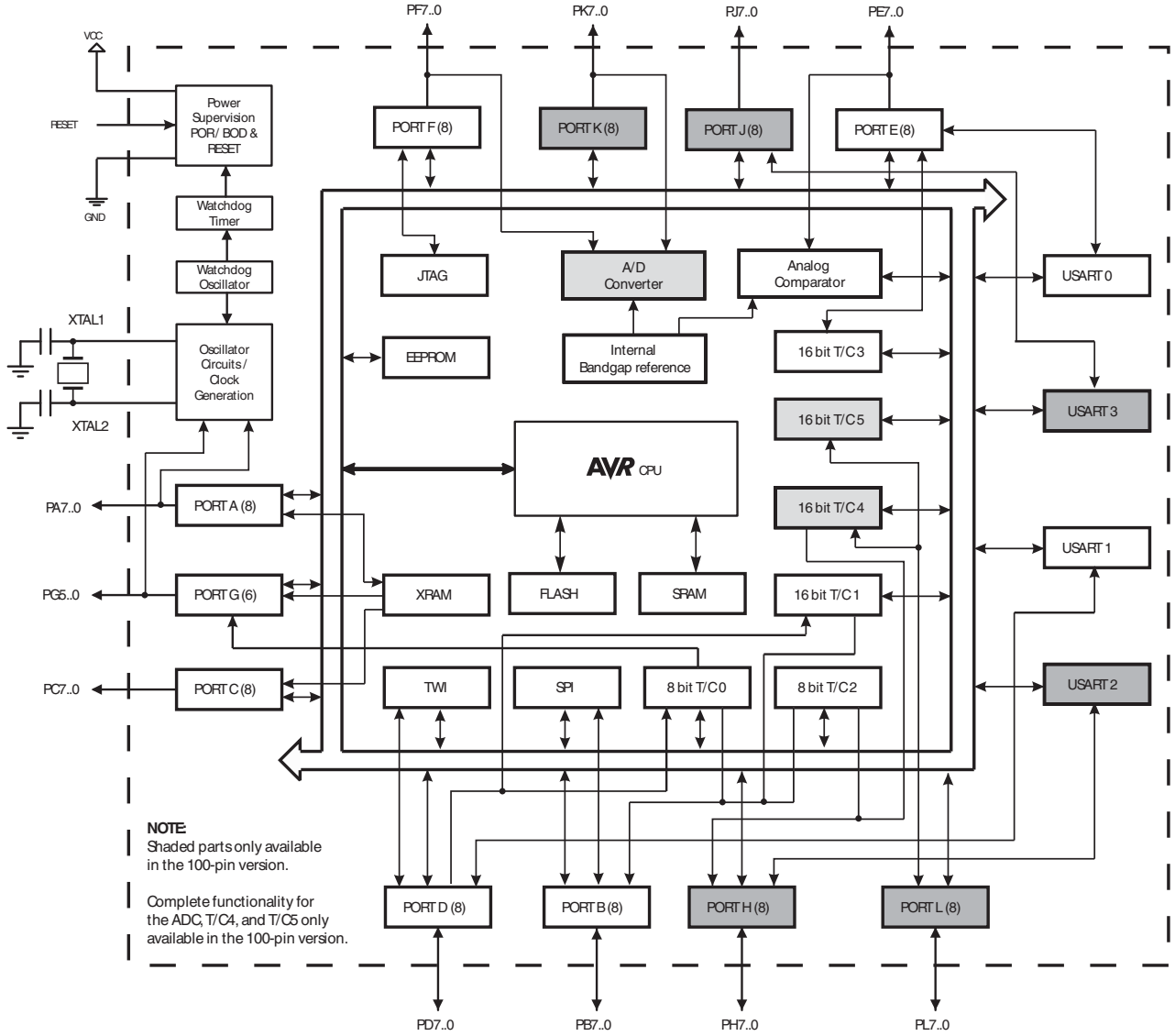
Note: The large center pad underneath the QFN/MLF package is made of metal and internally connected to GND. It should be soldered or glued to the board to ensure good mechanical stability. If the center pad is left unconnected, the package might loosen from the board.

2. Overview

The ATmega640/1280/1281/2560/2561 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega640/1280/1281/2560/2561 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

2.1 Block Diagram

Figure 2-1. Block Diagram



ATmega640/1280/1281/2560/2561

The Atmel® AVR® core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega640/1280/1281/2560/2561 provides the following features: 64K/128K/256K bytes of In-System Programmable Flash with Read-While-Write capabilities, 4Kbytes EEPROM, 8 Kbytes SRAM, 54/86 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), six flexible Timer/Counters with compare modes and PWM, 4 USARTs, a byte oriented 2-wire Serial Interface, a 16-channel, 10-bit ADC with optional differential input stage with programmable gain, programmable Watchdog Timer with Internal Oscillator, an SPI serial port, IEEE® std. 1149.1 compliant JTAG test interface, also used for accessing the On-chip Debug system and programming and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or Hardware Reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except Asynchronous Timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the Crystal/Resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption. In Extended Standby mode, both the main Oscillator and the Asynchronous Timer continue to run.

Atmel offers the QTouch® library for embedding capacitive touch buttons, sliders and wheels-functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offersrobust sensing and includes fully debounced reporting of touch keys and includes Adjacent KeySuppression® (AKS™) technology for unambiguous detection of key events. The easy-to-use QTouch Suite toolchain allows you to explore, develop and debug your own touch applications.

The device is manufactured using Atmel's high-density nonvolatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed in-system through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The boot program can use any interface to download the application program in the application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega640/1280/1281/2560/2561 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega640/1280/1281/2560/2561 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits.

2.2 Comparison Between ATmega1281/2561 and ATmega640/1280/2560

Each device in the ATmega640/1280/1281/2560/2561 family differs only in memory size and number of pins. Table 2-1 summarizes the different configurations for the six devices.

Table 2-1. Configuration Summary

Device	Flash	EEPROM	RAM	General Purpose I/O pins	16 bits resolution PWM channels	Serial USARTs	ADC Channels
ATmega640	64KB	4KB	8KB	86	12	4	16
ATmega1280	128KB	4KB	8KB	86	12	4	16
ATmega1281	128KB	4KB	8KB	54	6	2	8
ATmega2560	256KB	4KB	8KB	86	12	4	16
ATmega2561	256KB	4KB	8KB	54	6	2	8

2.3 Pin Descriptions

2.3.1 VCC

Digital supply voltage.

2.3.2 GND

Ground.

2.3.3 Port A (PA7..PA0)

Port A is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port A pins that are externally pulled low will source current if the pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port A also serves the functions of various special features of the ATmega640/1280/1281/2560/2561 as listed on page 78.

2.3.4 Port B (PB7..PB0)

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port B has better driving capabilities than the other ports.

Port B also serves the functions of various special features of the ATmega640/1280/1281/2560/2561 as listed on page 79.

2.3.5 Port C (PC7..PC0)

Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up

resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port C also serves the functions of special features of the ATmega640/1280/1281/2560/2561 as listed on page 82.

2.3.6 Port D (PD7..PD0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port D also serves the functions of various special features of the ATmega640/1280/1281/2560/2561 as listed on page 83.

2.3.7 Port E (PE7..PE0)

Port E is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port E output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port E pins that are externally pulled low will source current if the pull-up resistors are activated. The Port E pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port E also serves the functions of various special features of the ATmega640/1280/1281/2560/2561 as listed on page 86.

2.3.8 Port F (PF7..PF0)

Port F serves as analog inputs to the A/D Converter.

Port F also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port F output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port F pins that are externally pulled low will source current if the pull-up resistors are activated. The Port F pins are tri-stated when a reset condition becomes active, even if the clock is not running. If the JTAG interface is enabled, the pull-up resistors on pins PF7(TDI), PF5(TMS), and PF4(TCK) will be activated even if a reset occurs.

Port F also serves the functions of the JTAG interface.

2.3.9 Port G (PG5..PG0)

Port G is a 6-bit I/O port with internal pull-up resistors (selected for each bit). The Port G output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port G pins that are externally pulled low will source current if the pull-up resistors are activated. The Port G pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port G also serves the functions of various special features of the ATmega640/1280/1281/2560/2561 as listed on page 90.

2.3.10 Port H (PH7..PH0)

Port H is a 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port H output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port H pins that are externally pulled low will source current if the pull-up

resistors are activated. The Port H pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port H also serves the functions of various special features of the ATmega640/1280/2560 as listed on page 92.

2.3.11 Port J (PJ7..PJ0)

Port J is a 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port J output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port J pins that are externally pulled low will source current if the pull-up resistors are activated. The Port J pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port J also serves the functions of various special features of the ATmega640/1280/2560 as listed on page 94.

2.3.12 Port K (PK7..PK0)

Port K serves as analog inputs to the A/D Converter.

Port K is a 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port K output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port K pins that are externally pulled low will source current if the pull-up resistors are activated. The Port K pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port K also serves the functions of various special features of the ATmega640/1280/2560 as listed on page 96.

2.3.13 Port L (PL7..PL0)

Port L is a 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port L output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port L pins that are externally pulled low will source current if the pull-up resistors are activated. The Port L pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port L also serves the functions of various special features of the ATmega640/1280/2560 as listed on page 98.

2.3.14 $\overline{\text{RESET}}$

Reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. The minimum pulse length is given in "System and Reset Characteristics" on page 372. Shorter pulses are not guaranteed to generate a reset.

2.3.15 XTAL1

Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

2.3.16 XTAL2

Output from the inverting Oscillator amplifier.

2.3.17 AVCC

AVCC is the supply voltage pin for Port F and the A/D Converter. It should be externally connected to V_{CC}, even if the ADC is not used. If the ADC is used, it should be connected to V_{CC} through a low-pass filter.

2.3.18 AREF

This is the analog reference pin for the A/D Converter.

3. Resources

A comprehensive set of development tools and application notes, and datasheets are available for download on http://www.atmel.com/avr.

4. About Code Examples

This documentation contains simple code examples that briefly show how to use various parts of the device. Be aware that not all C compiler vendors include bit definitions in the header files and interrupt handling in C is compiler dependent. Please confirm with the C compiler documentation for more details.

These code examples assume that the part specific header file is included before compilation. For I/O registers located in extended I/O map, "IN", "OUT", "SBIS", "SBIC", "CBI", and "SBI" instructions must be replaced with instructions that allow access to extended I/O. Typically "LDS" and "STS" combined with "SBRS", "SBRC", "SBR", and "CBR".

5. Data Retention

Reliability Qualification results show that the projected data retention failure rate is much less than 1 ppm over 20 years at 85°C or 100 years at 25°C.

6. Capacitive touch sensing

The Atmel®QTouch® Library provides a simple to use solution to realize touch sensitive interfaces on most Atmel AVR® microcontrollers. The QTouch Library includes support for the QTouch and QMatrix® acquisition methods.

Touch sensing can be added to any application by linking the appropriate Atmel QTouch Library for the AVR Microcontroller. This is done by using a simple set of APIs to define the touch channels and sensors, and then calling the touch sensing API's to retrieve the channel information and determine the touch sensor states.

The QTouch Library is FREE and downloadable from the Atmel website at the following location: www.atmel.com/qtouchlibrary. For implementation details and other information, refer to the Atmel QTouch Library User Guide - also available for download from the Atmel website.

7. Register Summary

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x1FF)	Reserved	-	-	-	-	-	-	-	-	
...	Reserved	-	-	-	-	-	-	-	-	
(0x13F)	Reserved									
(0x13E)	Reserved									
(0x13D)	Reserved									
(0x13C)	Reserved									
(0x13B)	Reserved									
(0x13A)	Reserved									
(0x139)	Reserved									
(0x138)	Reserved									
(0x137)	Reserved									
(0x136)	UDR3	USART3 I/O Data Register								222
(0x135)	UBRR3H	-	-	-	-	USART3 Baud Rate Register High Byte				227
(0x134)	UBRR3L	USART3 Baud Rate Register Low Byte								227
(0x133)	Reserved	-	-	-	-	-	-	-	-	
(0x132)	UCSR3C	UMSEL31	UMSEL30	UPM31	UPM30	USBS3	UCSZ31	UCSZ30	UCPOL3	239
(0x131)	UCSR3B	RXCIE3	TXCIE3	UDRIE3	RXEN3	TXEN3	UCSZ32	RXB83	TXB83	238
(0x130)	UCSR3A	RXC3	TXC3	UDRE3	FE3	DOR3	UPE3	U2X3	MPCM3	238
(0x12F)	Reserved	-	-	-	-	-	-	-	-	
(0x12E)	Reserved	-	-	-	-	-	-	-	-	
(0x12D)	OCR5CH	Timer/Counter5 - Output Compare Register C High Byte								165
(0x12C)	OCR5CL	Timer/Counter5 - Output Compare Register C Low Byte								165
(0x12B)	OCR5BH	Timer/Counter5 - Output Compare Register B High Byte								165
(0x12A)	OCR5BL	Timer/Counter5 - Output Compare Register B Low Byte								165
(0x129)	OCR5AH	Timer/Counter5 - Output Compare Register A High Byte								164
(0x128)	OCR5AL	Timer/Counter5 - Output Compare Register A Low Byte								164
(0x127)	ICR5H	Timer/Counter5 - Input Capture Register High Byte								165
(0x126)	ICR5L	Timer/Counter5 - Input Capture Register Low Byte								165
(0x125)	TCNT5H	Timer/Counter5 - Counter Register High Byte								163
(0x124)	TCNT5L	Timer/Counter5 - Counter Register Low Byte								163
(0x123)	Reserved	-	-	-	-	-	-	-	-	
(0x122)	TCCR5C	FOC5A	FOC5B	FOC5C	-	-	-	-	-	162
(0x121)	TCCR5B	ICNC5	ICES5	-	WGM53	WGM52	CS52	CS51	CS50	160
(0x120)	TCCR5A	COM5A1	COM5A0	COM5B1	COM5B0	COM5C1	COM5C0	WGM51	WGM50	158
(0x11F)	Reserved	-	-	-	-	-	-	-	-	
(0x11E)	Reserved	-	-	-	-	-	-	-	-	
(0x11D)	Reserved	-	-	-	-	-	-	-	-	
(0x11C)	Reserved	-	-	-	-	-	-	-	-	
(0x11B)	Reserved	-	-	-	-	-	-	-	-	
(0x11A)	Reserved	-	-	-	-	-	-	-	-	
(0x119)	Reserved	-	-	-	-	-	-	-	-	
(0x118)	Reserved	-	-	-	-	-	-	-	-	
(0x117)	Reserved	-	-	-	-	-	-	-	-	
(0x116)	Reserved	-	-	-	-	-	-	-	-	
(0x115)	Reserved	-	-	-	-	-	-	-	-	
(0x114)	Reserved	-	-	-	-	-	-	-	-	
(0x113)	Reserved	-	-	-	-	-	-	-	-	
(0x112)	Reserved	-	-	-	-	-	-	-	-	
(0x111)	Reserved	-	-	-	-	-	-	-	-	
(0x110)	Reserved	-	-	-	-	-	-	-	-	
(0x10F)	Reserved	-	-	-	-	-	-	-	-	
(0x10E)	Reserved	-	-	-	-	-	-	-	-	
(0x10D)	Reserved	-	-	-	-	-	-	-	-	
(0x10C)	Reserved	-	-	-	-	-	-	-	-	
(0x10B)	PORTL	PORTL7	PORTL6	PORTL5	PORTL4	PORTL3	PORTL2	PORTL1	PORTL0	104
(0x10A)	DDRL	DDL7	DDL6	DDL5	DDL4	DDL3	DDL2	DDL1	DDL0	104
(0x109)	PINL	PINL7	PINL6	PINL5	PINL4	PINL3	PINL2	PINL1	PINL0	104
(0x108)	PORTK	PORTK7	PORTK6	PORTK5	PORTK4	PORTK3	PORTK2	PORTK1	PORTK0	103
(0x107)	DDRK	DDK7	DDK6	DDK5	DDK4	DDK3	DDK2	DDK1	DDK0	103
(0x106)	PINK	PINK7	PINK6	PINK5	PINK4	PINK3	PINK2	PINK1	PINK0	103
(0x105)	PORTJ	PORTJ7	PORTJ6	PORTJ5	PORTJ4	PORTJ3	PORTJ2	PORTJ1	PORTJ0	103
(0x104)	DDRJ	DDJ7	DDJ6	DDJ5	DDJ4	DDJ3	DDJ2	DDJ1	DDJ0	103
(0x103)	PINJ	PINJ7	PINJ6	PINJ5	PINJ4	PINJ3	PINJ2	PINJ1	PINJ0	103
(0x102)	PORTH	PORTH7	PORTH6	PORTH5	PORTH4	PORTH3	PORTH2	PORTH1	PORTH0	102
(0x101)	DDRH	DDH7	DDH6	DDH5	DDH4	DDH3	DDH2	DDH1	DDH0	103

