

General Description

The AAT4290 and AAT4291 SmartSwitch products are members of AnalogicTech's Application Specific Power MOSFET™ (ASPM™) product family. The AAT4290 and AAT4291 are five and three P-channel MOSFETs, respectively, configured for use as a microprocessor I/O expander. Having independent drain outputs and a common source input, they operate with an input voltage ranging from 1.8V to 5.5V, making them ideal for 2.5V, 3.3V, or 5V systems, as well as systems powered by lithium-ion/polymer batteries. Each switch features a 500ns turn-on time. The switch states are controlled by AnalogicTech's Simple Serial Control™ (S²Cwire™) interface which permits ease of control and efficiency of size. The quiescent supply current is very low, typically 5μA. In shutdown mode, the supply current is reduced to less than 1μA.

The AAT4290 and AAT4291 are offered in a Pb-free, 8-pin SC70JW package specified over the -40°C to +85°C temperature range.

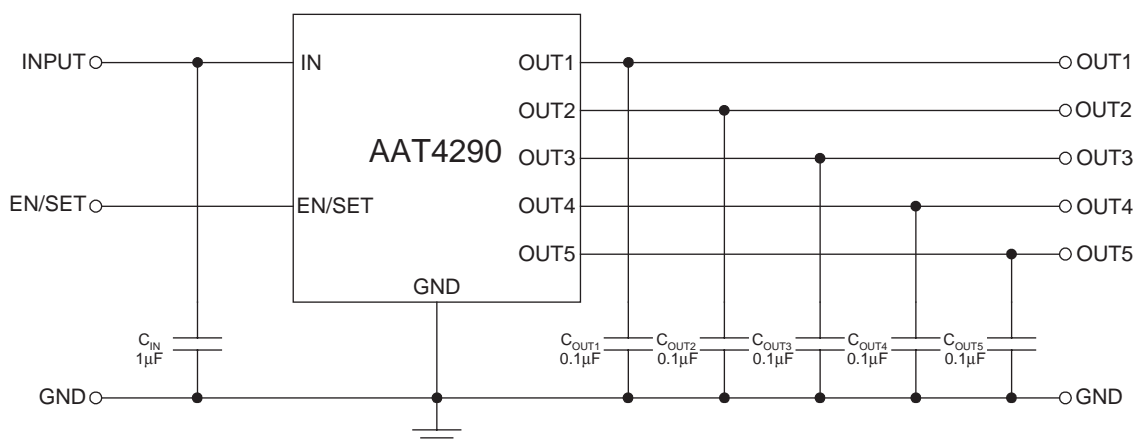
Features

- 1.8V to 5.5V Input Voltage Range
- 5 or 3 Independent Load Switches
- S²Cwire Interface
- 1.1Ω R_{DS(ON)} Per Switch
- Low Quiescent Current
 - 5μA
 - 0.1μA in Shutdown
- -40°C to +85°C Temperature Range
- 8-Pin SC70JW Package

Applications

- Cell Phones
- I/O Expansion
- Multiple Low Power Switching
- Personal Communication Devices
- Portable Electronic Devices

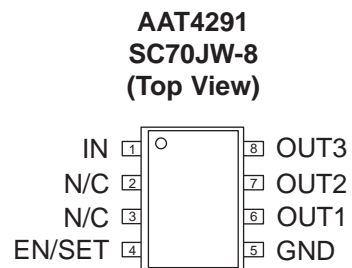
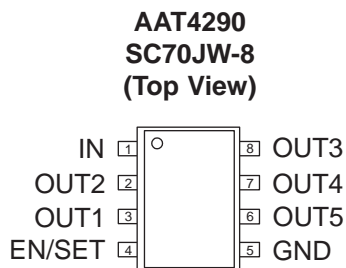
Typical Application



Pin Descriptions

| Pin # | | Symbol | Function |
|---------|---------|--------|--|
| AAT4290 | AAT4291 | | |
| 1 | 1 | IN | Input power supply is connected to the P-channel MOSFET sources. Connect a 1 μ F capacitor from IN to GND. |
| 2 | 7 | OUT2 | P-channel MOSFET drain. |
| 3 | 6 | OUT1 | P-channel MOSFET drain. |
| 4 | 4 | EN/SET | Input control pin using S ² Cwire serial interface. The device records rising edges of the clock and decodes them into 32 states (8 states for AAT4291) which controls the ON/OFF states of the MOSFETs. See Table 1 and Table 2 for output settings. |
| 5 | 5 | GND | Ground connection. |
| 6 | N/A | OUT5 | P-channel MOSFET drain. |
| 7 | N/A | OUT4 | P-channel MOSFET drain. |
| 8 | 8 | OUT3 | P-channel MOSFET drain. |
| N/A | 2, 3 | N/C | Not connected. |

Pin Configuration



Absolute Maximum Ratings¹

| Symbol | Description | Value | Units |
|---------------|-----------------------------------|------------------------|-------|
| V_{IN} | IN to GND | -0.3 to 6.0 | V |
| V_{OUT} | OUT to GND | -0.3 to $V_{IN} + 0.3$ | V |
| $V_{EN/SET}$ | EN/SET to GND | -0.3 to 6.0 | V |
| I_{MAX} | Maximum Continuous Switch Current | 250 | mA |
| $T_{STORAGE}$ | Storage Temperature Range | -65 to 150 | °C |
| V_{ESD} | ESD Rating - HBM ² | 4000 | V |

Thermal Characteristics

| Symbol | Description | Value | Units |
|---------------|---|-------|-------|
| θ_{JA} | Thermal Resistance ³ | 225 | °C/W |
| P_D | Maximum Power Dissipation ($T_A = 25^\circ\text{C}$) ⁴ | 440 | mW |

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum Rating should be applied at any one time.
2. Human body model is a 100pF capacitor discharged through a 1.5kΩ resistor to each pin.
3. Mounted on the board.
4. Derate 4.4mW/°C above 25°C.

