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## Appendix A - ATmega88 Automotive Automotive specification at 150°C

This document contains information specific to devices operating at temperatures up to 150°C. Only deviations are covered in this appendix, all other information can be found in the complete Automotive datasheet. The complete Automotive datasheet can be found on [www.atmel.com](http://www.atmel.com)



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**8-bit AVR<sup>®</sup>  
Microcontroller  
with 8K Bytes  
In-System  
Programmable  
Flash**

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**ATmega88  
Automotive**

**Appendix A**

**PRELIMINARY**

7607D-AVR-03/07



## Electrical Characteristics

### Absolute Maximum Ratings\*

Operating Temperature.....	-55°C to +150°C
Storage Temperature .....	-65°C to +175°C
Voltage on any Pin except $\overline{\text{RESET}}$ with respect to Ground .....	-0.5V to $V_{CC}+0.5V$
Voltage on $\overline{\text{RESET}}$ with respect to Ground.....	-0.5V to +13.0V
Maximum Operating Voltage .....	6.0V
DC Current per I/O Pin .....	30.0 mA
DC Current $V_{CC}$ and GND Pins.....	200.0 mA

\*NOTICE: Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### DC Characteristics

$T_A = -40^\circ\text{C}$  to  $150^\circ\text{C}$ ,  $V_{CC} = 2.7V$  to  $5.5V$  (unless otherwise noted)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
$V_{IL}$	Input Low Voltage, except XTAL1 and $\overline{\text{RESET}}$ pin	$V_{CC} = 2.7V - 5.5V$	-0.5		$0.3V_{CC}^{(1)}$	V
$V_{IH}$	Input High Voltage, except XTAL1 and $\overline{\text{RESET}}$ pins	$V_{CC} = 2.7V - 5.5V$	$0.6V_{CC}^{(2)}$		$V_{CC} + 0.5$	V
$V_{IL1}$	Input Low Voltage, XTAL1 pin	$V_{CC} = 2.7V - 5.5V$	-0.5		$0.1V_{CC}^{(1)}$	V
$V_{IH1}$	Input High Voltage, XTAL1 pin	$V_{CC} = 2.7V - 5.5V$	$0.7V_{CC}^{(2)}$		$V_{CC} + 0.5$	V
$V_{IL2}$	Input Low Voltage, $\overline{\text{RESET}}$ pin	$V_{CC} = 2.7V - 5.5V$	-0.5		$0.2V_{CC}^{(1)}$	V
$V_{IH2}$	Input High Voltage, $\overline{\text{RESET}}$ pin	$V_{CC} = 2.7V - 5.5V$	$0.9V_{CC}^{(2)}$		$V_{CC} + 0.5$	V
$V_{IL3}$	Input Low Voltage, $\overline{\text{RESET}}$ pin as I/O	$V_{CC} = 2.7V - 5.5V$	-0.5		$0.3V_{CC}^{(1)}$	V
$V_{IH3}$	Input High Voltage, $\overline{\text{RESET}}$ pin as I/O	$V_{CC} = 2.7V - 5.5V$	$0.6V_{CC}^{(2)}$		$V_{CC} + 0.5$	V
$V_{OL}$	Output Low Voltage <sup>(3)</sup> , I/O pin except $\overline{\text{RESET}}$	$I_{OL} = 20\text{mA}$ , $V_{CC} = 5V$ $I_{OL} = 5\text{mA}$ , $V_{CC} = 3V$			0.8 0.5	V
$V_{OH}$	Output High Voltage <sup>(4)</sup> , I/O pin except $\overline{\text{RESET}}$	$I_{OH} = -20\text{mA}$ , $V_{CC} = 5V$ $I_{OH} = -10\text{mA}$ , $V_{CC} = 3V$	4.0 2.2			V
$I_{IL}$	Input Leakage Current I/O Pin	$V_{CC} = 5.5V$ , pin low (absolute value)			1	$\mu\text{A}$
$I_{IH}$	Input Leakage Current I/O Pin	$V_{CC} = 5.5V$ , pin high (absolute value)			1	$\mu\text{A}$
$R_{RST}$	Reset Pull-up Resistor		30		60	$k\Omega$
$R_{PU}$	I/O Pin Pull-up Resistor		20		50	$k\Omega$

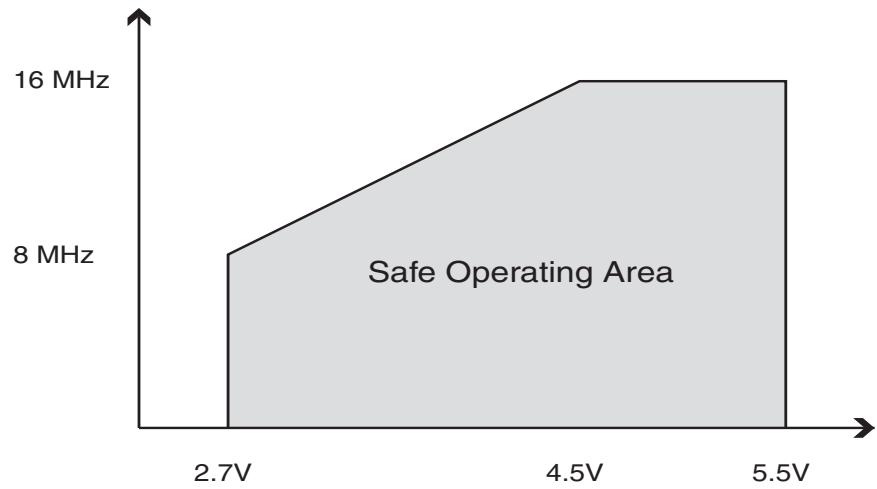
$T_A = -40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ ,  $V_{CC} = 2.7\text{V}$  to  $5.5\text{V}$  (unless otherwise noted) (Continued)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
$I_{CC}$	Power Supply Current <sup>(6)</sup>	Active 4MHz, $V_{CC} = 3\text{V}$ Active 8MHz, $V_{CC} = 5\text{V}$			8 16	mA
$I_{CC\text{ IDLE}}$		Active 16MHz, $V_{CC} = 5\text{V}$			25	mA
		Idle 4MHz, $V_{CC} = 3\text{V}$ Idle 8MHz, $V_{CC} = 5\text{V}$			6 12	mA
		Idle 16MHz, $V_{CC} = 5\text{V}$			14	mA
$I_{CC\text{ PWD}}$	Power-down mode	WDT enabled, $V_{CC} = 3\text{V}$ WDT enabled, $V_{CC} = 5\text{V}$			90 140	$\mu\text{A}$
		WDT disabled, $V_{CC} = 3\text{V}$ WDT disabled, $V_{CC} = 5\text{V}$			80 120	$\mu\text{A}$
$V_{ACIO}$	Analog Comparator Input Offset Voltage	$V_{CC} = 5\text{V}$ $V_{in} = V_{CC}/2$		<10	40	mV
$I_{ACLK}$	Analog Comparator Input Leakage Current	$V_{CC} = 5\text{V}$ $V_{in} = V_{CC}/2$	-50		50	nA
$t_{ACPD}$	Analog Comparator Propagation Delay	$V_{CC} = 4.0\text{V}$		500		ns