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x100)	PINH	PINH7	PINH6	PINH5	PINH4	PINH3	PINH2	PINH1	PINH0	103
(0xFF)	Reserved	-	-	-	-	-	-	-	-	
(0xFE)	Reserved	-	-	-	-	-	-	-	-	
(0xFD)	Reserved	-	-	-	-	-	-	-	-	
(0xFC)	Reserved	-	-	-	-	-	-	-	-	
(0xFB)	Reserved	-	-	-	-	-	-	-	-	
(0xFA)	Reserved	-	-	-	-	-	-	-	-	
(0xF9)	Reserved	-	-	-	-	-	-	-	-	
(0xF8)	Reserved	-	-	-	-	-	-	-	-	
(0xF7)	Reserved	-	-	-	-	-	-	-	-	
(0xF6)	Reserved	-	-	-	-	-	-	-	-	
(0xF5)	Reserved	-	-	-	-	-	-	-	-	
(0xF4)	Reserved	-	-	-	-	-	-	-	-	
(0xF3)	Reserved	-	-	-	-	-	-	-	-	
(0xF2)	Reserved	-	-	-	-	-	-	-	-	
(0xF1)	Reserved	-	-	-	-	-	-	-	-	
(0xF0)	Reserved	-	-	-	-	-	-	-	-	
(0xEF)	Reserved	-	-	-	-	-	-	-	-	
(0xEE)	Reserved	-	-	-	-	-	-	-	-	
(0xED)	Reserved	-	-	-	-	-	-	-	-	
(0xEC)	Reserved	-	-	-	-	-	-	-	-	
(0xEB)	Reserved	-	-	-	-		-	-	-	
(0xEA)	Reserved	-	-	-	-	-	-	-	-	
(0xE9)	Reserved	-	-	-	-	-	-	-	-	
(0xE8)	Reserved	-	-	-	-	-	-	-	-	
(0xE7)	Reserved	-	-	-	-		-	-	-	
(0xE6)	Reserved	-	-	-	-	-	-	-	-	
(0xE5)	Reserved	-	-	-	-	-	-	-	-	
(0xE4)	Reserved	-	-	-	-	-	-	-	-	
(0xE3)	Reserved	-	-	-	-		-	-	-	
(0xE2)	Reserved	-	-	-	-	-	-	-	-	
(0xE1)	Reserved	-	-	-	-		-	-	-	
(0xE0)	Reserved	-	-	-	-		-	-	-	
(0xDF)	Reserved	-	-	-	-	-	-	-	-	
(0xDE)	Reserved	-	-	-	-	-	-	-	-	
(0xDD)	Reserved	-	-	-	-		-	-	-	
(0xDC)	Reserved	-	-	-	-	-	-	-	-	
(0xDB)	Reserved	-	-	-	-	-	-	-	-	
(0xDA)	Reserved	-	-	-	-	-	-	-	-	
(0xD9)	Reserved	-	-	-	-		-	-	-	
(0xD8)	Reserved	-	-	-	-	-	-	-	-	
(0xD7)	Reserved	-	-	-	-	-	-	-	-	
(0xD6)	UDR2	USART2 I/O Data Register								222
(0xD5)	UBRR2H	-	-	-	-	USART2 Baud Rate Register High Byte				227
(0xD4)	UBRR2L	USART2 Baud Rate Register Low Byte								227
(0xD3)	Reserved	-	-	-	-	-	-	-	-	
(0xD2)	UCSR2C	UMSEL21	UMSEL20	UPM21	UPM20	USBS2	UCSZ21	UCSZ20	UCPOL2	239
(0xD1)	UCSR2B	RXCIE2	TXCIE2	UDRIE2	RXEN2	TXEN2	UCSZ22	RXB82	TXB82	238
(0xD0)	UCSR2A	RXC2	TXC2	UDRE2	FE2	DOR2	UPE2	U2X2	MPCM2	238
(0xCF)	Reserved	-	-	-	-	-	-	-	-	
(0xCE)	UDR1	USART1 I/O Data Register								222
(0xCD)	UBRR1H	-	-	-	-	USART1 Baud Rate Register High Byte				227
(0xCC)	UBRR1L	USART1 Baud Rate Register Low Byte								227
(0xCB)	Reserved	-	-	-	-	-	-	-	-	
(0xCA)	UCSR1C	UMSEL11	UMSEL10	UPM11	UPM10	USBS1	UCSZ11	UCSZ10	UCPOL1	239
(0xC9)	UCSR1B	RXCIE1	TXCIE1	UDRIE1	RXEN1	TXEN1	UCSZ12	RXB81	TXB81	238
(0xC8)	UCSR1A	RXC1	TXC1	UDRE1	FE1	DOR1	UPE1	U2X1	MPCM1	238
(0xC7)	Reserved	-	-	-	-	-	-	-	-	
(0xC6)	UDR0	USART0 I/O Data Register								222
(0xC5)	UBRR0H	-	-	-	-	USART0 Baud Rate Register High Byte				227
(0xC4)	UBRR0L	USART0 Baud Rate Register Low Byte								227
(0xC3)	Reserved	-	-	-	-	-	-	-	-	
(0xC2)	UCSR0C	UMSEL01	UMSEL00	UPM01	UPM00	USBS0	UCSZ01	UCSZ00	UCPOL0	239
(0xC1)	UCSR0B	RXCIE0	TXCIE0	UDRIE0	RXEN0	TXEN0	UCSZ02	RXB80	TXB80	238
(0xC0)	UCSR0A	RXC0	TXC0	UDRE0	FE0	DOR0	UPE0	U2X0	MPCM0	238
(0xBF)	Reserved	-	-	-	-	-	-	-	-	

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xBE)	Reserved	-	-	-	-	-	-	-	-	
(0xBD)	TWAMR	TWAM6	TWAM5	TWAM4	TWAM3	TWAM2	TWAM1	TWAM0	-	269
(0xBC)	TWCR	TWINT	TWEA	TWSTA	TWSTO	TWWC	TWEN	-	TWIE	266
(0xBB)	TWDR	2-wire Serial Interface Data Register								268
(0xBA)	TWAR	TWA6	TWA5	TWA4	TWA3	TWA2	TWA1	TWA0	TWGCE	269
(0xB9)	TWSR	TWS7	TWS6	TWS5	TWS4	TWS3	-	TWPS1	TWPS0	268
(0xB8)	TWBR	2-wire Serial Interface Bit Rate Register								266
(0xB7)	Reserved	-	-	-	-	-	-	-	-	
(0xB6)	ASSR	-	EXCLK	AS2	TCN2UB	OCR2AUB	OCR2BUB	TCR2AUB	TCR2BUB	184
(0xB5)	Reserved	-	-	-	-	-	-	-	-	
(0xB4)	OCR2B	Timer/Counter2 Output Compare Register B								191
(0xB3)	OCR2A	Timer/Counter2 Output Compare Register A								191
(0xB2)	TCNT2	Timer/Counter2 (8 Bit)								191
(0xB1)	TCCR2B	FOC2A	FOC2B	-	-	WGM22	CS22	CS21	CS20	190
(0xB0)	TCCR2A	COM2A1	COM2A0	COM2B1	COM2B0	-	-	WGM21	WGM20	191
(0xAF)	Reserved	-	-	-	-	-	-	-	-	
(0xAE)	Reserved	-	-	-	-	-	-	-	-	
(0xAD)	OCR4CH	Timer/Counter4 - Output Compare Register C High Byte								164
(0xAC)	OCR4CL	Timer/Counter4 - Output Compare Register C Low Byte								164
(0xAB)	OCR4BH	Timer/Counter4 - Output Compare Register B High Byte								164
(0xAA)	OCR4BL	Timer/Counter4 - Output Compare Register B Low Byte								164
(0xA9)	OCR4AH	Timer/Counter4 - Output Compare Register A High Byte								164
(0xA8)	OCR4AL	Timer/Counter4 - Output Compare Register A Low Byte								164
(0xA7)	ICR4H	Timer/Counter4 - Input Capture Register High Byte								165
(0xA6)	ICR4L	Timer/Counter4 - Input Capture Register Low Byte								165
(0xA5)	TCNT4H	Timer/Counter4 - Counter Register High Byte								163
(0xA4)	TCNT4L	Timer/Counter4 - Counter Register Low Byte								163
(0xA3)	Reserved	-	-	-	-	-	-	-	-	
(0xA2)	TCCR4C	FOC4A	FOC4B	FOC4C	-	-	-	-	-	162
(0xA1)	TCCR4B	ICNC4	ICES4	-	WGM43	WGM42	CS42	CS41	CS40	160
(0xA0)	TCCR4A	COM4A1	COM4A0	COM4B1	COM4B0	COM4C1	COM4C0	WGM41	WGM40	158
(0x9F)	Reserved	-	-	-	-	-	-	-	-	
(0x9E)	Reserved	-	-	-	-	-	-	-	-	
(0x9D)	OCR3CH	Timer/Counter3 - Output Compare Register C High Byte								164
(0x9C)	OCR3CL	Timer/Counter3 - Output Compare Register C Low Byte								164
(0x9B)	OCR3BH	Timer/Counter3 - Output Compare Register B High Byte								164
(0x9A)	OCR3BL	Timer/Counter3 - Output Compare Register B Low Byte								164
(0x99)	OCR3AH	Timer/Counter3 - Output Compare Register A High Byte								163
(0x98)	OCR3AL	Timer/Counter3 - Output Compare Register A Low Byte								163
(0x97)	ICR3H	Timer/Counter3 - Input Capture Register High Byte								165
(0x96)	ICR3L	Timer/Counter3 - Input Capture Register Low Byte								165
(0x95)	TCNT3H	Timer/Counter3 - Counter Register High Byte								162
(0x94)	TCNT3L	Timer/Counter3 - Counter Register Low Byte								162
(0x93)	Reserved	-	-	-	-	-	-	-	-	
(0x92)	TCCR3C	FOC3A	FOC3B	FOC3C	-	-	-	-	-	162
(0x91)	TCCR3B	ICNC3	ICES3	-	WGM33	WGM32	CS32	CS31	CS30	160
(0x90)	TCCR3A	COM3A1	COM3A0	COM3B1	COM3B0	COM3C1	COM3C0	WGM31	WGM30	158
(0x8F)	Reserved	-	-	-	-	-	-	-	-	
(0x8E)	Reserved	-	-	-	-	-	-	-	-	
(0x8D)	OCR1CH	Timer/Counter1 - Output Compare Register C High Byte								163
(0x8C)	OCR1CL	Timer/Counter1 - Output Compare Register C Low Byte								163
(0x8B)	OCR1BH	Timer/Counter1 - Output Compare Register B High Byte								163
(0x8A)	OCR1BL	Timer/Counter1 - Output Compare Register B Low Byte								163
(0x89)	OCR1AH	Timer/Counter1 - Output Compare Register A High Byte								163
(0x88)	OCR1AL	Timer/Counter1 - Output Compare Register A Low Byte								163
(0x87)	ICR1H	Timer/Counter1 - Input Capture Register High Byte								165
(0x86)	ICR1L	Timer/Counter1 - Input Capture Register Low Byte								165
(0x85)	TCNT1H	Timer/Counter1 - Counter Register High Byte								162
(0x84)	TCNT1L	Timer/Counter1 - Counter Register Low Byte								162
(0x83)	Reserved	-	-	-	-	-	-	-	-	
(0x82)	TCCR1C	FOC1A	FOC1B	FOC1C	-	-	-	-	-	161
(0x81)	TCCR1B	ICNC1	ICES1	-	WGM13	WGM12	CS12	CS11	CS10	160
(0x80)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	COM1C1	COM1C0	WGM11	WGM10	158
(0x7F)	DIDR1	-	-	-	-	-	-	AIN1D	AIN0D	274
(0x7E)	DIDR0	ADC7D	ADC6D	ADC5D	ADC4D	ADC3D	ADC2D	ADC1D	ADC0D	295
(0x7D)	DIDR2	ADC15D	ADC14D	ADC13D	ADC12D	ADC11D	ADC10D	ADC9D	ADC8D	295

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x7C)	ADMUX	REFS1	REFS0	ADLAR	MUX4	MUX3	MUX2	MUX1	MUX0	289
(0x7B)	ADCSRB	-	ACME	-	-	MUX5	ADTS2	ADTS1	ADTS0	272, 290, 294
(0x7A)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	292
(0x79)	ADCH	ADC Data Register High byte								294
(0x78)	ADCL	ADC Data Register Low byte								294
(0x77)	Reserved	-	-	-	-	-	-	-	-	
(0x76)	Reserved	-	-	-	-	-	-	-	-	
(0x75)	XMCRB	XMBK	-	-	-	-	XMM2	XMM1	XMM0	38
(0x74)	XMCRA	SRE	SRL2	SRL1	SRL0	SRW11	SRW10	SRW01	SRW00	37
(0x73)	TIMSK5	-	-	ICIE5	-	OCIE5C	OCIE5B	OCIE5A	TOIE5	166
(0x72)	TIMSK4	-	-	ICIE4	-	OCIE4C	OCIE4B	OCIE4A	TOIE4	166
(0x71)	TIMSK3	-	-	ICIE3	-	OCIE3C	OCIE3B	OCIE3A	TOIE3	166
(0x70)	TIMSK2	-	-	-	-	-	OCIE2B	OCIE2A	TOIE2	193
(0x6F)	TIMSK1	-	-	ICIE1	-	OCIE1C	OCIE1B	OCIE1A	TOIE1	166
(0x6E)	TIMSK0	-	-	-	-	-	OCIE0B	OCIE0A	TOIE0	134
(0x6D)	PCMSK2	PCINT23	PCINT22	PCINT21	PCINT20	PCINT19	PCINT18	PCINT17	PCINT16	116
(0x6C)	PCMSK1	PCINT15	PCINT14	PCINT13	PCINT12	PCINT11	PCINT10	PCINT9	PCINT8	116
(0x6B)	PCMSK0	PCINT7	PCINT6	PCINT5	PCINT4	PCINT3	PCINT2	PCINT1	PCINT0	117
(0x6A)	EICRB	ISC71	ISC70	ISC61	ISC60	ISC51	ISC50	ISC41	ISC40	114
(0x69)	EICRA	ISC31	ISC30	ISC21	ISC20	ISC11	ISC10	ISC01	ISC00	113
(0x68)	PCICR	-	-	-	-	-	PCIE2	PCIE1	PCIE0	115
(0x67)	Reserved	-	-	-	-	-	-	-	-	
(0x66)	OSCCAL	Oscillator Calibration Register								50
(0x65)	PRR1	-	-	PRTIM5	PRTIM4	PRTIM3	PRUSART3	PRUSART2	PRUSART1	57
(0x64)	PRR0	PRTWI	PRTIM2	PRTIM0	-	PRTIM1	PRSPI	PRUSART0	PRADC	56
(0x63)	Reserved	-	-	-	-	-	-	-	-	
(0x62)	Reserved	-	-	-	-	-	-	-	-	
(0x61)	CLKPR	CLKPCE	-	-	-	CLKPS3	CLKPS2	CLKPS1	CLKPS0	50
(0x60)	WDTCSR	WDIF	WDIE	WDP3	WDCE	WDE	WDP2	WDP1	WDP0	67
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	14
0x3E (0x5E)	SPH	SP15	SP14	SP13	SP12	SP11	SP10	SP9	SP8	16
0x3D (0x5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	16
0x3C (0x5C)	EIND	-	-	-	-	-	-	-	EIND0	17
0x3B (0x5B)	RAMPZ	-	-	-	-	-	-	RAMPZ1	RAMPZ0	17
0x3A (0x5A)	Reserved	-	-	-	-	-	-	-	-	
0x39 (0x59)	Reserved	-	-	-	-	-	-	-	-	
0x38 (0x58)	Reserved	-	-	-	-	-	-	-	-	
0x37 (0x57)	SPMCSR	SPMIE	RWWSB	SIGRD	RWWSRE	BLBSET	PGWRT	PGERS	SPMEN	332
0x36 (0x56)	Reserved	-	-	-	-	-	-	-	-	
0x35 (0x55)	MCUCR	JTD	-	-	PUD	-	-	IVSEL	IVCE	67, 110, 100, 308
0x34 (0x54)	MCUSR	-	-	-	JTRF	WDRF	BORF	EXTRF	PORF	308
0x33 (0x53)	SMCR	-	-	-	-	SM2	SM1	SM0	SE	52
0x32 (0x52)	Reserved	-	-	-	-	-	-	-	-	
0x31 (0x51)	OCDR	OCDR7	OCDR6	OCDR5	OCDR4	OCDR3	OCDR2	OCDR1	OCDR0	301
0x30 (0x50)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	272
0x2F (0x4F)	Reserved	-	-	-	-	-	-	-	-	
0x2E (0x4E)	SPDR	SPI Data Register								204
0x2D (0x4D)	SPSR	SPIF	WCOL	-	-	-	-	-	SPI2X	203
0x2C (0x4C)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	202
0x2B (0x4B)	GPIOR2	General Purpose I/O Register 2								37
0x2A (0x4A)	GPIOR1	General Purpose I/O Register 1								37
0x29 (0x49)	Reserved	-	-	-	-	-	-	-	-	
0x28 (0x48)	OCR0B	Timer/Counter0 Output Compare Register B								133
0x27 (0x47)	OCR0A	Timer/Counter0 Output Compare Register A								133
0x26 (0x46)	TCNT0	Timer/Counter0 (8 Bit)								133
0x25 (0x45)	TCCR0B	FOC0A	FOC0B	-	-	WGM02	CS02	CS01	CS00	132
0x24 (0x44)	TCCR0A	COM0A1	COM0A0	COM0B1	COM0B0	-	-	WGM01	WGM00	129
0x23 (0x43)	GTCCR	TSM	-	-	-	-	-	PSRASY	PSRSYNC	170, 194
0x22 (0x42)	EEARH	-	-	-	-	EEPROM Address Register High Byte				35
0x21 (0x41)	EEARL	EEPROM Address Register Low Byte								35
0x20 (0x40)	EEDR	EEPROM Data Register								35
0x1F (0x3F)	EECR	-	-	EEPM1	EEPM0	EERIE	EEMPE	EEPE	EERE	35
0x1E (0x3E)	GPIOR0	General Purpose I/O Register 0								37
0x1D (0x3D)	EIMSK	INT7	INT6	INT5	INT4	INT3	INT2	INT1	INT0	115
0x1C (0x3C)	EIFR	INTF7	INTF6	INTF5	INTF4	INTF3	INTF2	INTF1	INTF0	115
0x1B (0x3B)	PCIFR	-	-	-	-	-	PCIF2	PCIF1	PCIF0	116

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x1A (0x3A)	TIFR5	-	-	ICF5	-	OCF5C	OCF5B	OCF5A	TOV5	166
0x19 (0x39)	TIFR4	-	-	ICF4	-	OCF4C	OCF4B	OCF4A	TOV4	167
0x18 (0x38)	TIFR3	-	-	ICF3	-	OCF3C	OCF3B	OCF3A	TOV3	167
0x17 (0x37)	TIFR2	-	-	-	-	-	OCF2B	OCF2A	TOV2	193
0x16 (0x36)	TIFR1	-	-	ICF1	-	OCF1C	OCF1B	OCF1A	TOV1	167
0x15 (0x35)	TIFR0	-	-	-	-	-	OCF0B	OCF0A	TOV0	134
0x14 (0x34)	PORTG	-	-	PORTG5	PORTG4	PORTG3	PORTG2	PORTG1	PORTG0	102
0x13 (0x33)	DDRG	-	-	DDG5	DDG4	DDG3	DDG2	DDG1	DDG0	102
0x12 (0x32)	PING	-	-	PING5	PING4	PING3	PING2	PING1	PING0	102
0x11 (0x31)	PORTF	PORTF7	PORTF6	PORTF5	PORTF4	PORTF3	PORTF2	PORTF1	PORTF0	101
0x10 (0x30)	DDRF	DDF7	DDF6	DDF5	DDF4	DDF3	DDF2	DDF1	DDF0	102
0x0F (0x2F)	PINF	PINF7	PINF6	PINF5	PINF4	PINF3	PINF2	PINF1	PINF0	102
0x0E (0x2E)	PORTE	PORTE7	PORTE6	PORTE5	PORTE4	PORTE3	PORTE2	PORTE1	PORTE0	101
0x0D (0x2D)	DDRE	DDE7	DDE6	DDE5	DDE4	DDE3	DDE2	DDE1	DDE0	101
0x0C (0x2C)	PINE	PINE7	PINE6	PINE5	PINE4	PINE3	PINE2	PINE1	PINE0	102
0x0B (0x2B)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	101
0x0A (0x2A)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	101
0x09 (0x29)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	101
0x08 (0x28)	PORTC	PORTC7	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	101
0x07 (0x27)	DDRC	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	101
0x06 (0x26)	PINC	PINC7	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	101
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	100
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	100
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	100
0x02 (0x22)	PORTA	PORTA7	PORTA6	PORTA5	PORTA4	PORTA3	PORTA2	PORTA1	PORTA0	100
0x01 (0x21)	DDRA	DDA7	DDA6	DDA5	DDA4	DDA3	DDA2	DDA1	DDA0	100
0x00 (0x20)	PINA	PINA7	PINA6	PINA5	PINA4	PINA3	PINA2	PINA1	PINA0	100

Notes:
1. For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
2. I/O registers within the address range $00 - $1F are directly bit-accessible using the SBI and CBI instructions. In these registers, the value of single bits can be checked by using the SBIS and SBIC instructions.
3. Some of the status flags are cleared by writing a logical one to them. Note that the CBI and SBI instructions will operate on all bits in the I/O register, writing a one back into any flag read as set, thus clearing the flag. The CBI and SBI instructions work with registers 0x00 to 0x1F only.
4. When using the I/O specific commands IN and OUT, the I/O addresses $00 - $3F must be used. When addressing I/O registers as data space using LD and ST instructions, $20 must be added to these addresses. The ATmega640/1280/1281/2560/2561 is a complex microcontroller with more peripheral units than can be supported within the 64 location reserved in Opcode for the IN and OUT instructions. For the Extended I/O space from $60 - $1FF in SRAM, only the ST/STS/STD and LD/LDS/LDD instructions can be used.

8. Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ARITHMETIC AND LOGIC INSTRUCTIONS					
ADD	Rd, Rr	Add two Registers	Rd ← Rd + Rr	Z, C, N, V, H	1
ADC	Rd, Rr	Add with Carry two Registers	Rd ← Rd + Rr + C	Z, C, N, V, H	1
ADIW	Rdl,K	Add Immediate to Word	Rdh:Rdl ← Rdh:Rdl + K	Z, C, N, V, S	2
SUB	Rd, Rr	Subtract two Registers	Rd ← Rd - Rr	Z, C, N, V, H	1
SUBI	Rd, K	Subtract Constant from Register	Rd ← Rd - K	Z, C, N, V, H	1
SBC	Rd, Rr	Subtract with Carry two Registers	Rd ← Rd - Rr - C	Z, C, N, V, H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	Rd ← Rd - K - C	Z, C, N, V, H	1
SBIW	Rdl,K	Subtract Immediate from Word	Rdh:Rdl ← Rdh:Rdl - K	Z, C, N, V, S	2
AND	Rd, Rr	Logical AND Registers	Rd ← Rd • Rr	Z, N, V	1
ANDI	Rd, K	Logical AND Register and Constant	Rd ← Rd • K	Z, N, V	1
OR	Rd, Rr	Logical OR Registers	Rd ← Rd v Rr	Z, N, V	1
ORI	Rd, K	Logical OR Register and Constant	Rd ← Rd v K	Z, N, V	1
EOR	Rd, Rr	Exclusive OR Registers	Rd ← Rd ⊕ Rr	Z, N, V	1
COM	Rd	One's Complement	Rd ← 0xFF – Rd	Z, C, N, V	1
NEG	Rd	Two's Complement	Rd ← 0x00 – Rd	Z, C, N, V, H	1
SBR	Rd,K	Set Bit(s) in Register	Rd ← Rd v K	Z, N, V	1
CBR	Rd,K	Clear Bit(s) in Register	Rd ← Rd • (0xFF - K)	Z, N, V	1
INC	Rd	Increment	Rd ← Rd + 1	Z, N, V	1
DEC	Rd	Decrement	Rd ← Rd – 1	Z, N, V	1
TST	Rd	Test for Zero or Minus	Rd ← Rd • Rd	Z, N, V	1
CLR	Rd	Clear Register	Rd ← Rd ⊕ Rd	Z, N, V	1
SER	Rd	Set Register	Rd ← 0xFF	None	1
MUL	Rd, Rr	Multiply Unsigned	R1:R0 ← Rd x Rr	Z, C	2
MULS	Rd, Rr	Multiply Signed	R1:R0 ← Rd x Rr	Z, C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	R1:R0 ← Rd x Rr	Z, C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	R1:R0 ← (Rd x Rr) << 1	Z, C	2
FMULS	Rd, Rr	Fractional Multiply Signed	R1:R0 ← (Rd x Rr) << 1	Z, C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	R1:R0 ← (Rd x Rr) << 1	Z, C	2
BRANCH INSTRUCTIONS					
RJMP	k	Relative Jump	PC ← PC + k + 1	None	2
IJMP		Indirect Jump to (Z)	PC ← Z	None	2
EIJMP		Extended Indirect Jump to (Z)	PC ←(EIND:Z)	None	2
JMP	k	Direct Jump	PC ← k	None	3
RCALL	k	Relative Subroutine Call	PC ← PC + k + 1	None	4
ICALL		Indirect Call to (Z)	PC ← Z	None	4
EICALL		Extended Indirect Call to (Z)	PC ←(EIND:Z)	None	4
CALL	k	Direct Subroutine Call	PC ← k	None	5
RET		Subroutine Return	PC ← STACK	None	5
RETI		Interrupt Return	PC ← STACK	I	5
CPSE	Rd,Rr	Compare, Skip if Equal	if (Rd = Rr) PC ← PC + 2 or 3	None	1/2/3
CP	Rd,Rr	Compare	Rd – Rr	Z, N, V, C, H	1
CPC	Rd,Rr	Compare with Carry	Rd – Rr – C	Z, N, V, C, H	1
CPI	Rd,K	Compare Register with Immediate	Rd – K	Z, N, V, C, H	1
SBRC	Rr, b	Skip if Bit in Register Cleared	if (Rr(b)=0) PC ← PC + 2 or 3	None	1/2/3
SBRS	Rr, b	Skip if Bit in Register is Set	if (Rr(b)=1) PC ← PC + 2 or 3	None	1/2/3
SBIC	P, b	Skip if Bit in I/O Register Cleared	if (P(b)=0) PC ← PC + 2 or 3	None	1/2/3
SBIS	P, b	Skip if Bit in I/O Register is Set	if (P(b)=1) PC ← PC + 2 or 3	None	1/2/3
BRBS	s, k	Branch if Status Flag Set	if (SREG(s) = 1) then PC←PC+k + 1	None	1/2
BRBC	s, k	Branch if Status Flag Cleared	if (SREG(s) = 0) then PC←PC+k + 1	None	1/2
BREQ	k	Branch if Equal	if (Z = 1) then PC ← PC + k + 1	None	1/2
BRNE	k	Branch if Not Equal	if (Z = 0) then PC ← PC + k + 1	None	1/2
BRCS	k	Branch if Carry Set	if (C = 1) then PC ← PC + k + 1	None	1/2
BRCC	k	Branch if Carry Cleared	if (C = 0) then PC ← PC + k + 1	None	1/2
BRSH	k	Branch if Same or Higher	if (C = 0) then PC ← PC + k + 1	None	1/2
BRLO	k	Branch if Lower	if (C = 1) then PC ← PC + k + 1	None	1/2
BRMI	k	Branch if Minus	if (N = 1) then PC ← PC + k + 1	None	1/2
BRPL	k	Branch if Plus	if (N = 0) then PC ← PC + k + 1	None	1/2
BRGE	k	Branch if Greater or Equal, Signed	if (N ⊕ V= 0) then PC ← PC + k + 1	None	1/2
BRLT	k	Branch if Less Than Zero, Signed	if (N ⊕ V= 1) then PC ← PC + k + 1	None	1/2
BRHS	k	Branch if Half Carry Flag Set	if (H = 1) then PC ← PC + k + 1	None	1/2
BRHC	k	Branch if Half Carry Flag Cleared	if (H = 0) then PC ← PC + k + 1	None	1/2
BRTS	k	Branch if T Flag Set	if (T = 1) then PC ← PC + k + 1	None	1/2
BRTC	k	Branch if T Flag Cleared	if (T = 0) then PC ← PC + k + 1	None	1/2

Mnemonics	Operands	Description	Operation	Flags	#Clocks
BRVS	k	Branch if Overflow Flag is Set	if (V = 1) then PC ← PC + k + 1	None	1/2
BRVC	k	Branch if Overflow Flag is Cleared	if (V = 0) then PC ← PC + k + 1	None	1/2
BRIE	k	Branch if Interrupt Enabled	if (I = 1) then PC ← PC + k + 1	None	1/2
BRID	k	Branch if Interrupt Disabled	if (I = 0) then PC ← PC + k + 1	None	1/2
BIT AND BIT-TEST INSTRUCTIONS					
SBI	P,b	Set Bit in I/O Register	I/O(P,b) ← 1	None	2
CBI	P,b	Clear Bit in I/O Register	I/O(P,b) ← 0	None	2
LSL	Rd	Logical Shift Left	Rd(n+1) ← Rd(n), Rd(0) ← 0	Z, C, N, V	1
LSR	Rd	Logical Shift Right	Rd(n) ← Rd(n+1), Rd(7) ← 0	Z, C, N, V	1
ROL	Rd	Rotate Left Through Carry	Rd(0)←C,Rd(n+1)← Rd(n),C←Rd(7)	Z, C, N, V	1
ROR	Rd	Rotate Right Through Carry	Rd(7)←C,Rd(n)← Rd(n+1),C←Rd(0)	Z, C, N, V	1
ASR	Rd	Arithmetic Shift Right	Rd(n) ← Rd(n+1), n=0..6	Z, C, N, V	1
SWAP	Rd	Swap Nibbles	Rd(3..0)←Rd(7..4),Rd(7..4)←Rd(3..0)	None	1
BSET	s	Flag Set	SREG(s) ← 1	SREG(s)	1
BCLR	s	Flag Clear	SREG(s) ← 0	SREG(s)	1
BST	Rr, b	Bit Store from Register to T	T ← Rr(b)	T	1
BLD	Rd, b	Bit load from T to Register	Rd(b) ← T	None	1
SEC		Set Carry	C ← 1	C	1
CLC		Clear Carry	C ← 0	C	1
SEN		Set Negative Flag	N ← 1	N	1
CLN		Clear Negative Flag	N ← 0	N	1
SEZ		Set Zero Flag	Z ← 1	Z	1
CLZ		Clear Zero Flag	Z ← 0	Z	1
SEI		Global Interrupt Enable	I ← 1	I	1
CLI		Global Interrupt Disable	I ← 0	I	1
SES		Set Signed Test Flag	S ← 1	S	1
CLS		Clear Signed Test Flag	S ← 0	S	1
SEV		Set Twos Complement Overflow.	V ← 1	V	1
CLV		Clear Twos Complement Overflow	V ← 0	V	1
SET		Set T in SREG	T ← 1	T	1
CLT		Clear T in SREG	T ← 0	T	1
SEH		Set Half Carry Flag in SREG	H ← 1	H	1
CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
DATA TRANSFER INSTRUCTIONS					
MOV	Rd, Rr	Move Between Registers	Rd ← Rr	None	1
MOVW	Rd, Rr	Copy Register Word	Rd+1:Rd ← Rr+1:Rr	None	1
LDI	Rd, K	Load Immediate	Rd ← K	None	1
LD	Rd, X	Load Indirect	Rd ← (X)	None	2
LD	Rd, X+	Load Indirect and Post-Inc.	Rd ← (X), X ← X + 1	None	2
LD	Rd, - X	Load Indirect and Pre-Dec.	X ← X - 1, Rd ← (X)	None	2
LD	Rd, Y	Load Indirect	Rd ← (Y)	None	2
LD	Rd, Y+	Load Indirect and Post-Inc.	Rd ← (Y), Y ← Y + 1	None	2
LD	Rd, - Y	Load Indirect and Pre-Dec.	Y ← Y - 1, Rd ← (Y)	None	2
LDD	Rd,Y+q	Load Indirect with Displacement	Rd ← (Y + q)	None	2
LD	Rd, Z	Load Indirect	Rd ← (Z)	None	2
LD	Rd, Z+	Load Indirect and Post-Inc.	Rd ← (Z), Z ← Z+1	None	2
LD	Rd, -Z	Load Indirect and Pre-Dec.	Z ← Z - 1, Rd ← (Z)	None	2
LDD	Rd, Z+q	Load Indirect with Displacement	Rd ← (Z + q)	None	2
LDS	Rd, k	Load Direct from SRAM	Rd ← (k)	None	2
ST	X, Rr	Store Indirect	(X) ← Rr	None	2
ST	X+, Rr	Store Indirect and Post-Inc.	(X) ← Rr, X ← X + 1	None	2
ST	- X, Rr	Store Indirect and Pre-Dec.	X ← X - 1, (X) ← Rr	None	2
ST	Y, Rr	Store Indirect	(Y) ← Rr	None	2
ST	Y+, Rr	Store Indirect and Post-Inc.	(Y) ← Rr, Y ← Y + 1	None	2
ST	- Y, Rr	Store Indirect and Pre-Dec.	Y ← Y - 1, (Y) ← Rr	None	2
STD	Y+q,Rr	Store Indirect with Displacement	(Y + q) ← Rr	None	2
ST	Z, Rr	Store Indirect	(Z) ← Rr	None	2
ST	Z+, Rr	Store Indirect and Post-Inc.	(Z) ← Rr, Z ← Z + 1	None	2
ST	-Z, Rr	Store Indirect and Pre-Dec.	Z ← Z - 1, (Z) ← Rr	None	2
STD	Z+q,Rr	Store Indirect with Displacement	(Z + q) ← Rr	None	2
STS	k, Rr	Store Direct to SRAM	(k) ← Rr	None	2
LPM		Load Program Memory	R0 ← (Z)	None	3
LPM	Rd, Z	Load Program Memory	Rd ← (Z)	None	3
LPM	Rd, Z+	Load Program Memory and Post-Inc	Rd ← (Z), Z ← Z+1	None	3
ELPM		Extended Load Program Memory	R0 ← (RAMPZ:Z)	None	3
ELPM	Rd, Z	Extended Load Program Memory	Rd ← (RAMPZ:Z)	None	3

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ELPM	Rd, Z+	Extended Load Program Memory	Rd ← (RAMPZ:Z), RAMPZ:Z ←RAMPZ:Z+1	None	3
SPM		Store Program Memory	(Z) ← R1:R0	None	-
IN	Rd, P	In Port	Rd ← P	None	1
OUT	P, Rr	Out Port	P ← Rr	None	1
PUSH	Rr	Push Register on Stack	STACK ← Rr	None	2
POP	Rd	Pop Register from Stack	Rd ← STACK	None	2
MCU CONTROL INSTRUCTIONS					
NOP		No Operation		None	1
SLEEP		Sleep	(see specific descr. for Sleep function)	None	1
WDR		Watchdog Reset	(see specific descr. for WDR/timer)	None	1
BREAK		Break	For On-chip Debug Only	None	N/A

Note: EICALL and EIJMP do not exist in ATmega640/1280/1281.
ELPM does not exist in ATmega640.