## Maximum Speed vs. $V_{CC}$

Maximum frequency is dependent on  $V_{CC}$ . As shown in Figure 131, the Maximum Frequency vs.  $V_{CC}$  curve is linear between  $2.7V < V_{CC} < 4.5V$ .

**Figure 1.** Maximum Frequency vs.  $V_{CC}$



## ADC Characteristics<sup>(6)</sup>

$T_A = -40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ ,  $V_{CC} = 4.5\text{V}$  to  $5.5\text{V}$  (unless otherwise noted)

Symbol	Parameter	Condition	Min	Typ	Max	Units
	Resolution			10		Bits
	Absolute accuracy (Including INL, DNL, quantization error, gain and offset error)	$V_{REF} = 4\text{V}$ , $V_{CC} = 4\text{V}$ , ADC clock = 200 kHz		2	3.5	LSB
		$V_{REF} = 4\text{V}$ , $V_{CC} = 4\text{V}$ , ADC clock = 200 kHz Noise Reduction Mode		2	3.5	LSB
	Integral Non-Linearity (INL)	$V_{REF} = 4\text{V}$ , $V_{CC} = 4\text{V}$ , ADC clock = 200 kHz		0.6	2.5	LSB
	Differential Non-Linearity (DNL)	$V_{REF} = 4\text{V}$ , $V_{CC} = 4\text{V}$ , ADC clock = 200 kHz		0.30	1.0	LSB
	Gain Error	$V_{REF} = 4\text{V}$ , $V_{CC} = 4\text{V}$ , ADC clock = 200 kHz	-3.5	-1.3	3.5	LSB
	Offset Error	$V_{REF} = 4\text{V}$ , $V_{CC} = 4\text{V}$ , ADC clock = 200 kHz		1.8	3.5	LSB
	Conversion Time	Free Running Conversion	13 cycles			$\mu\text{s}$
	Clock Frequency		50		200	kHz
$AV_{CC}$	Analog Supply Voltage		$V_{CC} - 0.3$		$V_{CC} + 0.3$	V
$V_{REF}$	Reference Voltage		1.0		$AV_{CC}$	V
$V_{IN}$	Input Voltage		GND		$V_{REF}$	V
	Input Bandwidth			38.5		kHz
$V_{INT}$	Internal Voltage Reference		1.0	1.1	1.2	V
$R_{REF}$	Reference Input Resistance		25.6	32	38.4	k $\Omega$
$R_{AIN}$	Analog Input Resistance			100		M $\Omega$

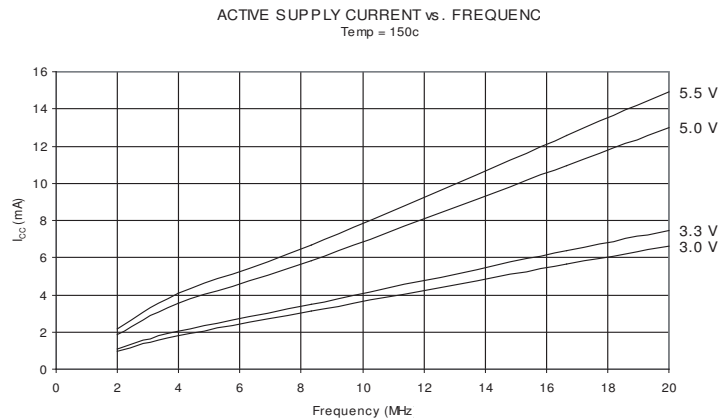
- Notes:
- “Max” means the highest value where the pin is guaranteed to be read as low
  - “Min” means the lowest value where the pin is guaranteed to be read as high
  - Although each I/O port can sink more than the test conditions (20mA at  $V_{CC} = 5\text{V}$ ) under steady state conditions (non-transient), the following must be observed:
    - 1] The sum of all IOL, for all ports, should not exceed 400 mA.
    - 2] The sum of all IOL, for ports C0 - C5, should not exceed 200 mA.
    - 3] The sum of all IOL, for ports C6, D0 - D4, should not exceed 300 mA.
    - 4] The sum of all IOL, for ports B0 - B7, D5 - D7, should not exceed 300 mA.
 If IOL exceeds the test condition, VOL may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test condition.
  - Although each I/O port can source more than the test conditions (20mA at  $V_{CC} = 5\text{V}$ ) under steady state conditions (non-transient), the following must be observed:
    - 1] The sum of all IOH, for all ports, should not exceed 400 mA.
    - 2] The sum of all IOH, for ports C0 - C5, should not exceed 200 mA.
    - 3] The sum of all IOH, for ports C6, D0 - D4, should not exceed 300 mA.
    - 4] The sum of all IOH, for ports B0 - B7, D5 - D7, should not exceed 300 mA.

If IOH exceeds the test condition, VOH may exceed the related specification. Pins are not guaranteed to source current greater than the listed test condition.  
 5. Minimum  $V_{CC}$  for Power-down is 2.5V.