9. Ordering Information

9.1 ATmega640

Speed (MHz)[2]	Power Supply	Ordering Code	Package[1][3]	Operation Range
8	1.8 - 5.5V	ATmega640V-8AU ATmega640V-8AUR[4] ATmega640V-8CU ATmega640V-8CUR[4]	100A 100A 100C1 100C1	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega640-16AU ATmega640-16AUR[4] ATmega640-16CU ATmega640-16CUR[4]	100A 100A 100C1 100C1	

Notes:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. See “Speed Grades” on page 369.
3. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
4. Tape & Reel

Package Type	
100A	100-lead, Thin (1.0mm) Plastic Gull Wing Quad Flat Package (TQFP)
100C1	100-ball, Chip Ball Grid Array (CBGA)

9.2 ATmega1280

Speed (MHz)[2]	Power Supply	Ordering Code	Package[1][3]	Operation Range
8	1.8V - 5.5V	ATmega1280V-8AU ATmega1280V-8AUR[4] ATmega1280V-8CU ATmega1280V-8CUR[4]	100A 100A 100C1 100C1	Industrial (-40°C to 85°C)
16	2.7V - 5.5V	ATmega1280-16AU ATmega1280-16AUR[4] ATmega1280-16CU ATmega1280-16CUR[4]	100A 100A 100C1 100C1	

Notes:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. See "Speed Grades" on page 369.
3. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
4. Tape & Reel

Package Type	
100A	100-lead, Thin (1.0mm) Plastic Gull Wing Quad Flat Package (TQFP)
100C1	100-ball, Chip Ball Grid Array (CBGA)

9.3 ATmega1281

Speed (MHz)[2]	Power Supply	Ordering Code	Package[1][3]	Operation Range
8	1.8 - 5.5V	ATmega1281V-8AU ATmega1281V-8AUR[4] ATmega1281V-8MU ATmega1281V-8MUR[4]	64A 64A 64M2 64M2	Industrial (-40°C to 85°C)
16	2.7 - 5.5V	ATmega1281-16AU ATmega1281-16AUR[4] ATmega1281-16MU ATmega1281-16MUR[4]	64A 64A 64M2 64M2	

Notes:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. See "Speed Grades" on page 369.
3. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
4. Tape & Reel

Package Type	
64A	64-lead, Thin (1.0mm) Plastic Gull Wing Quad Flat Package (TQFP)
64M2	64-pad, 9mm × 9mm × 1.0mm Body, Quad Flat No-lead/Micro Lead Frame Package (QFN/MLF)

9.4 ATmega2560

Speed (MHz)[2]	Power Supply	Ordering Code	Package[1][3]	Operation Range
8	1.8V - 5.5V	ATmega2560V-8AU ATmega2560V-8AUR[4] ATmega2560V-8CU ATmega2560V-8CUR[4]	100A 100A 100C1 100C1	Industrial (-40°C to 85°C)
16	4.5V - 5.5V	ATmega2560-16AU ATmega2560-16AUR[4] ATmega2560-16CU ATmega2560-16CUR[4]	100A 100A 100C1 100C1	

Notes:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. See "Speed Grades" on page 369.
3. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
4. Tape & Reel

Package Type	
100A	100-lead, Thin (1.0mm) Plastic Gull Wing Quad Flat Package (TQFP)
100C1	100-ball, Chip Ball Grid Array (CBGA)

9.5 ATmega2561

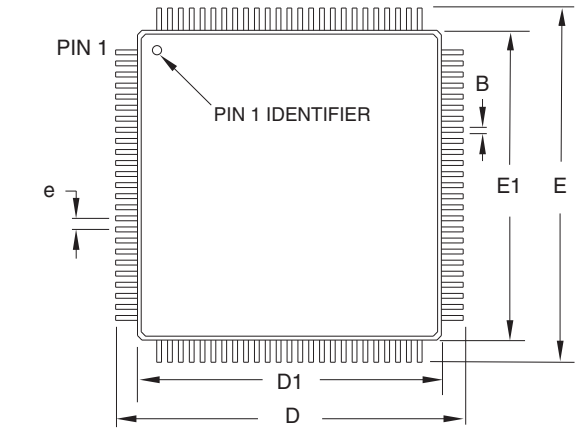
Speed (MHz)[2]	Power Supply	Ordering Code	Package[1][3]	Operation Range
8	1.8V - 5.5V	ATmega1281V-8AU ATmega1281V-8AUR[4] ATmega1281V-8MU ATmega1281V-8MUR[4]	64A 64A 64M2 64M2	Industrial (-40°C to 85°C)
16	4.5V - 5.5V	ATmega1281-16AU ATmega1281-16AUR[4] ATmega1281-16MU ATmega1281-16MUR[4]	64A 64A 64M2 64M2	

Notes:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. See "Speed Grades" on page 369.
3. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
4. Tape & Reel

Package Type	
64A	64-lead, Thin (1.0mm) Plastic Gull Wing Quad Flat Package (TQFP)
64M2	64-pad, 9mm × 9mm × 1.0mm Body, Quad Flat No-lead/Micro Lead Frame Package (QFN/MLF)

10. Packaging Information

10.1 100A



COMMON DIMENSIONS
(Unit of Measure = mm)

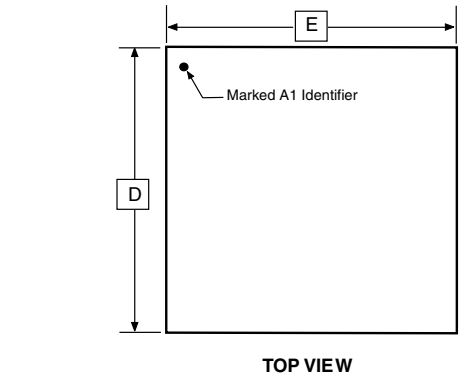
SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	1.20	
A1	0.05	–	0.15	
A2	0.95	1.00	1.05	
D	15.75	16.00	16.25	
D1	13.90	14.00	14.10	Note 2
E	15.75	16.00	16.25	
E1	13.90	14.00	14.10	Note 2
B	0.17	–	0.27	
C	0.09	–	0.20	
L	0.45	–	0.75	
e	0.50 TYP			

Notes:
1. This package conforms to JEDEC reference MS-026, Variation AED.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
3. Lead coplanarity is 0.08 mm maximum.

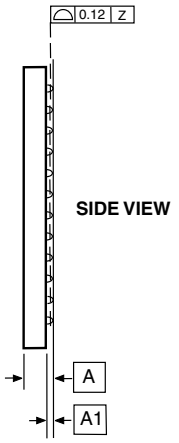
2010-10-20

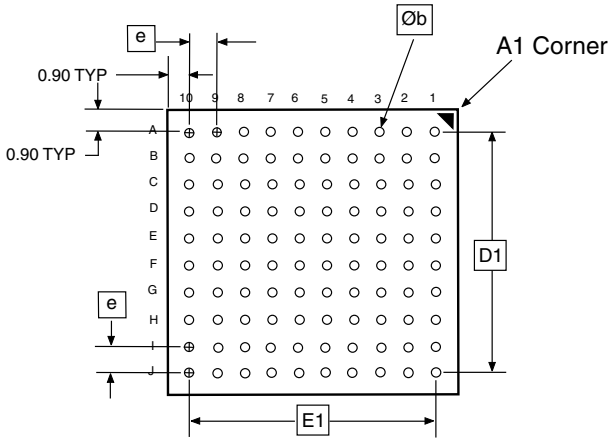
	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**100A,** 100-lead, 14 x 14 mm Body Size, 1.0 mm Body Thickness, 0.5 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)	100A	D

10.2 100C1



TOP VIEW





BOTTOM VIEW

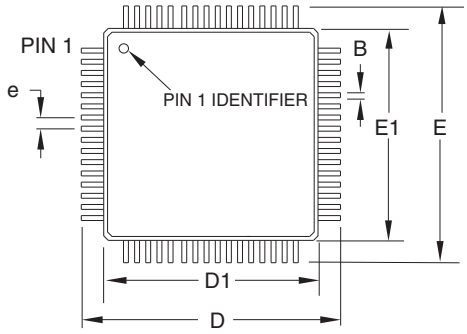
COMMON DIMENSIONS
(Unit of Measure = mm)

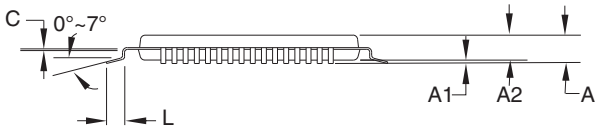
SYMBOL	MIN	NOM	MAX	NOTE
A	1.10	–	1.20	
A1	0.30	0.35	0.40	
D	8.90	9.00	9.10	
E	8.90	9.00	9.10	
D1	7.10	7.20	7.30	
E1	7.10	7.20	7.30	
Øb	0.35	0.40	0.45	
e	0.80 TYP			

5/25/06

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**100C1**, 100-ball, 9 x 9 x 1.2 mm Body, Ball Pitch 0.80 mm Chip Array BGA Package (CBGA)	100C1	A

10.3 64A





COMMON DIMENSIONS
(Unit of Measure = mm)

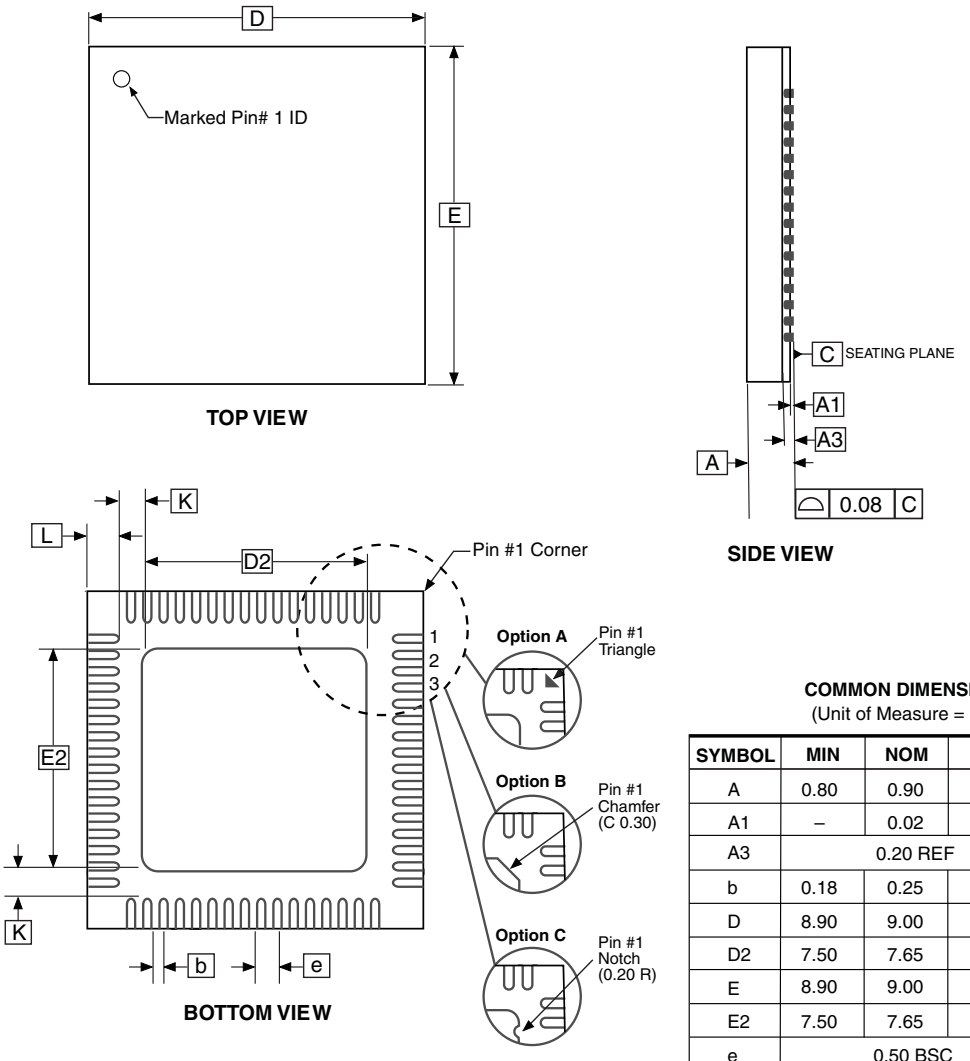
SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	1.20	
A1	0.05	–	0.15	
A2	0.95	1.00	1.05	
D	15.75	16.00	16.25	
D1	13.90	14.00	14.10	Note 2
E	15.75	16.00	16.25	
E1	13.90	14.00	14.10	Note 2
B	0.30	–	0.45	
C	0.09	–	0.20	
L	0.45	–	0.75	
e	0.80 TYP			

Notes:
1. This package conforms to JEDEC reference MS-026, Variation AEB.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
3. Lead coplanarity is 0.10 mm maximum.

2010-10-20

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**64A,** 64-lead, 14 x 14 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)	64A	C

10.4 64M2



COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	0.80	0.90	1.00	
A1	–	0.02	0.05	
A3		0.20 REF		
b	0.18	0.25	0.30	
D	8.90	9.00	9.10	
D2	7.50	7.65	7.80	
E	8.90	9.00	9.10	
E2	7.50	7.65	7.80	
e		0.50 BSC		
L	0.35	0.40	0.45	
K	0.20	0.27	0.40	

Notes: 1. JEDEC Standard MO-220, (SAW Singulation) Fig. 1, VMMD.
2. Dimension and tolerance conform to ASMEY14.5M-1994.

2010-10-20

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**64M2**, 64-pad, 9 x 9 x 1.0 mm Body, Lead Pitch 0.50 mm, 7.65 mm Exposed Pad, Micro Lead Frame Package (MLF)	64M2	E

11. Errata

11.1 ATmega640 rev. B

- **Inaccurate ADC conversion in differential mode with 200× gain**
- **High current consumption in sleep mode**

1. **Inaccurate ADC conversion in differential mode with 200× gain**
   With AVCC <3.6V, random conversions will be inaccurate. Typical absolute accuracy may reach 64 LSB.

   Problem Fix/Workaround
   None.

2. **High current consumption in sleep mode**
   If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

   Problem Fix/Workaround
   Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.2 ATmega640 rev. A

- **Inaccurate ADC conversion in differential mode with 200× gain**
- **High current consumption in sleep mode**

1. **Inaccurate ADC conversion in differential mode with 200× gain**
   With AVCC <3.6V, random conversions will be inaccurate. Typical absolute accuracy may reach 64 LSB.

   Problem Fix/Workaround
   None.

2. **High current consumption in sleep mode**
   If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

   Problem Fix/Workaround
   Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.3 ATmega1280 rev. B

- **Inaccurate ADC conversion in differential mode with 200× gain**
- **High current consumption in sleep mode**

1. **Inaccurate ADC conversion in differential mode with 200× gain**
   With AVCC <3.6V, random conversions will be inaccurate. Typical absolute accuracy may reach 64 LSB.

Problem Fix/Workaround
None.

2. **High current consumption in sleep mode**
If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

Problem Fix/Workaround
Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.4 ATmega1280 rev. A

- **Inaccurate ADC conversion in differential mode with 200× gain**
- **High current consumption in sleep mode**

1. **Inaccurate ADC conversion in differential mode with 200× gain**
With AVCC <3.6V, random conversions will be inaccurate. Typical absolute accuracy may reach 64 LSB.

Problem Fix/Workaround
None.

2. **High current consumption in sleep mode**
If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

Problem Fix/Workaround
Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.5 ATmega1281 rev. B

- **Inaccurate ADC conversion in differential mode with 200× gain**
- **High current consumption in sleep mode**

1. **Inaccurate ADC conversion in differential mode with 200× gain**
With AVCC <3.6V, random conversions will be inaccurate. Typical absolute accuracy may reach 64 LSB.

Problem Fix/Workaround
None.

2. **High current consumption in sleep mode**
If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

Problem Fix/Workaround
Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.6 ATmega1281 rev. A

- **Inaccurate ADC conversion in differential mode with 200× gain**
- **High current consumption in sleep mode**

1. **Inaccurate ADC conversion in differential mode with 200× gain**

   With AVCC <3.6V, random conversions will be inaccurate. Typical absolute accuracy may reach 64 LSB.

   Problem Fix/Workaround

   None.

2. **High current consumption in sleep mode**

   If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

   Problem Fix/Workaround

   Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.7 ATmega2560 rev. F

Not sampled.

11.8 ATmega2560 rev. E

No known errata.

11.9 ATmega2560 rev. D

Not sampled.

11.10 ATmega2560 rev. C

- **High current consumption in sleep mode**

1. **High current consumption in sleep mode**

   If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

   Problem Fix/Workaround

   Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.11 ATmega2560 rev. B

Not sampled.

11.12 ATmega2560 rev. A

- **Non-Read-While-Write area of flash not functional**
- **Part does not work under 2.4 volts**
- **Incorrect ADC reading in differential mode**
- **Internal ADC reference has too low value**
- **IN/OUT instructions may be executed twice when Stack is in external RAM**
- **EEPROM read from application code does not work in Lock Bit Mode 3**

1. **Non-Read-While-Write area of flash not functional**

   The Non-Read-While-Write area of the flash is not working as expected. The problem is related to the speed of the part when reading the flash of this area.

   Problem Fix/Workaround

   - Only use the first 248K of the flash.

   - If boot functionality is needed, run the code in the Non-Read-While-Write area at maximum 1/4th of the maximum frequency of the device at any given voltage. This is done by writing the CLKPR register before entering the boot section of the code.

2. **Part does not work under 2.4 volts**

   The part does not execute code correctly below 2.4 volts.