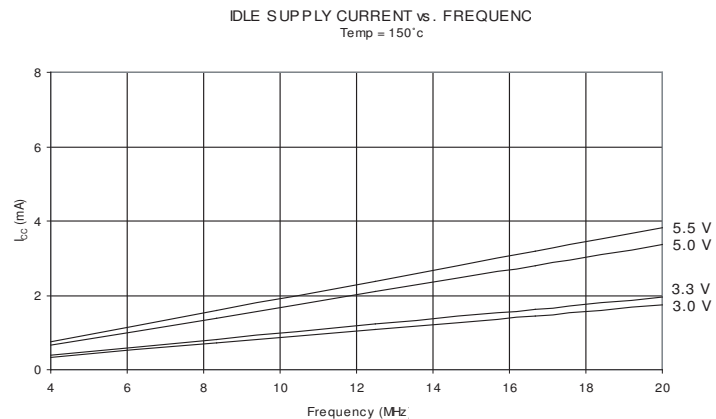
## ATmega88 Automotive Typical Characteristics

### Active Supply Current

**Figure 2.** Active Supply Current vs. Frequency (1 - 20 MHz)

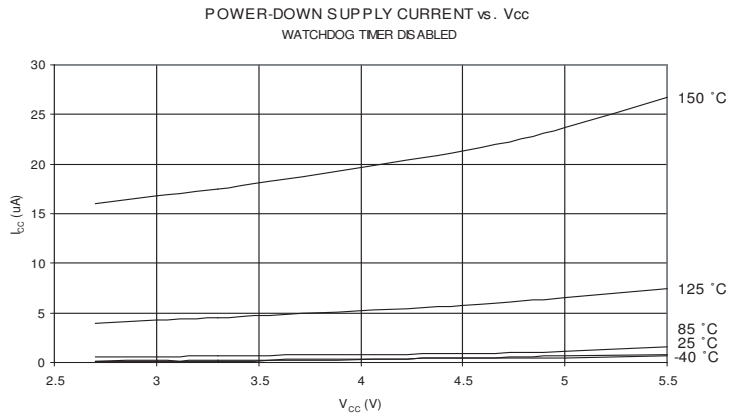


**Figure 3.** Idle Supply Current vs. Frequency (1 - 20 MHz)

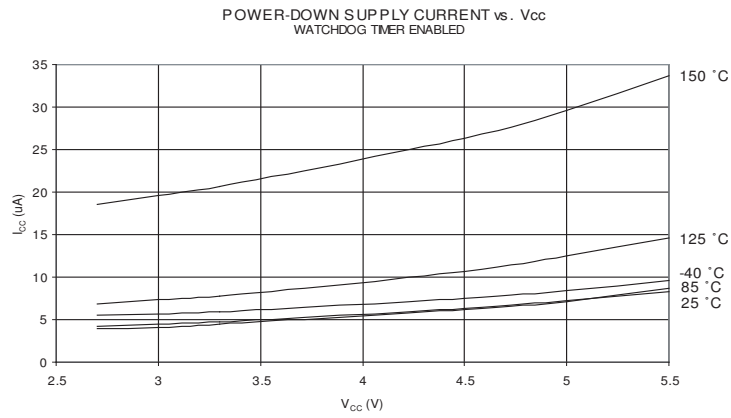


### Power-Down Supply Current

**Figure 4.** Power-Down Supply Current vs.  $V_{CC}$  (Watchdog Timer Disabled)

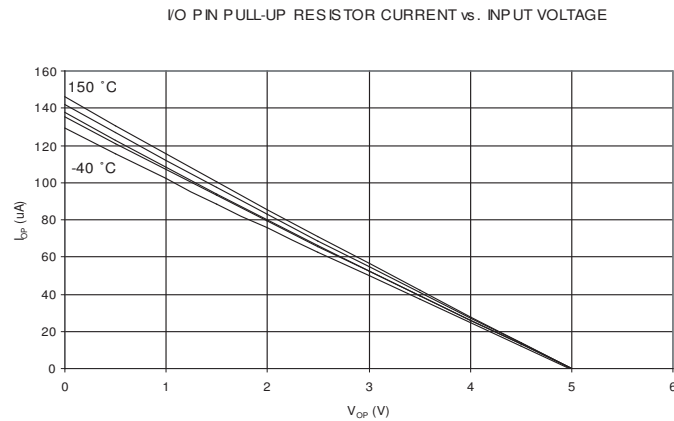


**Figure 5.** Power-Down Supply Current vs.  $V_{CC}$  (Watchdog Timer Enabled)

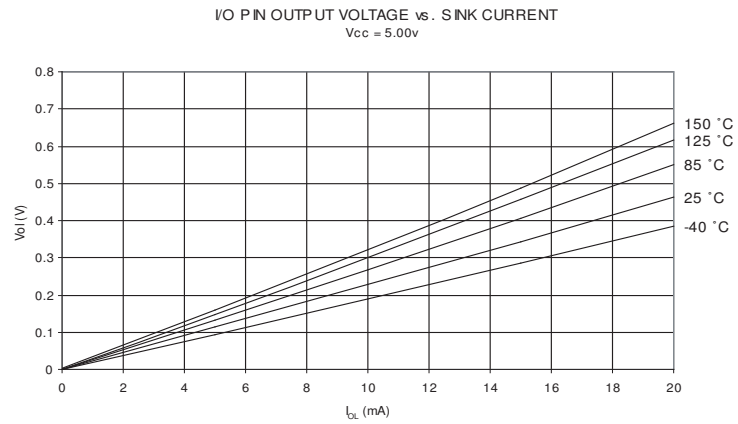


## Pin Pull-up

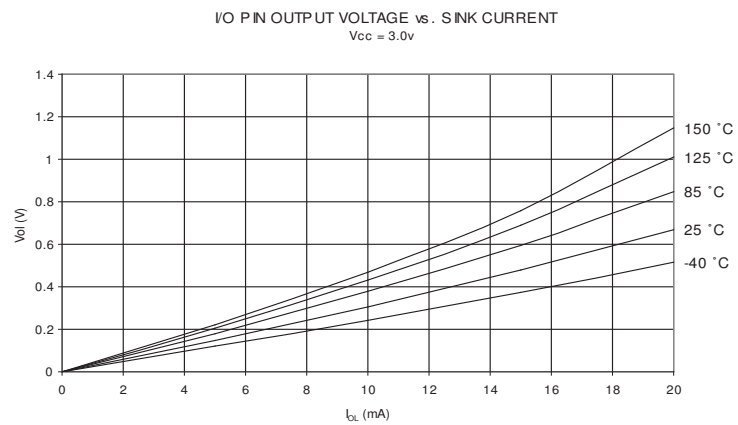
**Figure 6.** I/O Pin Pull-up Resistor Current vs. Input Voltage ( $V_{CC} = 5V$ )



**Figure 7.** Output Low Voltage vs. Output Low Current ( $V_{CC} = 5V$ )

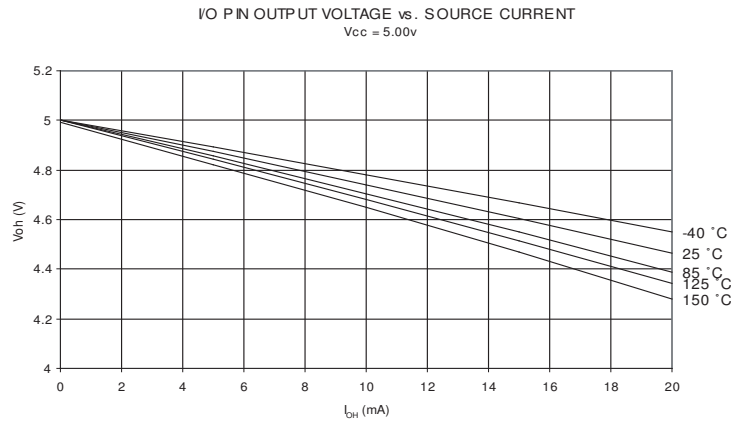


**Figure 8.** Output Low Voltage vs. Output Low Current ( $V_{CC} = 3V$ )

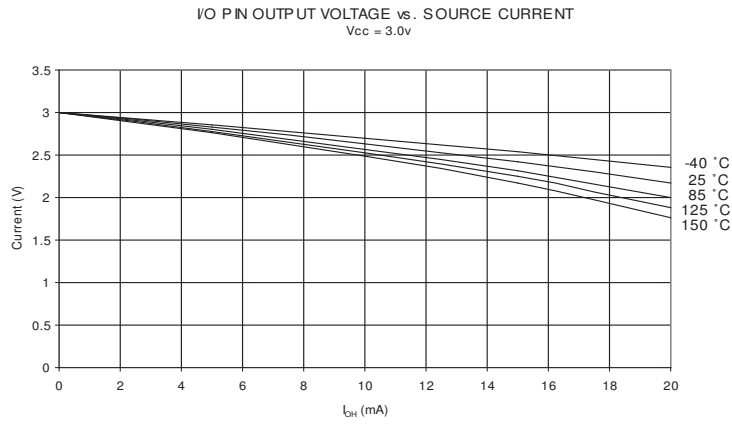


**Figure 9.** Output High Voltage vs. Output High Current ( $V_{CC} = 5V$ )

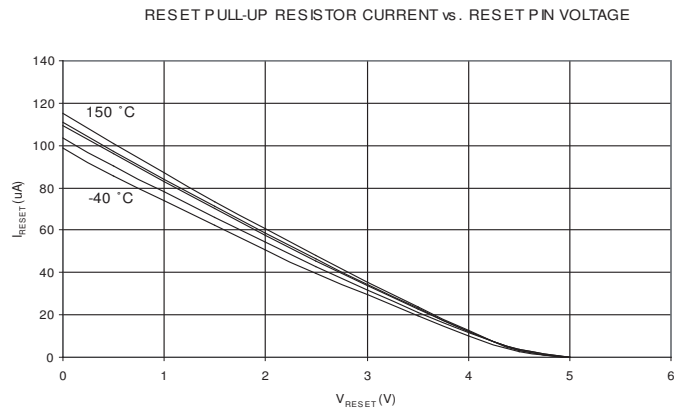




**Figure 10.** Output High Voltage vs. Output High Current (V<sub>CC</sub> = 3V)

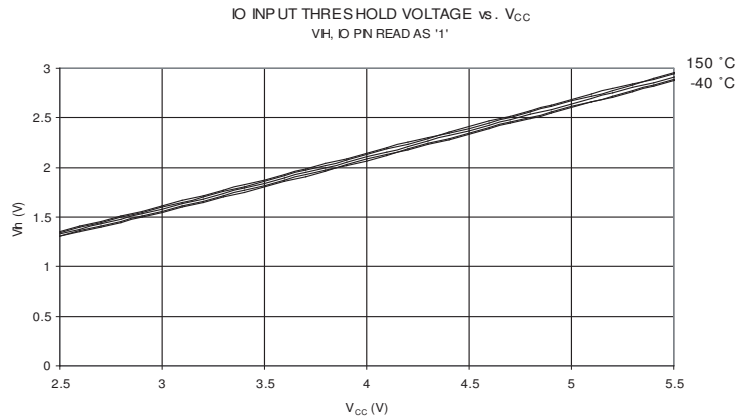


**Figure 11.** Reset Pull-Up Resistor Current vs. Reset Pin Voltage (V<sub>CC</sub> = 5V)

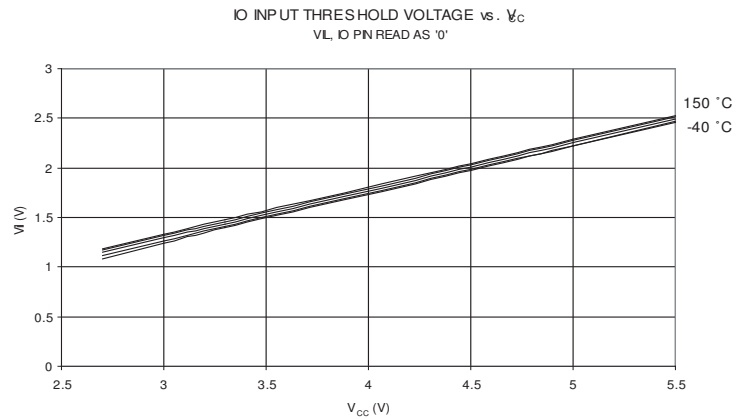


**Pin Thresholds and Hysteresis**

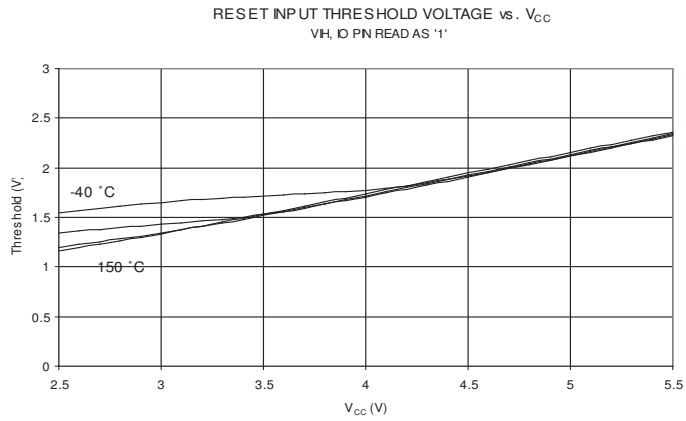
**Figure 12.** I/O Pin Input Threshold vs.  $V_{CC}$  ( $V_{IH}$ , I/O Pin Read as '1')



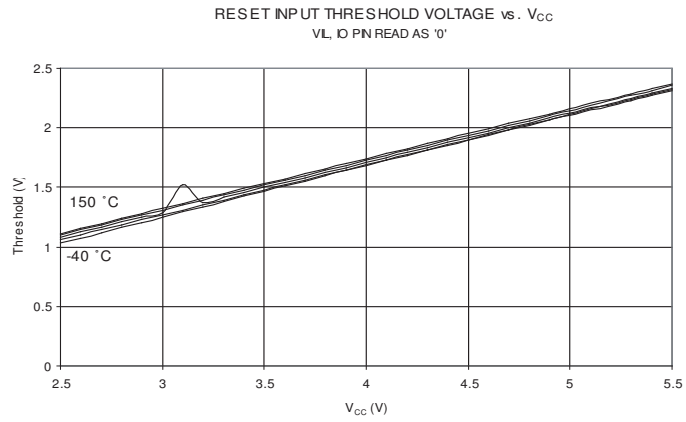