   Problem Fix/Workaround

   Do not use the part at voltages below 2.4 volts.

3. **Incorrect ADC reading in differential mode**

   The ADC has high noise in differential mode. It can give up to 7 LSB error.

   Problem Fix/Workaround

   Use only the 7 MSB of the result when using the ADC in differential mode.

4. **Internal ADC reference has too low value**

   The internal ADC reference has a value lower than specified.

   Problem Fix/Workaround

   - Use AVCC or external reference.

   - The actual value of the reference can be measured by applying a known voltage to the ADC when using the internal reference. The result when doing later conversions can then be calibrated.

5. **IN/OUT instructions may be executed twice when Stack is in external RAM**

   If either an IN or an OUT instruction is executed directly before an interrupt occurs and the stack pointer is located in external ram, the instruction will be executed twice. In some cases this will cause a problem, for example:

   - If reading SREG it will appear that the I-flag is cleared.

   - If writing to the PIN registers, the port will toggle twice.

   - If reading registers with interrupt flags, the flags will appear to be cleared.

Problem Fix/Workaround
There are two application work-arounds, where selecting one of them, will be omitting the issue:

- Replace IN and OUT with LD/LDS/LDD and ST/STS/STD instructions.

- Use internal RAM for stack pointer.

6. **EEPROM read from application code does not work in Lock Bit Mode 3**
When the Memory Lock Bits LB2 and LB1 are programmed to mode 3, EEPROM read does not work from the application code.

Problem Fix/Workaround
Do not set Lock Bit Protection Mode 3 when the application code needs to read from EEPROM.

11.13 ATmega2561 rev. F

Not sampled.

11.14 ATmega2561 rev. E

No known errata.

11.15 ATmega2561 rev. D

Not sampled.

11.16 ATmega2561 rev. C

- **High current consumption in sleep mode.**

1. **High current consumption in sleep mode**
If a pending interrupt cannot wake the part up from the selected sleep mode, the current consumption will increase during sleep when executing the SLEEP instruction directly after a SEI instruction.

Problem Fix/Workaround
Before entering sleep, interrupts not used to wake the part from the sleep mode should be disabled.

11.17 ATmega2561 rev. B

Not sampled.

11.18 ATmega2561 rev. A

- **Non-Read-While-Write area of flash not functional**
- **Part does not work under 2.4 Volts**
- **Incorrect ADC reading in differential mode**
- **Internal ADC reference has too low value**
- **IN/OUT instructions may be executed twice when Stack is in external RAM**
- **EEPROM read from application code does not work in Lock Bit Mode 3**

1. **Non-Read-While-Write area of flash not functional**
   The Non-Read-While-Write area of the flash is not working as expected. The problem is related to the speed of the part when reading the flash of this area.

   Problem Fix/Workaround
   - Only use the first 248K of the flash.

   - If boot functionality is needed, run the code in the Non-Read-While-Write area at maximum 1/4th of the maximum frequency of the device at any given voltage. This is done by writing the CLKPR register before entering the boot section of the code.

2. **Part does not work under 2.4 volts**
   The part does not execute code correctly below 2.4 volts.

   Problem Fix/Workaround
   Do not use the part at voltages below 2.4 volts.

3. **Incorrect ADC reading in differential mode**
   The ADC has high noise in differential mode. It can give up to 7 LSB error.

   Problem Fix/Workaround
   Use only the 7 MSB of the result when using the ADC in differential mode.

4. **Internal ADC reference has too low value**
   The internal ADC reference has a value lower than specified.

   Problem Fix/Workaround
   - Use AVCC or external reference.

   - The actual value of the reference can be measured by applying a known voltage to the ADC when using the internal reference. The result when doing later conversions can then be calibrated.

5. **IN/OUT instructions may be executed twice when Stack is in external RAM**
   If either an IN or an OUT instruction is executed directly before an interrupt occurs and the stack pointer is located in external ram, the instruction will be executed twice. In some cases this will cause a problem, for example:

   - If reading SREG it will appear that the I-flag is cleared.

   - If writing to the PIN registers, the port will toggle twice.

   - If reading registers with interrupt flags, the flags will appear to be cleared.

   Problem Fix/Workaround
   There are two application workarounds, where selecting one of them, will be omitting the issue:

   - Replace IN and OUT with LD/LDS/LDD and ST/STS/STD instructions.

   - Use internal RAM for stack pointer.

6. **EEPROM read from application code does not work in Lock Bit Mode 3**
   When the Memory Lock Bits LB2 and LB1 are programmed to mode 3, EEPROM read does not work from the application code.

Problem Fix/Workaround

Do not set Lock Bit Protection Mode 3 when the application code needs to read from EEPROM.

12. Datasheet Revision History

Please note that the referring page numbers in this section are referring to this document.The referring revision in this section are referring to the document revision.

12.1 Rev. 2549N-05/11

1. Added Atmel QTouch Library Support and QTouch Sensing Capablity Features
2. Updated Cross-reference in “Bit 5, 2:0 - WDP3:0: Watchdog Timer Prescaler 3, 2, 1 and 0” on page 68
3. Updated Assembly codes in section “USART Initialization” on page 210
4. Added “Standard Power-On Reset” on page 372.
5. Added “Enhanced Power-On Reset” on page 373.
6. Updated Figure 32-13 on page 393
7. Updated “Ordering Information” on page 20 to include Tape & Reel devices.

12.2 Rev. 2549M-09/10

1. Updated typos in Figure 26-9 on page 285 and in Figure 26-10 on page 285.
2. Note is added below Table 1-1 on page 3.
3. The values for “typical characteristics” in Table 31-9 on page 377 and Table 31-10 on page 378, has been rounded.
4. Units for tRST and tBOD in Table 31-3 on page 372 have been changed from “ns” to “µs”.
5. The figure text for Table 31-2 on page 371 has been changed.
6. Text in first column in Table 30-3 on page 336 has been changed from “Fuse Low Byte” to “Extended Fuse Byte”.
7. The text in “Power Reduction Register” on page 54 has been changed.
8. The value of the inductor in Figure 26-9 on page 285 and Figure 26-10 on page 285 has been changed to 10 µH.
9. “Port A” has been changed into “Port K” in the first paragraph of “Features” on page 275.
10. Minimum wait delay for tWD_EEPROM in Table 30-16 on page 351 has been changed from 9.0ms to 3.6ms
11. Dimension A3 is added in “64M2” on page 28.
12. Several cross-references are corrected.
13. “COM0A1:0” on page 130 is corrected to “COM0B1:0”.
14. Corrected some Figure and Table numbering.
15. Updated Section 10.6 “Low Frequency Crystal Oscillator” on page 45.

12.3 Rev. 2549L-08/07

1. Updated note in Table 10-11 on page 47.
2. Updated Table 10-3 on page 43, Table 10-5 on page 44, Table 10-9 on page 47.
3. Updated typos in “DC Characteristics” on page 367
4. Updated “Clock Characteristics” on page 371
5. Updated “External Clock Drive” on page 371.
6. Added “System and Reset Characteristics” on page 372.

7. Updated “SPI Timing Characteristics” on page 375.
8. Updated “ADC Characteristics – Preliminary Data” on page 377.
9. Updated ordering code in “ATmega640” on page 20.

12.4 Rev. 2549K-01/07

1. Updated Table 1-1 on page 3.
2. Updated “Pin Descriptions” on page 7.
3. Updated “Stack Pointer” on page 16.
4. Updated “Bit 1 – EEPE: EEPROM Programming Enable” on page 36.
5. Updated Assembly code example in “Thus, when the BOD is not enabled, after setting the ACBG bit or enabling the ADC, the user must always allow the reference to start up before the output from the Analog Comparator or ADC is used. To reduce power consumption in Power-down mode, the user can avoid the three conditions above to ensure that the reference is turned off before entering Power-down mode.” on page 63.
6: Updated “EIMSK – External Interrupt Mask Register” on page 115.
7. Updated Bit description in “PCIFR – Pin Change Interrupt Flag Register” on page 116.
8. Updated code example in “USART Initialization” on page 210.
9. Updated Figure 26-8 on page 284.
10. Updated “DC Characteristics” on page 367.

12.5 Rev. 2549J-09/06

1. Updated “” on page 46.
2. Updated code example in “Moving Interrupts Between Application and Boot Section” on page 109.
3. Updated “Timer/Counter Prescaler” on page 186.
4. Updated “Device Identification Register” on page 303.
5. Updated “Signature Bytes” on page 338.
6. Updated “Instruction Set Summary” on page 17.

12.6 Rev. 2549I-07/06

1. Added “Data Retention” on page 11.
2. Updated Table 16-3 on page 129, Table 16-6 on page 130, Table 16-8 on page 131, Table 17-2 on page 148, Table 17-4 on page 159, Table 17-5 on page 160, Table 20-3 on page 187, Table 20-6 on page 188 and Table 20-8 on page 189.
3. Updated “Fast PWM Mode” on page 150.

12.7 Rev. 2549H-06/06

1. Updated “” on page 46.
2. Updated “OSCCAL – Oscillator Calibration Register” on page 50.
3. Added Table 31-1 on page 371.

12.8 Rev. 2549G-06/06

1. Updated “Features” on page 1.
2. Added Figure 1-2 on page 3, Table 1-1 on page 3.
3. Updated “” on page 46.
4. Updated “Power Management and Sleep Modes” on page 52.
5. Updated note for Table 12-1 on page 68.
6. Updated Figure 26-9 on page 285 and Figure 26-10 on page 285.
7. Updated “Setting the Boot Loader Lock Bits by SPM” on page 324.
8. Updated “Ordering Information” on page 20.
9. Added Package information “100C1” on page 26.
10. Updated “Errata” on page 29.

12.9 Rev. 2549F-04/06

1. Updated Figure 9-3 on page 31, Figure 9-4 on page 31 and Figure 9-5 on page 32.
2. Updated Table 20-2 on page 187 and Table 20-3 on page 187.
3. Updated Features in “ADC – Analog to Digital Converter” on page 275.
4. Updated “Fuse Bits” on page 336.

12.10 Rev. 2549E-04/06

1. Updated “Features” on page 1.
2. Updated Table 12-1 on page 62.
3. Updated note for Table 12-1 on page 62.
4. Updated “Bit 6 – ACBG: Analog Comparator Bandgap Select” on page 273.
5. Updated “Prescaling and Conversion Timing” on page 278.
5. Updated “Maximum speed vs. V_{CC}” on page 373.
6. Updated “Ordering Information” on page 20.

12.11 Rev. 2549D-12/05

1. Advanced Information Status changed to Preliminary.
2. Changed number of I/O Ports from 51 to 54.
3. Updatet typos in “TCCR0A – Timer/Counter Control Register A” on page 129.
4. Updated Features in “ADC – Analog to Digital Converter” on page 275.
5. Updated Operation in“ADC – Analog to Digital Converter” on page 275
6. Updated Stabilizing Time in “Changing Channel or Reference Selection” on page 282.
7. Updated Figure 26-1 on page 276, Figure 26-9 on page 285, Figure 26-10 on page 285.
8. Updated Text in “ADCSRB – ADC Control and Status Register B” on page 290.
9. Updated Note for Table 4 on page 43, Table 13-15 on page 86, Table 26-3 on page 289 and Table 26-6 on page 295.
10. Updated Table 31-9 on page 377 and Table 31-10 on page 378.
11. Updated “Filling the Temporary Buffer (Page Loading)” on page 323.
12. Updated “Typical Characteristics” on page 385.
13. Updated “Packaging Information” on page 25.
14. Updated “Errata” on page 29.

12.12 Rev. 2549C-09/05

1. Updated Speed Grade in section "Features" on page 1.
2. Added "Resources" on page 11.
3. Updated "SPI – Serial Peripheral Interface" on page 195. In Slave mode, low and high period SPI clock must be larger than 2 CPU cycles.
4. Updated "Bit Rate Generator Unit" on page 247.
5. Updated "Maximum speed vs. V_{CC}" on page 373.
6. Updated "Ordering Information" on page 20.
7. Updated "Packaging Information" on page 25. Package 64M1 replaced by 64M2.
8. Updated "Errata" on page 29.

12.13 Rev. 2549B-05/05

1. JTAG ID/Signature for ATmega640 updated: 0x9608.
2. Updated Table 13-7 on page 81.
3. Updated "Serial Programming Instruction set" on page 352.
4. Updated "Errata" on page 29.

12.14 Rev. 2549A-03/05

1. Initial version.

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2549NS–AVR–05/11

5.2. Anexo B: Hoja de Especificaciones RTD Pt100 W-EYK [2]

Heraeus Nexensos

W-EYK, Insert Pt Temperature Sensor with Stainless-Steel Housing according to DIN EN 60751

Temperature range -40 °C to +500 °C

- Platinum sensor encapsulated in protective stainless steel housing
- Hi-temperature fiberglass insulated connection wires
- High maximum operating temperature +500 °C
- Housing resistant to oils, organic and inoranic bases and alkalis (medium concentration)

The dimensionally stable stainless steel protective tube allows easy mounting in corresponding mating holes. Applications include temperature measurement in gas, including HVAC equipment at elevated temperatures. Measurement accuracy is optimized for tempertures between 0 °C and 100 °C.

Nominal Resistance R_0 [Ω]	Tolerance Class	Order Number
Pt100	F 0.10 / Class 1/3 B	30500109
Pt1000	F 0.10 / Class 1/3 B	31500989

Temperature and Tolerance Range
Tolerance Class F 0.10 / 1/3 B 0 °C to +100 °C

Temperature Coefficient
TCR = 3850 ppm/K

Connection Wire
Fiberglass insulated twisted pair Ni wire
2 x 0.5 mm (24 AWG), 300 mm long

Internal Conductor Resistance
0.04 Ω/ft.(0.48 Ω/m) for each conductor

Housing
Closed end tube,stainless steel 1.4571 (316 Ti)

Applications
- HVAC
- Data Logging
- Laboratory instrumentation
- Oven temperature
- Hi-temp temperature sensing

Image for illustration purposes only

Heraeus Nexensos USA, a division of Heraeus Epurio LLC, USA
Web: www.heraeus-nexensos.com
Contact: nexensos.america@heraeus.com

Document: 20003959423 | Part 001 | Version 00 | Status: 09/2021

Heraeus Nexensos

W-EYK, Insert Pt Temperature Sensor with Stainless-Steel Housing according to DIN EN 60751

Temperature range -40 °C to +500 °C

Features

- Corrosion resistant stainless steel protective housing
- High- temperature fiberglass-insulated connection wires
- Widely used for a variety of temperature sensing applications
- Available in Pt100 or Pt 1000 resistance values
- +500 °C maximum operating temperature

Options

- Wire length
- Resistance Value
- Connectors

Resistance vs Temperature Table

Reference table @ www.herae.us/technical-information

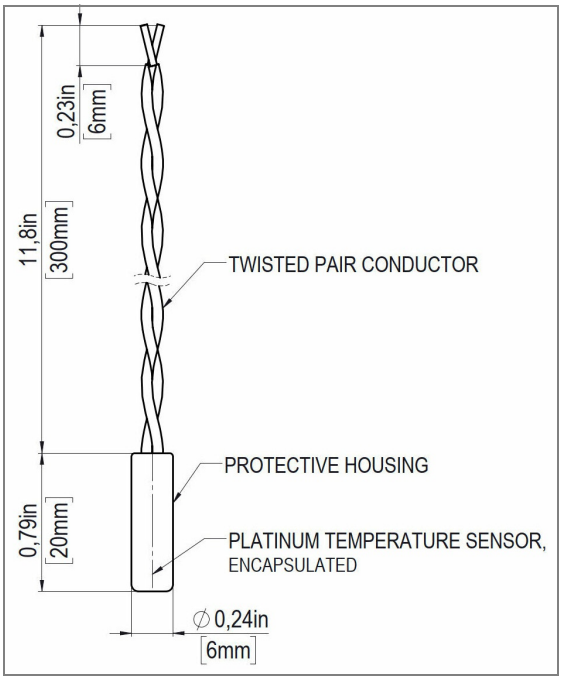

Image for illustration purposes only

RoHS konform

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Document: 20003959423 I Part 001 I Version 00 I Status: 09/2021

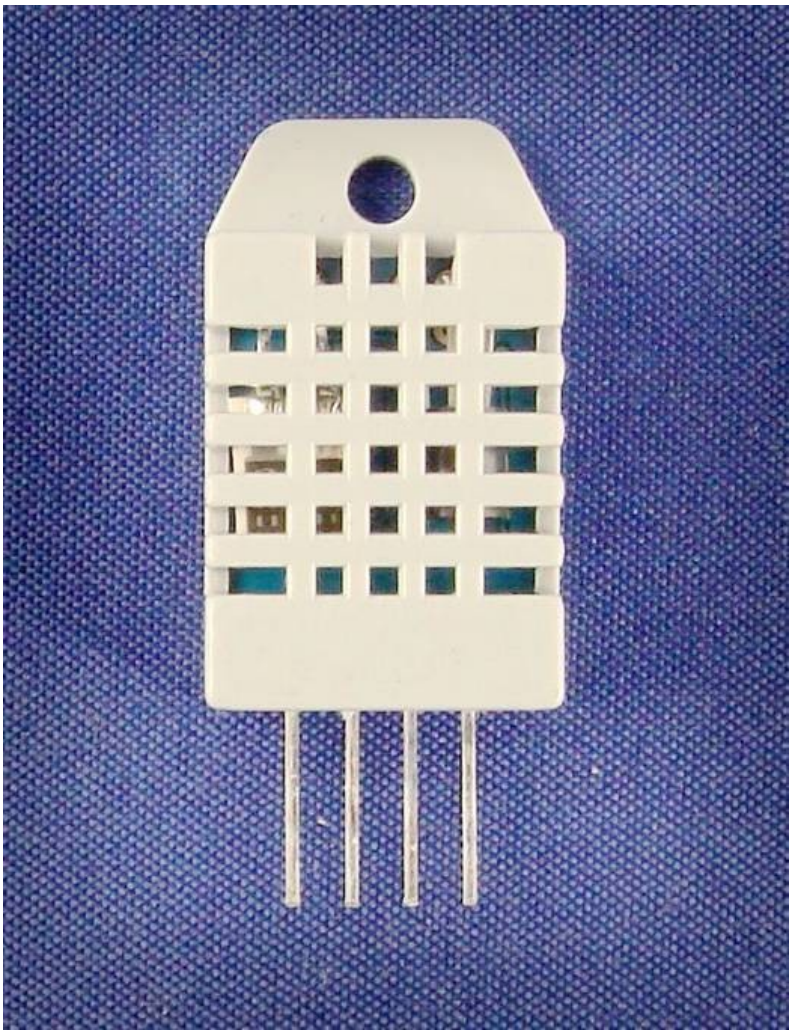
5.3. Anexo C: Hoja de Especificaciones DHT22 [3]

Aosong Electronics Co.,Ltd

Your specialist in innovating humidity & temperature sensors

Digital-output relative humidity & temperature sensor/module

DHT22 (DHT22 also named as AM2302)



Capacitive-type humidity and temperature module/sensor

1

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1. Feature & Application:

* Full range temperature compensated * Relative humidity and temperature measurement
* Calibrated digital signal *Outstanding long-term stability *Extra components not needed
* Long transmission distance * Low power consumption *4 pins packaged and fully interchangeable

2. Description:

DHT22 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability.Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.