**Figure 13.** I/O Pin Input Threshold vs.  $V_{CC}$  ( $V_{IL}$ , I/O Pin Read as '0')



**Figure 14.** Reset Input Threshold Voltage vs.  $V_{CC}$  ( $V_{IH}$ , Reset Pin Read as '1')



**Figure 15.** Reset Input Threshold Voltage vs.  $V_{CC}$  (VIL, Reset Pin Read as '0')



Internal Oscillator Speed

**Figure 16.** Watchdog Oscillator Frequency vs.  $V_{CC}$

WATCHDOG OSCILLATOR FREQUENCY vs. TEMPERATURE  
V<sub>CC</sub> from 2.7V to 5.5V

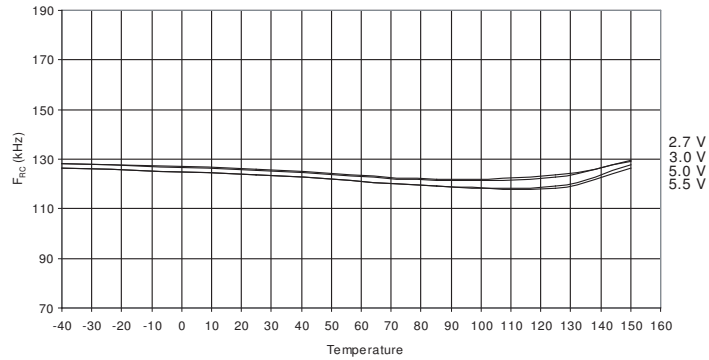


Figure 17. Calibrated 8 MHz RC Oscillator Frequency vs. Temperature

CALIBRATED 8MHz RC OSCILLATOR FREQUENCY vs. TEMPERATURE

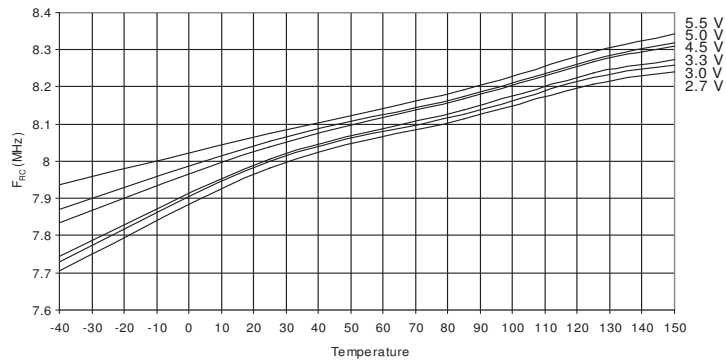
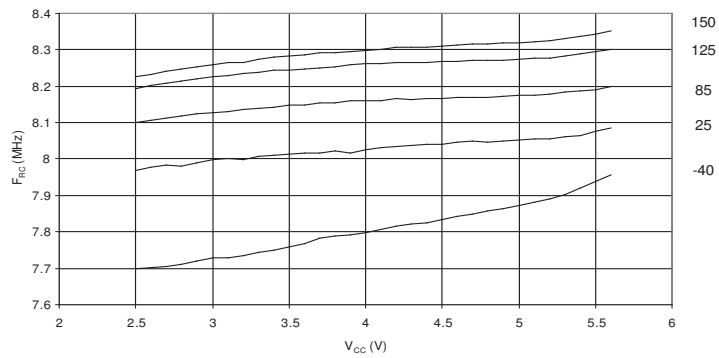
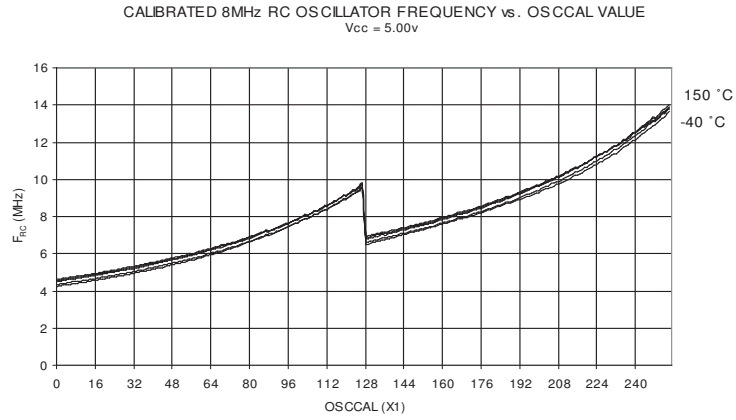