Small size & low consumption & long transmission distance(20m) enable DHT22 to be suited in all kinds of harsh application occasions.

Single-row packaged with four pins, making the connection very convenient.

3. Technical Specification:

Model	DHT22
Power supply	3.3-6V DC
Output signal	digital signal via single-bus
Sensing element	Polymer capacitor
Operating range	humidity 0-100%RH; temperature -40~80Celsius
Accuracy	humidity +-2%RH(Max +-5%RH); temperature <+-0.5Celsius
Resolution or sensitivity	humidity 0.1%RH; temperature 0.1Celsius
Repeatability	humidity +-1%RH; temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH
Long-term Stability	+-0.5%RH/year
Sensing period	Average: 2s
Interchangeability	fully interchangeable
Dimensions	small size 14*18*5.5mm; big size 22*28*5mm

4. Dimensions: (unit----mm)

1) Small size dimensions: (unit----mm)

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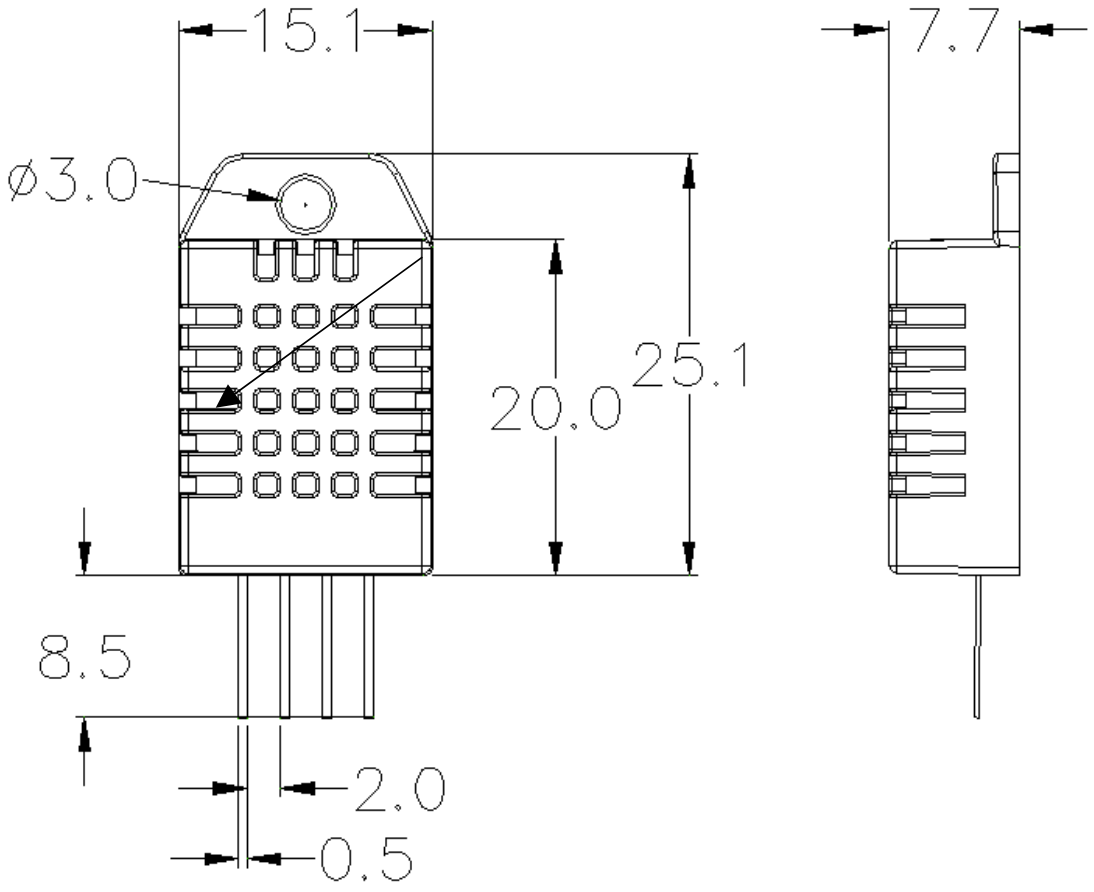

Pin sequence number: 1 2 3 4 (from left to right direction).

Pin	Function
1	VDD----power supply
2	DATA--signal
3	NULL
4	GND

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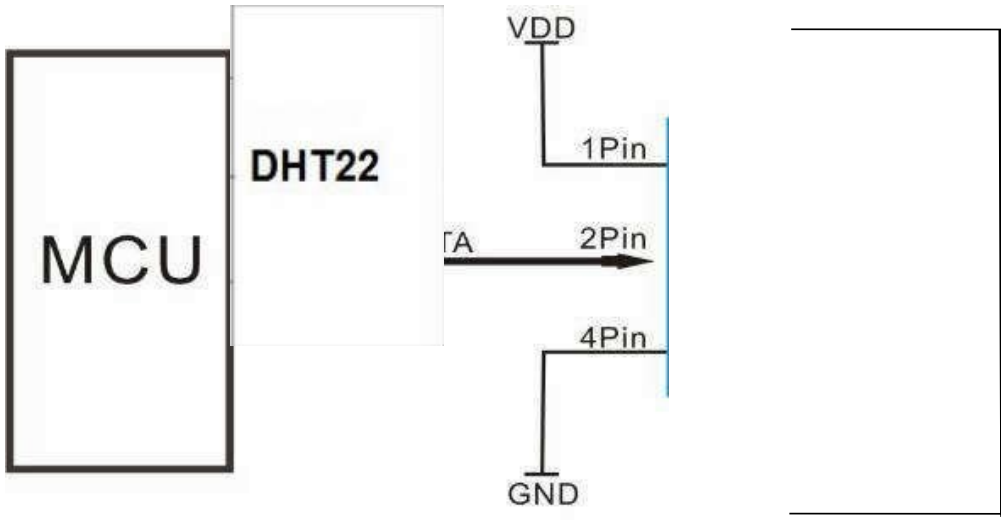
5. Electrical connection diagram:



3Pin---NC, AM2302 is another name for DHT22

6. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-6V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

Single-bus data is used for communication between MCU and DHT22, it costs 5mS for single time communication.

Data is comprised of integral and decimal part, the following is the formula for data.

DHT22 send out higher data bit firstly!

DATA=8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data+8 bit check-sum

If the data transmission is right, check-sum should be the last 8 bit of "8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data".

When MCU send start signal, DHT22 change from low-power-consumption-mode to running-mode. When MCU finishs sending the start signal, DHT22 will send response signal of 40-bit data that reflect the relative humidity

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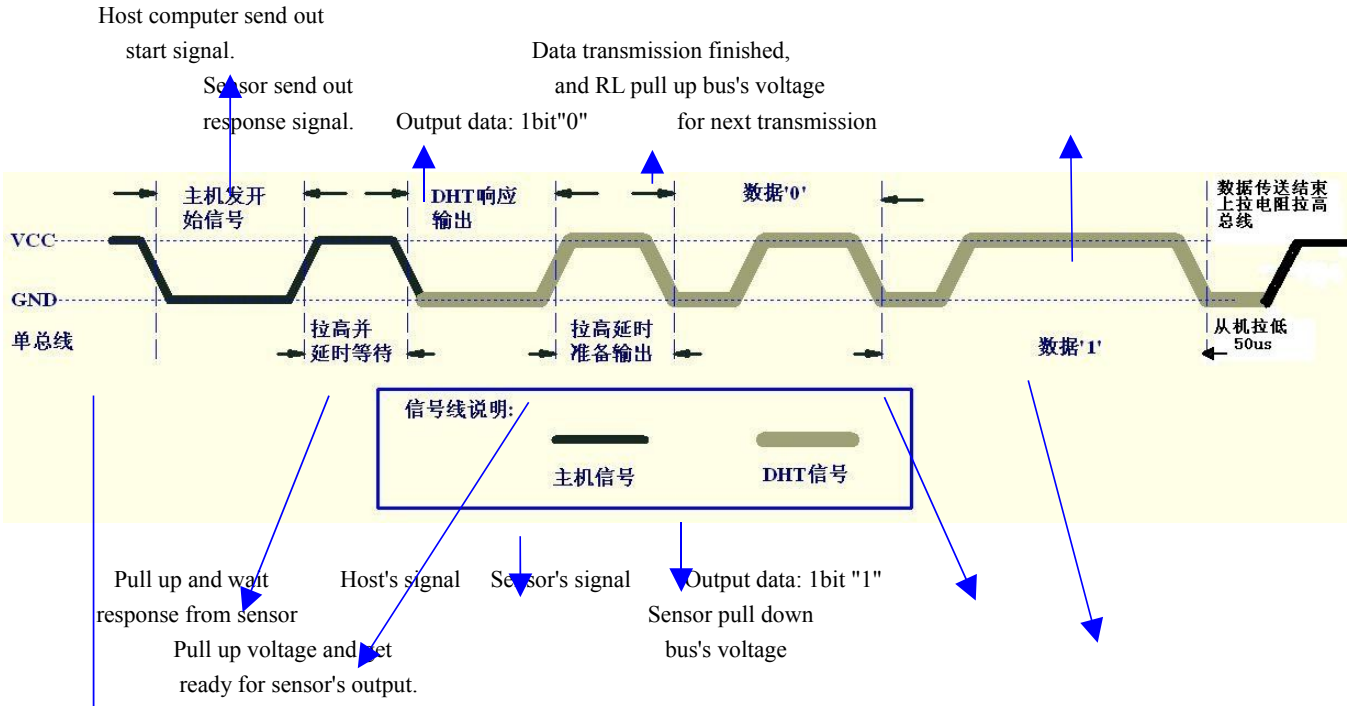
and temperature information to MCU. Without start signal from MCU, DHT22 will not give response signal to MCU. One start signal for one time's response data that reflect the relative humidity and temperature information from DHT22. DHT22 will change to low-power-consumption-mode when data collecting finish if it don't receive start signal from MCU again.

1) Check bellow picture for overall communication process:



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2) Step 1: MCU send out start signal to DHT22

Data-bus's free status is high voltage level. When communication between MCU and DHT22 begin, program of MCU will transform data-bus's voltage level from high to low level and this process must beyond at least 1ms to ensure DHT22 could detect MCU's signal, then MCU will wait 20-40us for DHT22's response.

Check bellow picture for step 1:

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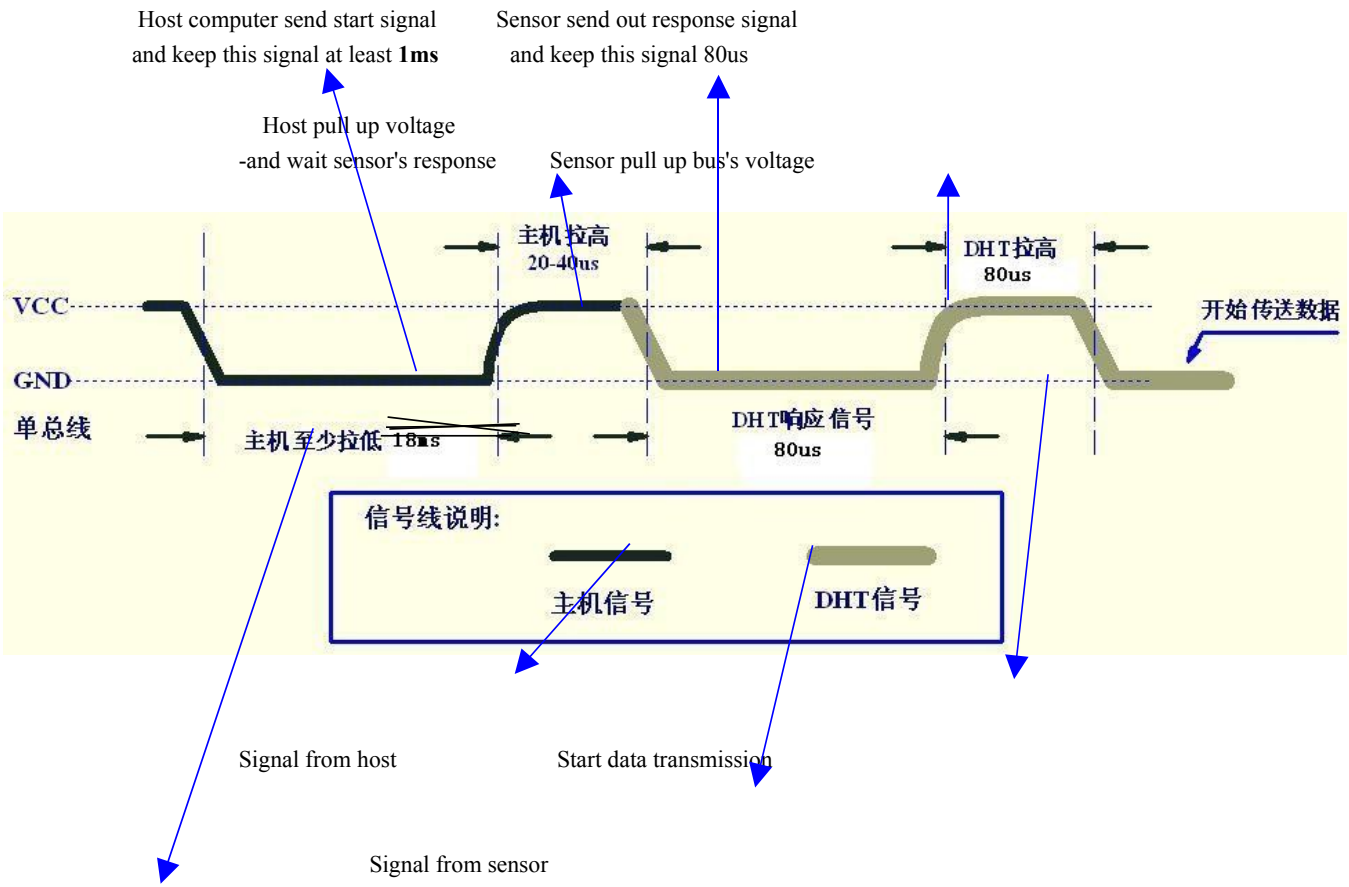

Single-bus signal

Step 2: DHT22 send response signal to MCU

When DHT22 detect the start signal, DHT22 will send out low-voltage-level signal and this signal last 80us as response signal, then program of DHT22 transform data-bus's voltage level from low to high level and last 80us for DHT22's preparation to send data.