Figure 18. Calibrated 8 MHz RC Oscillator Frequency vs. V<sub>CC</sub>

CALIBRATED 8MHz RC OSCILLATOR FREQUENCY vs. OPERATING VOLTAGE

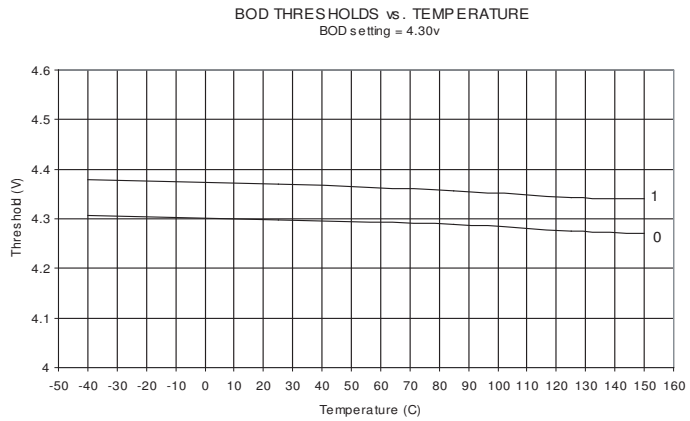


**Figure 19.** Calibrated 8 MHz RC Oscillator Frequency vs. OSCCAL Value

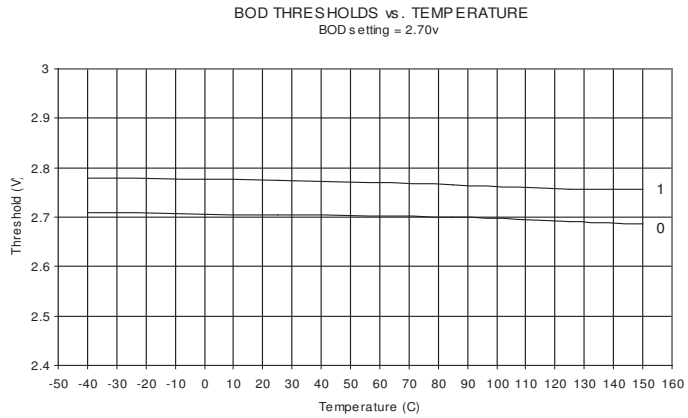


**BOD Thresholds and Analog Comparator Offset**

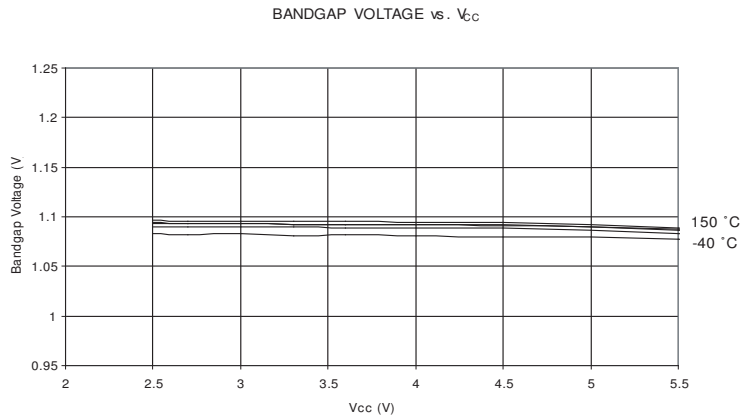
**Figure 20.** BOD Threshold vs. Temperature (BODLEVEL is 4.0V)