Check bellow picture for step 2:

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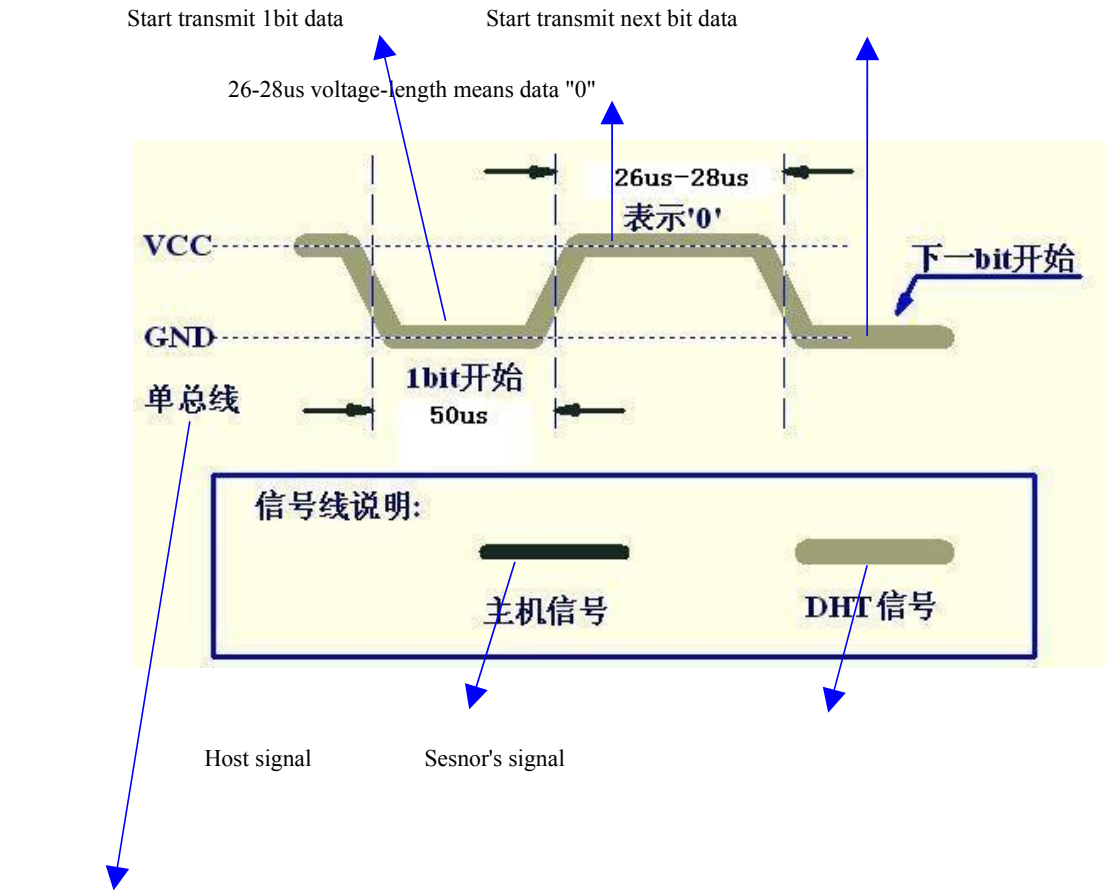

Step 3: DHT22 send data to MCU

When DHT22 is sending data to MCU, every bit's transmission begin with low-voltage-level that last 50us, the following high-voltage-level signal's length decide the bit is "1" or "0".

Check bellow picture for step 3:

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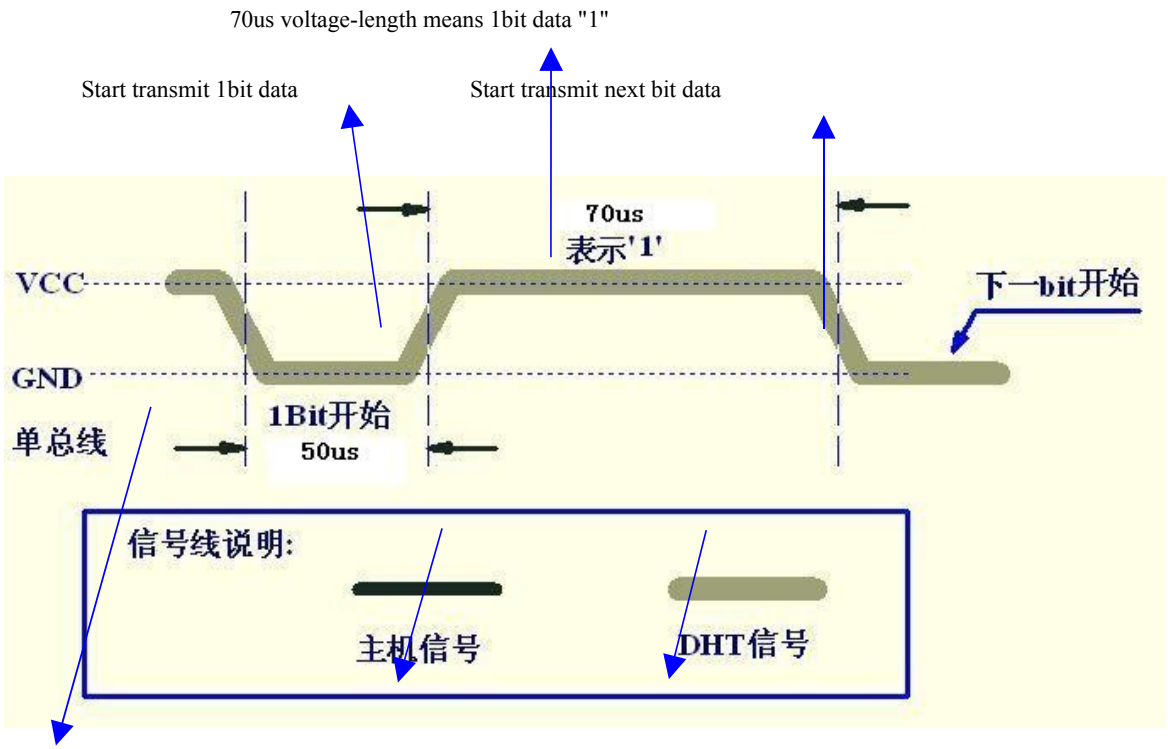

Host signal Sesnor's signal

Single-bus signal

If signal from DHT22 is always high-voltage-level, it means DHT22 is not working properly, please check the electrical connection status.

7. Electrical Characteristics:

Item	Condition	Min	Typical	Max	Unit
Power supply	DC	3.3	5	6	V
Current supply	Measuring	1		1.5	mA
	Stand-by	40	Null	50	uA
Collecting period	Second		2		Second

*Collecting period should be : >2 second.

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8. Attentions of application:

(1) Operating and storage conditions

We don't recommend the applying RH-range beyond the range stated in this specification. The DHT22 sensor can recover after working in non-normal operating condition to calibrated status, but will accelerate sensors' aging.

(2) Attentions to chemical materials

Vapor from chemical materials may interfere DHT22's sensitive-elements and debase DHT22's sensitivity.

(3) Disposal when (1) & (2) happens

Step one: Keep the DHT22 sensor at condition of Temperature 50~60Celsius, humidity <10%RH for 2 hours;

Step two: After step one, keep the DHT22 sensor at condition of Temperature 20~30Celsius, humidity >70%RH for 5 hours.

(4) Attention to temperature's affection

Relative humidity strongly depend on temperature, that is why we use temperature compensation technology to ensure accurate measurement of RH. But it's still be much better to keep the sensor at same temperature when sensing.

DHT22 should be mounted at the place as far as possible from parts that may cause change to temperature.

(5) Attentions to light

Long time exposure to strong light and ultraviolet may debase DHT22's performance.

(6) Attentions to connection wires

The connection wires' quality will effect communication's quality and distance, high quality shielding-wire is recommended.

(7) Other attentions

* Welding temperature should be bellow 260Celsius.
* Avoid using the sensor under dew condition.
* Don't use this product in safety or emergency stop devices or any other occasion that failure of DHT22 may cause personal injury.

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5.4. Anexo D: Hoja de Especificaciones WSS100 [4]

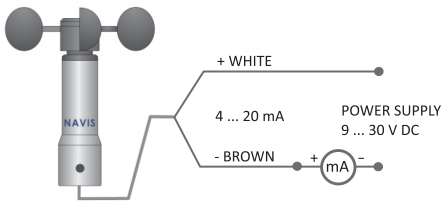
NAVIS

WIND SPEED SENSOR

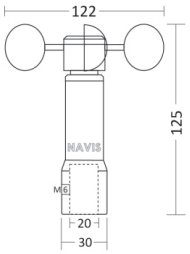
WSS 100/4-20 mA

- **low starting speed**
- **wind tunnel tested**
- **field replaceable bearings**
- **replaceable anemometer cups**
- **full ceramic ball bearings (option) for low starting speed and long bearings life time**
- **linear output curve - linearization of cups rotation and starting threshold compensation**

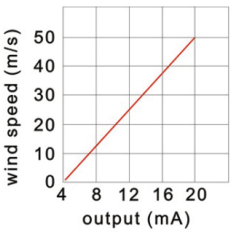
WIRING



DIMENSIONS



OUTPUT



NAVIS elektronika
E-mail: info@navis-elektronika.com
www.navis-anemometers.com

NAVIS

ORDERING INFORMATION

MODELS

- WSS100/4-20mA
- WSS100/4-20mA/CER

OPTIONS

- Individualy wind tunnel tested sensors with calibration certificate
- Measnet calibration certificate
- various cable length

SPARE PARTS

1 Spare anemometer cups
2 WS sensor head with bearings
3 WS sensor head with ceramic bearings

1

2, 3

TECHNICAL DATA

Wind speed measurement range:	0,7 ... 50,0 m/s
Starting threshold:	0,6 m/s
Operating voltage:	9...30 V DC
Signal output: .	4...20 mA, 2 wire 4 mA = 0 m/s; 20 mA = 50 m/s
Output update:	4/sec
Output averaging period:	1 s
Accuracy:	+/- 0,15 m/s or 2,5% (up to 40 m/s)
Resolution:	0,1 m/s
Loop resistance:	max. 600Ω /24V
Reverse polarity protection:	YES
Transient voltage protection:	YES
Temperature operating range:	-30 ... +55 °C
Relative humidity:	0 ... 100%
Rotation sensor type:	hall effect sensor
Cable:	Liyy 2 x 0,34 mm²; 10 m standard
Bearings (replaceable):	2 x precision stainless steel ball bearings (WSS100/4-20mA) 2 x full ceramic Ball bearings (WSS100/4-20mA/CER)
Material - housing:	anodized aluminum
- cups (replaceable):	PA (Polyamide)
Weight:	120 g, without cable
Mounting:	the sensor mounts on a pipe with ø 20 mm outside diameter

Subject to technical modification without notice

CE

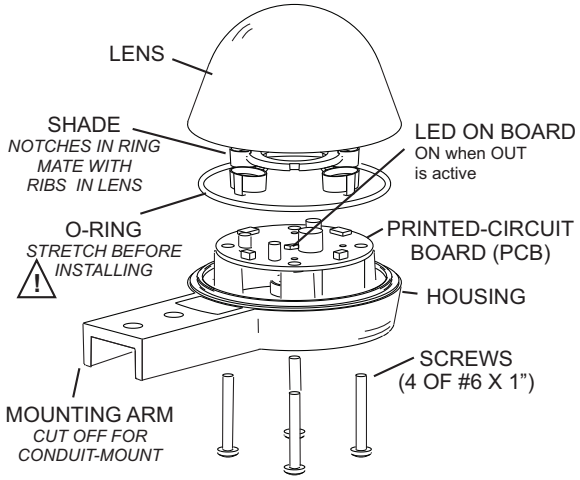
NAVIS elektronika
E-mail: info@navis-elektronika.com
www.navis-anemometers.com

5.5. Anexo E: Hoja de Especificaciones RG-11 [5]

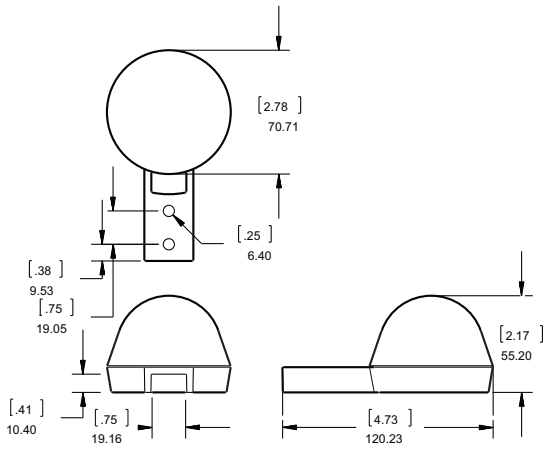
HYDREON

HYDREON CORPORATION

MODEL RG-11
OPTICAL RAIN GAUGE



EXPLODED VIEW



DIMENSIONAL VIEW

INSTALLING THE RAIN SENSOR

1. Determine the Mode / Set DIP switches
You must set the DIP switches so that the RG-11 behaves the right way for your application. The pages that follow describe each of the possible modes, and how to set the DIP switches.

2. Mount the Rain Gauge
Mount the rain Gauge where it gets a clear measurement of precipitation– away from overhangs, etc.

The mounting arm is designed to fit over a strap 0.75" (19 mm) wide. Two 0.25" (holes 6.35 mm) are placed 0.75" (19 mm) part.

The gland style connector goes in the bottom hole. Be sure to use wire rated for outdoor (high-UV) use.

For conduit applications, the mounting arm may be removed, and the wiring hole drilled out using a step drill to accommodate a ½" EMT compression connector or similar style of conduit connector.

3. Assemble the Rain Gauge as shown.
The silicone O-ring fits nicely in the lens groove, but it can fall or slip out during assembly. After the unit is assembled, verify that the O-ring is properly seated by confirming that you can see it through the lens, all the way around.

The Rain Gauge must be assembled when dry. Any water trapped inside can condense and cause corrosion. You may optionally add extra desiccant packets (not supplied). If the Rain Gauge is not subject to splashing or sprayed water, you may optionally vent the enclosure by drilling a 1/8" (3 mm) hole in the bottom of the case.

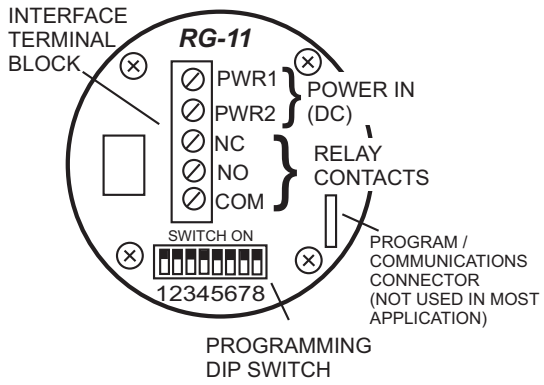
- APPLICATION WARNING -

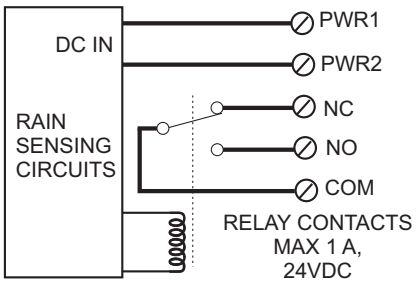
Do not use the RG-11 in any application where the false indication of water or a missed valid detection of water could cause damage to life or property. It is the responsibility of the system designer / integrator to design redundancy into the system so that the failure of any one component, including the RG-11 or other sensor, does not result in disaster. The manufacturer of the RG-11, Hydreon Corporation, will in no way be liable for consequential damages due to the failure or false indication of one of its sensors.

HYDREON

HYDREON CORPORATION

RAIN GAUGE CONNECTIONS

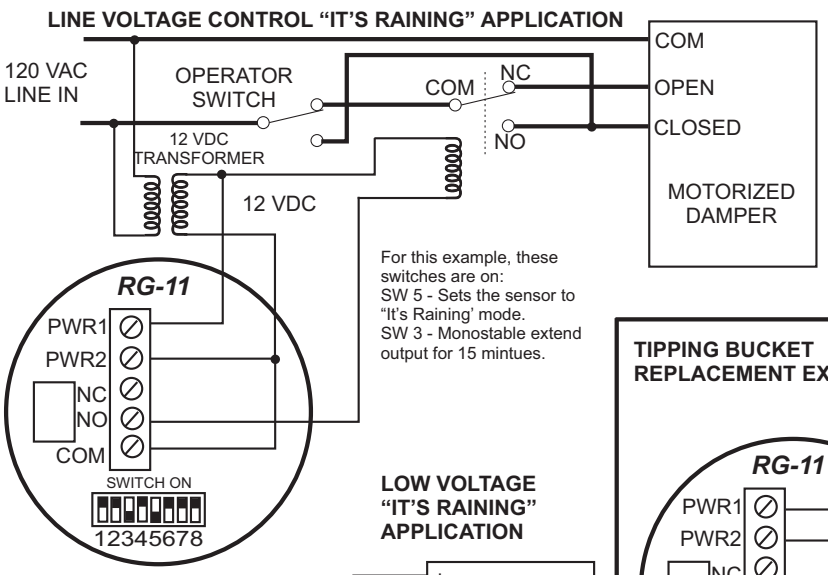




EQUIVALENT SCHEMATIC

RAIN GAUGE WIRING EXAMPLES

LINE VOLTAGE CONTROL "IT'S RAINING" APPLICATION

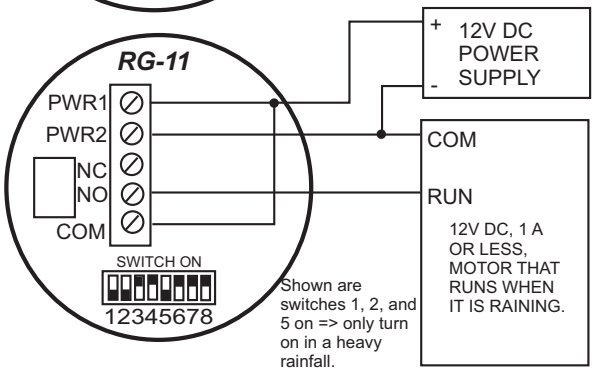


The relay output of the RG-11 is rated for 24VDC, at 1 A. Thus, the RG-11 cannot drive a line voltage (120 VAC) load without an external relay.

The RG-11 requires a DC supply and may not be directly powered from the 120 VAC line.

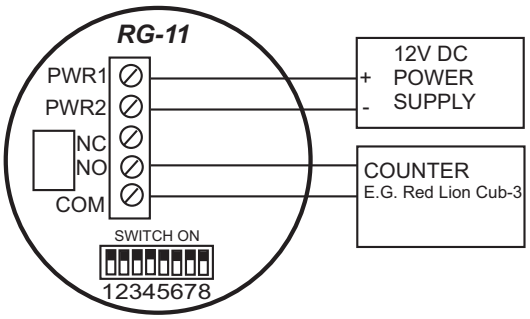
For this example, these switches are on:
SW 5 - Sets the sensor to "It's Raining' mode.
SW 3 - Monostable extend output for 15 mintues.