**Figure 21.** BOD Threshold vs. Temperature (BODLEVEL is 2.7V)

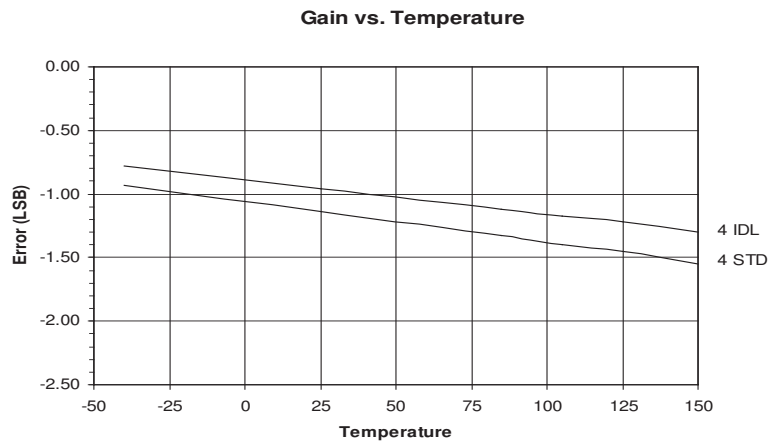


**Figure 22.** Bandgap Voltage vs.  $V_{CC}$

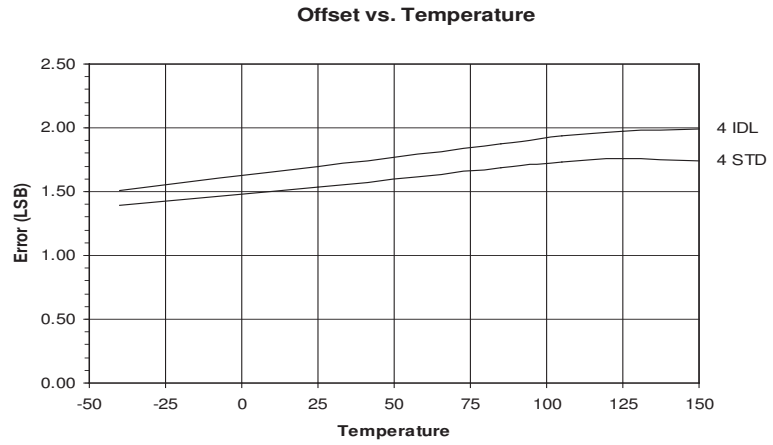


**Peripheral Units**

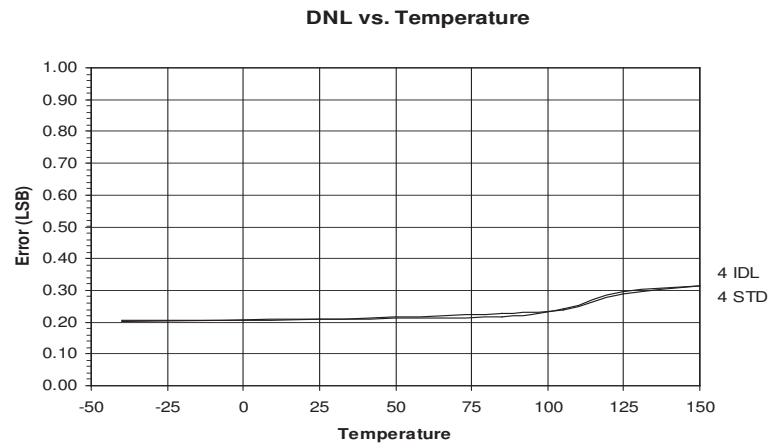
**Figure 23.** Analog to Digital Converter GAIN vs.  $V_{CC}$



**Figure 24.** Analog to Digital Converter OFFSET vs.  $V_{CC}$

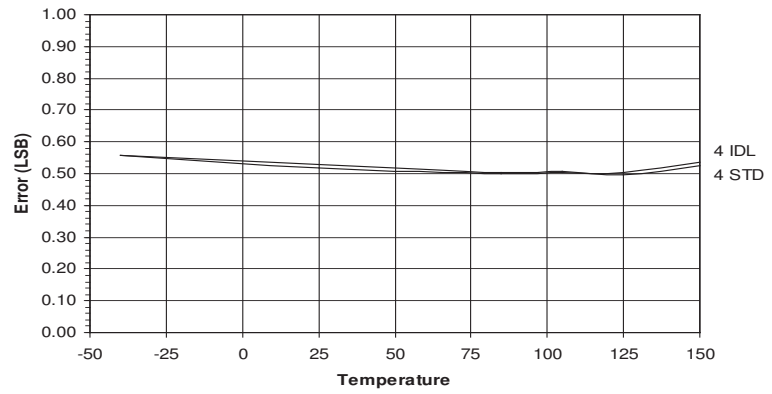


**Figure 25.** Analog to Digital Converter DNL vs.  $V_{CC}$



**Figure 26.** Analog to Digital Converter INL vs.  $V_{CC}$

INL vs. Temperature



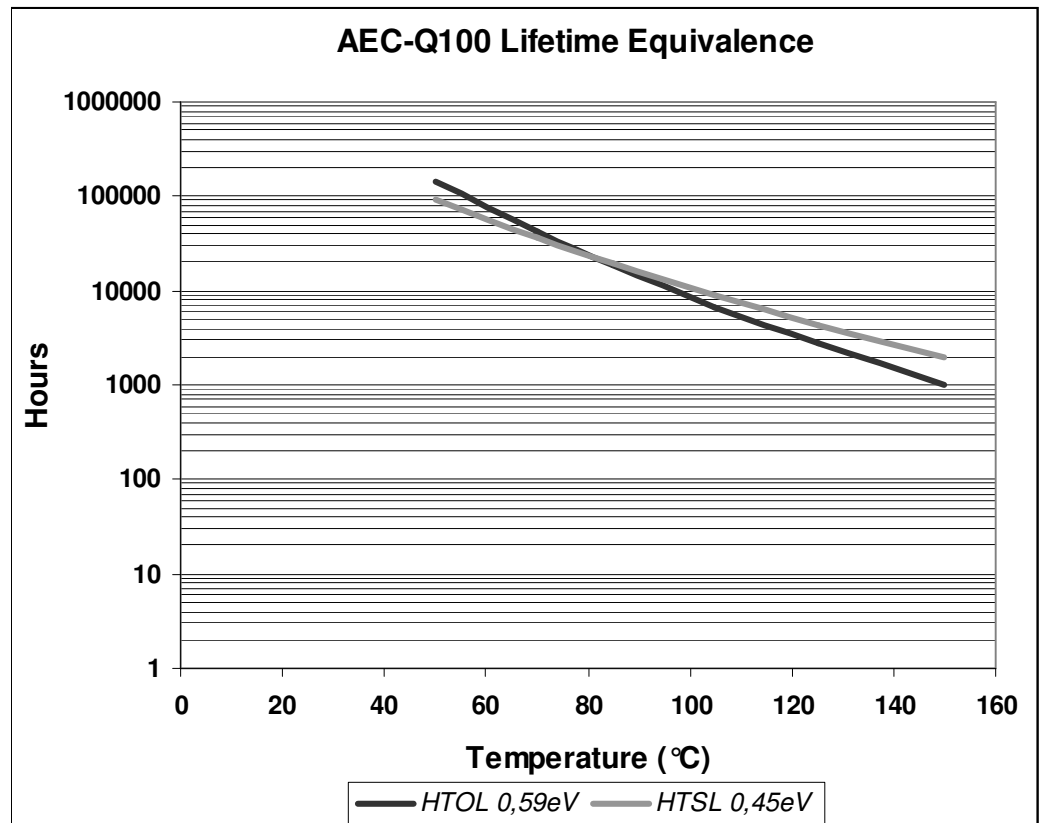


## Grade 0 Qualification

The ATmega88 has been developed and manufactured according to the most stringent quality assurance requirements of ISO-TS-16949 and verified during product qualification as per AEC-Q100 grade 0.