LOW VOLTAGE "IT'S RAINING" APPLICATION



Shown are switches 1, 2, and 5 on => only turn on in a heavy rainfall.

TIPPING BUCKET REPLACEMENT EXAMPLE



In many cases, the RG-11 may directly replace tipping buckets in existing systems.
The switch settings shown here- all off– will emulate a tipping bucket of 0.01"

Specifications

Parameter	Value
Input Voltage	Nominal 12 VDC (Range 10 -15 VDC) 50V surge Reverse polarity protected to 50V
Current Drain	15 mA nominal. (No outputs on, not raining, no heater) about 1.5 mA in micro-power sleep mode. 50 mA with output on. 55 mA - With heater on, 12V DC input.
Output	Relay closure, Normally Open and Normally Closed contacts. Max load 1A, 24 VDC.
Operating Temperature range	-40 C to +60C

DIP Switches
Set the DIP switches for the application according to the tables below. Generally, a few switch positions (5, 6, and 7) set the overall mode of operation, and others (1, 2, 3, 4) adjust the behavior within the modes.
In the tables, 1 = Switch on, 0 = Switch off, X = switch in either position.

Software Revision
This manual corresponds to software revision 016. The software revision is printed on a sticker place on the connector block. See www.rainsensors.com (click on “support”) for information about differences in software revisions. Differences are generally minor.

Switch 8 is Enable Micro-power Sleep Mode in most applications.
Most applications will use SW 8 off. If micro-power is enabled, the low-power heater is disabled. In micro-power mode, if a long time (about 20 min) has elapsed since the last rain was detected, the unit will enter a less sensitive sleep mode. A large drop will cause it to exit sleep mode and resume normal operation. This is for battery or solar powered applications. Micro-power mode is disabled in Condensation sensing mode and in irrigation mode. Switch 8 must be off for First Flush Controller. The unit will not read the DIP switches during sleep.

OUT LED
The LED in the center of the circuit board turns on when OUT is on, as an aid to debugging.

Condensation
Generally, the RG-11 will sense condensation as if it were rainfall, but this seldom amounts to a significant accumulation of water. The built-in low power heater (DIP SW 8 off) will tend to reduce condensation.

Ambient Light Interference
The RG-11 is almost completely immune to the effects of ambient light, and may freely be mounted in direct sunlight.

Heater Notes
A built-in low power (0.25W) heater extends operation of the device to freezing (32 F or 0C). This is disabled if the micro-power (SW 8) is enabled. Note that this is a very modest amount of power; it will tend to drive off a modest amount of frost, but will not melt ice.

Dark Sensing
Turns output on when it is dusk-- nominally less than 2000 lux. This is for applications such as retracting sun-shields in the evening, when they are not needed. (Only in Mode 1, “It's Raining” applications.)

LED Flicker / Relay Buzz
If the relay and LED remain on for a long period of time (seconds), the LED may flicker, and the relay may make a barely audible buzz. This is because the RG-11 pulse-width modulates the relay drive signal to reduce current consumption. It does this to prevent excessive heat in the RG-11. This does not affect functionality in any way.

J2 Connector

J2 is a pin-field on 0.1” centers, used for programming, development, and testing of the RG-11. Most applications do not connect to J2, and we make this information available only for special applications.

Connector field is 0.025” square pins on 0.1” centers. An example compatible connector is Molex part number 22-01-3067. This is available from Digi-Key as part number WM2004-ND. The necessary crimp-on wire terminals are Molex 08-55-0131 / DigiKey WM4591-ND.

J2 Pin assignments
J2 - 1 GND
J2 - 2 +5V OUT
J2 - 3 SW4
J2 - 4 SW1
J2 - 5 SW2
J2 - 6 RS232 and SW 5.

Remote Switching
These connections may be used to remotely operate the corresponding switches, by grounding the connections. This can be used for operator-accessible sensitivity adjustment in wiper control applications.

RS-232 communications
Requires an external resistor. See the “support” link on www.rainsensors.com. Modes that require SW 5 on (It's Raining, Wiper Control and First Flush) cannot use RS-232.

Mode 0: Tipping Bucket
Rain Gauge emulates a tipping bucket of the specified size.

Switch							Behavior
7	6	5	4	3	2	1	
0	0	0	X	0	0	0	Bucket Size = 0.01”
				0	0	1	Bucket Size = 0.001” (Sensitive)
				0	1	0	Bucket Size = 0.0001” (Very sensitive)
				1	0	0	Bucket Size = 0.2 mm
				1	0	1	Bucket Size = 0.01 mm (sensitive)
				1	1	0	Bucket Size = 0.001 mm (Very sensitive)
			1	1	1	1	Reserved for system test

In tipping bucket mode, the Rain Gauge effectively emulates a tipping bucket of the specified size. For example, if the DIP switches are set to a tipping bucket mode with a bucket size of 0.01", then the output will pulse ON for 50mS each time 0.01" of water accumulates, just as a tipping bucket would. This can be externally totalized, and used to measure rainfall rates. Bucket sizes of 0.001" and 0.0001" are similar, generating pulses at accumulations of one one-thousandth, and one ten-thousands of an inch, respectively. These emulate what a tipping bucket would do if it were possible to make one that small. Metric bucket sizes are available as well, or the Inch unit scales may be scaled with external equipment.

Accuracy
We do not claim an accuracy spec for the RG-11. For more information see the “Tipping Bucket” link on www.rainsensors.com.

Mode 1: It's Raining
Rain Gauge turns on the relay to indicate that it is raining when the rainfall has reached a given intensity.

Switch							Function
7	6	5	4	3	2	1	
0	0	1	X	X	0	0	Very sensitive-- first detected raindrop.
					0	1	Sensitive-- turn on with very light rainfall (0.1” per hour).
					1	0	Medium Sensitivity-- turn on with medium rain (0.25” per hour. You would want your car's wipers on steady slow)
					1	1	Low Sensitivity-- turn on in heavy rainfall. (1” per hour. You would want your car's wipers on high)
			X	0	X	X	Output off when rain stops.
				1			Output Monostable Extended by 15 minutes
			0	X	X	X	No Dark-Detect - Normal operation
			1				Dark Detect

Use this mode to control equipment that should be controlled, enabled, open, closed, and so forth depending on whether or not it is raining. The output turns on when a given rate of rainfall is detected, and turns off after it has dropped below a threshold.

Each of the sensitivity levels (set by switches 1 and 2) provides different trip and release points. There is much hysteresis built in, but real rain fall rates typically fluctuate, even in what you may perceive as a “steady rain”, so expect the output to turn on and off. The output will remain on for between about 30 seconds and 5 minutes after the last detected rain drop, depending on sensitivity setting and actual conditions.

Monostable Extend = Switch 3 ON
To prevent some piece of equipment from turning constantly on and off (or opening / closing, etc.) you can enable the Monostable extend (Switch 3). That will hold the output on for 15 minutes after the rain has ceased.

Dark Detect = Switch 4 ON
If this enabled, the output will also turn on when the ambient light drops below about 2000 lux. This feature may be used to retract a sun-shade awning when it is dark.

Mode 2: Condensation Sensor
Rain Gauge detects condensation or frost formation on the surface.

Switch							Behavior
7	6	5	4	3	2	1	
0	1	0	0	0	0	0	Very Sensitive- first sign of condensation
					0	1	Sensitive
					1	0	Medium Low
					1	1	Low

The rain sensor senses condensation by detecting a shift from the "clear" condition. The relay closes when the condensation occurs, and opens when the condensation goes away. The rain sensor is set to very gradually adapt the clear condition, so that very gradual build up of dirt or other contaminants do not cause a false trip.

Condensation sensing mode disables the heater and micro-power mode.

Mode 3: Wiper Control
Rain sensing wiper control from off through intermittent and steady slow speeds.

Switch							Behavior
7	6	5	4	3	2	1	
0	1	1	0	x	0	0	Normal Wiper Control
			0		0	1	Wipe More
			0		1	0	Wipe a Lot More
			0		1	1	Wipe a Whole Lot More
			1		0	0	Wipe Less
			1		0	1	Wipe a Lot Less
			1		1	0	Wipe a Whole Lot Less
			1		1	1	Wipe hardly at all
			x	0	x	x	Normal Slow Cycle Time (1.2 to 3 sec.)
				1			Long Slow Cycle Time (3 – 8 sec.)

See rainsensors.com for instructions that are just for wiper control applications. (Click on “Wiper Control”).

The RG-11 may be used to control a wiper system. The output relay turns on when the slow motor winding should be engaged. This will typically be used to drive an external relay, which will, in turn, drive the wiper motor windings. This may be used for the wipers for a boat, ship, locomotive, observation window, or many other applications. The RG-11 does not care what the wipers are wiping.

WARNING: The relay contacts of the RG-11 can control only a 1A load, and wiper systems generally require many times that current. The RG-11 MUST be used with a suitable external relay in wiper control applications.

The nominal wiper control is set so that it properly controls the wipers of a passenger car. It is optimized for wiper systems that require between 1.2 and 3 seconds to make a single complete actuation of the wipers. A long cycle time is provide (Switch 4 on) for systems with a wiper actuation cycle time between 3 and 8 seconds. In all cases, the RG-11 provides a pulse to initiate the wiper actuation. Most wiper system will include some sort of cam feedback mechanism that causes the wipers to keep running until they reach a home position.

Mount the RG-11 so that it generally gets the same rainfall as the surface to be wiped. Usually, this means about a 45 degree angle. The RG-11 does not need to be within the actual field of view of the window. Adjust the sensitivity control DIP switches (3, 2, and 1) to set the system to wipe more or less, depending on the needs of the installation.

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Mode 4: Irrigation Control
Rain Gauge output on means inhibit watering.

Switch								Behavior
8	7	6	5	4	3	2	1	
X	1	0	X	X	0	0	0	Typical Water Control. Inhibit watering for up to 5 days.
					0	0	1	Water More
					0	1	0	Water a lot more
					1	0	0	Water Less
					1	0	1	Water a lot less
				0	X	X	X	Inhibit irrigation during a storm
				1				Allow irrigation during a storm
			0	X	X	X	X	Inhibit irrigation during freeze
			1					Allow irrigation during freeze
0								Normal Evaporation Rate
1								Hi Evaporation Rate

See rainsensors.com for instructions that are just for irrigation control applications. (Click on "Irrigation Control")

The RG-11 may be set to provide precise control of an irrigation system. Typically, the installation will connect to the COM and NC relay contacts to interrupt the valves when watering should be inhibited. Note that the RG-11 also requires 24 VAC (or other suitable supply.)

The nominal irrigation profile is set so that the ground receives an inch of water per week. It will inhibit watering upon the accumulation of 0.2 inches of water, and re-enable the system after that water has evaporated. This can be a short as less than a day, or as long as six days, depending on rainfall. Additional DIP switch settings are provided for allowing more or less watering, as shown in the table below.

Nominally (Switch 4 off), the RG-11 will inhibit watering during a storm, even if not much water has accumulated. The reasoning is that if it is raining hard now, the rainfall is likely to deliver enough accumulation to justify inhibiting at least the current cycle of watering. This prevents the "it's pouring, but my sprinklers are still running" objection from the customer, and the accompanying excessive runoff and muddy ground. The feature may be defeated by turning switch 4 on.

Normally, the RG-11 will inhibit irrigation if the temperature drops below freezing, or nominally about 34 degrees. If SW 5 is on, the RG-11 will allow irrigation below 34 degrees. Micro-power mode is disabled in irrigation control.

Evaporation Rate
Normal Evaporation Rate = 0.11 inches per day
Hi Evaporation Rate = 0.22 inches per day
In irrigation mode, if Switch 8 is on, the control assumes a high evaporation (or transpiration rate). Set this switch to ON for sandy soil or other conditions where the soil tends to dry out quickly. The system will re-enable the irrigation sooner.

Mode 6: Drop Detector

Switch							Behavior
7	6	5	4	3	2	1	
1	1	0	0	X	0	0	Normal drop threshold
					0	1	Sensitive Drop threshold. Expect rare false trips.
					1	0	Hi drop threshold. Trip only with large drops.
				0	X	X	One pulse per drop, longer pulses for bigger drops
				1			Multiple pulses per larger drop

The RG-11 may also provide drop detection. Use this if you want to do your own, external data interpretation. The output will pulse once with each detected drop. Normally, it will produce longer pulses (in multiples of 200 mS) for larger drops. If set to multiple pulses per drop (SW 3 ON), each detected drop will generate one or more 100 mS pulses, depending on drop size.

In sensitive mode, the threshold for drop detection is lowered to below the normal level. This makes the system more sensitive, but raises the possibility of false detections. It is up to the system designer to determine the proper tradeoff. Similarly, the Hi drop threshold will provide an output only for large drops, making false detections unlikely, for installations were a false detection is especially objectionable.

Mode 7: First Flush / Rain Water Harvest
Rain Gauge output on means rain water is being harvested and first flush has occurred.

Switch								Behavior		
8	7	6	5	4	3	2	1	Level (in)	Gallons	Clean Time (days)
0	1	1	1	X	0	0	0	0.02	12	3
					0	0	1	0.04	25	5
					0	1	0	0.08	50	9
					0	1	1	0.16	100	13
					1	0	0	0.20	125	15
					1	0	1	0.24	150	17
					1	1	0	0.28	175	19
					1	1	1	0.32	200	21
				0	X	X	X	Normal Clean Time		
				1				Gets Dirty Fast		

Note: Switch 8 must be off for this mode.

The RG-11 can be used in a Rain Water Harvest / First Flush application. In this mode, the RG-11 will not change the relay state until a certain amount of water has fallen. After a certain amount of water has been detected, the relay opens, diverting the water to a proper holding tank. So configured, the output relay acts as an "Enable Harvest" control, indicating that at least the desired amount of rainfall has accumulated.

Level
The amount of water that will accumulate before the relay closes.

Gallons
The number of gallons per thousand square feet of collected area that are diverted. Note that a conventional first flush diverter system totalizes water after it has made it through the collection system. The RG-11 enables the system as soon as the threshold has fallen, which may be substantially sooner. Take this into account when designing your system.

Clean Time
After the rainstorm is over and the relay of the RG-11 is once again open, it will take some time for the collecting surface to become dirty again, and once again require a complete first flush. Clean time means how many days, after the water stopped, it takes for the system to require a full flush. Up to that time, the system will flush less. For example, a system is set to flush 0.08 of accumulation, and thus the clean time is 8 days. If a storm comes after only 4 days, the system will flush only half as much water before enabling harvest again.

Gets Dirty Fast = Switch 4 ON
If switch 4 is on, the system remains enabled for only 12 hours after the rain storm stops. Also, the Clean Time is halved. Use this setting if the surface becomes contaminated especially quickly.

SAFETY, LIMITS OF RAIN GAUGE LIABILITY, AND WARRANTY

Only the rain sensor is covered-- absolutely no consequential damages. If this policy is unacceptable in your installation, do not use the RG-11.

It is the responsibility of the systems integrator and purchaser of the Rain Gauge to insure a safe installation. Any mechanical system, including one that incorporates a Rain Gauge, requires appropriate safety interlocks. Hydreon Corporation (Hydreon) warrants only the actual cost of the sensor, and only that it is free from defects in workmanship.

The Rain Gauge is warranted to be free from defects for a period of one year from date of purchase. Under no circumstances will Hydreon be liable for any consequential damages due to failure or any other mishap involving a Rain Gauge. Hydreon's liability in the event of a failure, or inability to sense a condition, is limited to the actual cost of the particular sensor. Explicitly, if other objects are destroyed due to water damage, or if any object is destroyed because of a false indication of water, Hydreon is in no way whatsoever liable for anything other than the cost of the Rain Gauge, and then only if the Rain Gauge is shown to have some defect in materials or workmanship. Limitations and imperfections of the Rain Gauge do not constitute a defect. Further, if some valuable data is not gathered because an erroneous indication of any sort due to the Rain Gauge, Hydreon is liable only for the cost of the Rain Gauge.

It is the responsibility of the system designer and purchasers of the Rain Gauge to insure that a failure of the Rain Gauge will not cause consequential damages. If a failure in Rain Gauge would cause disaster, we recommend against deployment of the Rain Gauge, or against the system in which the Rain Gauge is deployed. If a failure of a Rain Gauge would cause great expense, Hydreon recommends redundant Rain Gauges, and even in that case do not assume any liability for consequential damages. It is the responsibility of the system designer and purchasers of the Rain Gauge to be aware of performance limitations of the device. If a Rain Gauge fails for any reason Hydreon will not be responsible for the labor of servicing and or installing and/or removing the Rain Gauge. Labor is NOT COVERED. Transportation of the suspected failed Rain Gauge to Hydreon is the responsibility of the purchaser. Hydreon recommends that the system designer perform a Failure-Mode Effects Analysis that includes the possibility of Rain Gauge failure. If a potential purchaser of the Rain Gauge does not agree with these terms, we ask that the potential purchaser not buy the Rain Gauge. Deployment of the Rain Gauge implies understanding and agreeing to these limits of liability.

Apply engineering judgment: Hydreon does not claim the RG-11 is a perfect rain sensor. It is what it is, and senses what it senses.

CASE and COSMETIC POLICY
Some amount of yellowing or discoloration of the case is considered normal cosmetic aging of the device, and sensors so affect will not be replaced under warranty. Tiny cracks or crazing within the lens is also considered cosmetic, and units so affected will be replaced only if they are deemed by Hydreon corporation to be considered to be of a functional nature.