AEC-Q100 qualification relies on temperature accelerated stress testing. High temperature field usage however may result in less significant stress test acceleration. In order to prevent the risk that ATmega88 lifetime would not satisfy the application end-of-life reliability requirements, Atmel has extended the testing, whenever applicable (High Temperature Operating Life Test, High Temperature Storage Life, Data Retention, Thermal Cycles), far beyond the AEC-Q100 requirements. Thereby, Atmel verified the ATmega88 has a long safe lifetime period after the grade 0 qualification acceptance limits.

The valid domain calculation depends on the activation energy of the potential failure mechanism that is considered. Examples are given in figure 1. Therefore any temperature mission profile which could exceed the AEC-Q100 equivalence domain shall be submitted to Atmel for a thorough reliability analysis





## Ordering Information

### ATmega88 Automotive

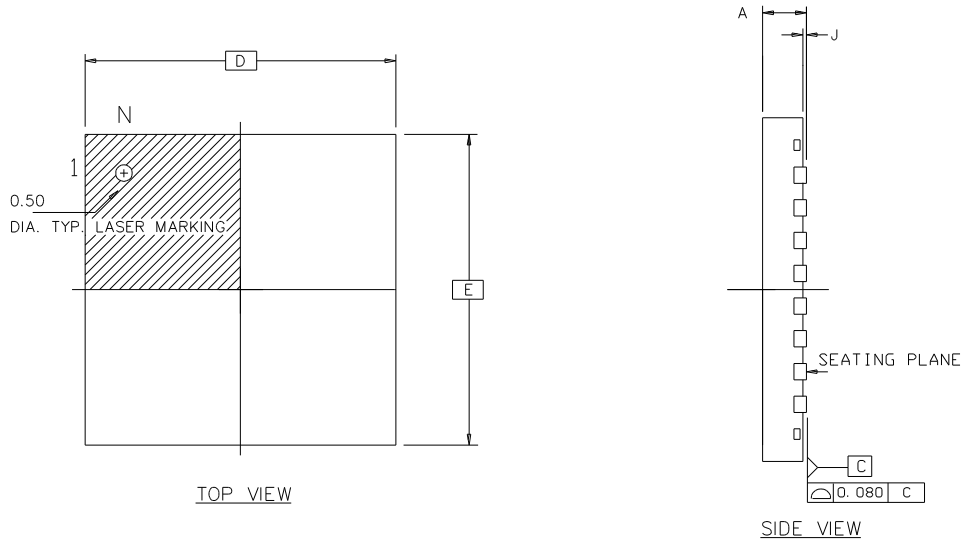
Speed (MHz)	Power Supply	Ordering Code	Package <sup>(1)</sup>	Operation Range
16 <sup>(2)</sup>	2.7 - 5.5V	ATmega88-15MT2	PN	Extended (-40°C to 150°C)

Notes: 1. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.  
2. For Speed vs.  $V_{CC}$ , see complete datasheet.

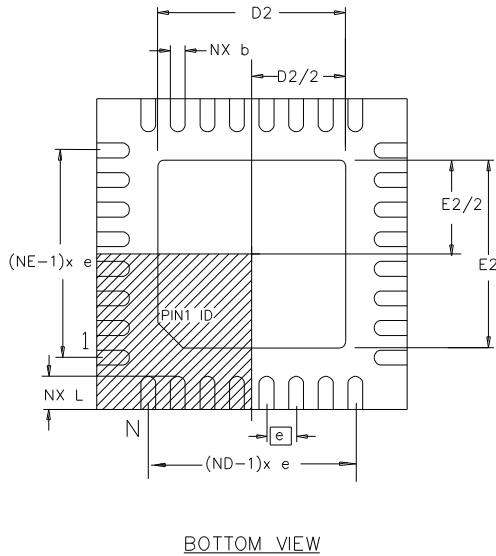
Package Type	
PN	32-pad, 5 x 5 x 1.0 mm body, lead pitch 0.50 mm, Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF): E2/D2 3.1 +/- 0.1mm

PN

32 LEADS Quad Flat No lead



DRAWINGS NOT SCALED



	MM			INCH		
	MIN	NDM	MAX	MIN	NDM	MAX
A	0.80	-	1.00	.032	-	.040
J	0.00		0.05	.000		.002
D/E	5.00 +/-	0.10		.197 +/-		.004
D2/E2	*	*	*	-	-	-
N	32					
ND	8					
NE	8					
e	0.50 BSC			.020 BSC		
L	0.30	0.40	0.50	.012	.016	.020
b	0.18	0.25	0.30	.007	.010	.012

\*See Package Information

Compliant JEDEC Standard MO-220 variation VHHD-2



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44306 Nantes Cedex 3, France  
Tel: (33) 2-40-18-18-18  
Fax: (33) 2-40-18-19-60

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13106 Rousset Cedex, France  
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Fax: (33) 4-42-53-60-01

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Fax: 1(719) 540-1759

Scottish Enterprise Technology Park  
Maxwell Building  
East Kilbride G75 0QR, Scotland  
Tel: (44) 1355-803-000  
Fax: (44) 1355-242-743

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74025 Heilbronn, Germany  
Tel: (49) 71-31-67-0  
Fax: (49) 71-31-67-2340

1150 East Cheyenne Mtn. Blvd.  
Colorado Springs, CO 80906, USA  
Tel: 1(719) 576-3300  
Fax: 1(719) 540-1759

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38521 Saint-Egreve Cedex, France  
Tel: (33) 4-76-58-30-00  
Fax: (33) 4-76-58-34-80

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