Electrical Characteristics

$V_{IN} = 5.0V$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted. Typical values are $T_A = 25^{\circ}C$.

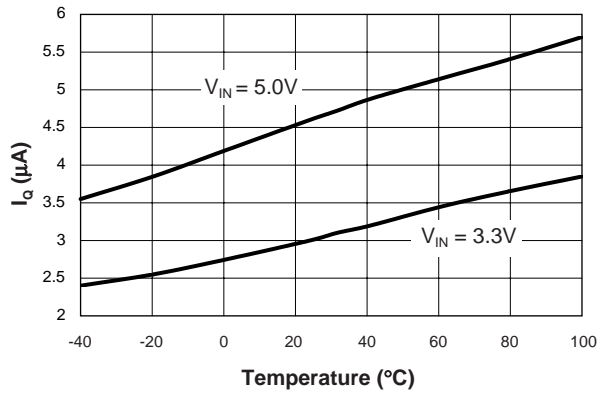
| Symbol | Description | Conditions | Min | Typ | Max | Units |
|--------------------------------|---------------------------------------|---|-----|------|-----|-----------------|
| V_{IN} | Operation Voltage | | 1.8 | | 5.5 | V |
| I_Q | Quiescent Current | $V_{IN} = 5.5V$, EN/SET = V_{IN} , $I_{OUT} = 0$, All Switches ON | | 4.5 | 8 | μA |
| $I_{Q(OFF)}$ | Off Supply Current | EN/SET = 0, $V_{IN} = 5.5V$, V_{OUT} Open | | | 1 | μA |
| $I_{SD(OFF)}$ | Off Switch Current | EN/SET = 0, $V_{IN} = 5.5V$, $V_{OUTn} = 0$ | | 0.1 | 1 | μA |
| V_{UVLO} | Under-Voltage Lockout | V_{IN} Falling | | 1.2 | | V |
| $V_{UVLO(hys)}$ | Under-Voltage Lockout Hysteresis | | | 250 | | mV |
| $R_{DS(ON)}$ | On Resistance | $V_{IN} = 1.8V$, $T_A = 25^{\circ}C$ | | 2.5 | 3.8 | Ω |
| | | $V_{IN} = 3.0V$, $T_A = 25^{\circ}C$ | | 1.5 | 2.2 | |
| | | $V_{IN} = 4.2V$, $T_A = 25^{\circ}C$ | | 1.2 | 1.8 | |
| | | $V_{IN} = 5.0V$, $T_A = 25^{\circ}C$ | | 1.1 | 1.7 | |
| T_{CRDS} | On Resistance Temperature Coefficient | | | 2800 | | ppm $^{\circ}C$ |
| AAT4290-1 and AAT4291-1 | | | | | | |
| $T_{D(ON)}$ | Output Turn-On Delay Time | $V_{IN} = 5V$, $R_{LOAD} = 500\Omega$, $C_{OUT} = 0.1\mu F$ | | 40 | | ns |
| T_R | Turn-On Rise Time | $V_{IN} = 5V$, $R_{LOAD} = 500\Omega$, $C_{OUT} = 0.1\mu F$ | | 270 | | ns |
| $T_{D(OFF)}$ | Turn-Off Delay Time | $V_{IN} = 5V$, $R_{LOAD} = 500\Omega$ | | 40 | | ns |
| EN/SET | | | | | | |
| $V_{EN(L)}$ | Enable Threshold Low | $V_{IN} = 1.8V$ | | | 0.4 | V |
| $V_{EN(H)}$ | Enable Threshold High | $V_{IN} = 5.5V$ | 1.6 | | | V |
| T_{LO} | EN/SET Low Time | $V_{EN/SET} < 0.4V$ | 100 | | | ns |
| T_{HI} | Minimum EN/SET High Time | $V_{IN} \leq 2.5V$ | | | 500 | ns |
| | | $V_{IN} > 2.5V$ | | | 250 | |
| T_O | EN/SET Off Timeout | | | 2.6 | 4.0 | μs |
| T_{LAT} | EN/SET Latch Timeout | | | 2.6 | 4.0 | μs |
| I_{SINK} | EN/SET Input Leakage | $V_{EN/SET} = 5.5V$ | | 0.01 | 1 | μA |

1. The AAT4290/91 is guaranteed to meet performance specifications over the $-40^{\circ}C$ to $+85^{\circ}C$ operating temperature range and is assured by design, characterization, and correlation with statistical process controls.

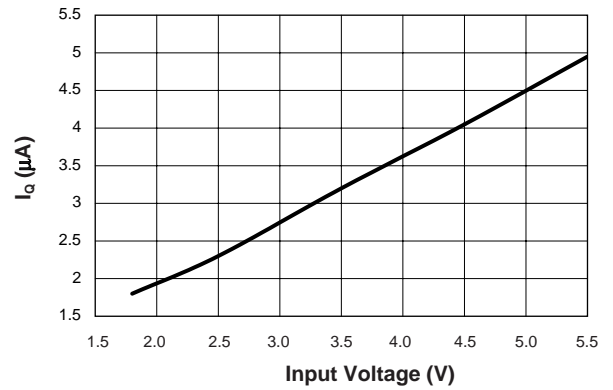
Typical Characteristics

Unless otherwise noted, $V_{IN} = 5V$, $C_{IN} = 1\mu F$, $C_{OUTX} = 0.1\mu F$, $T_A = 25^\circ C$.

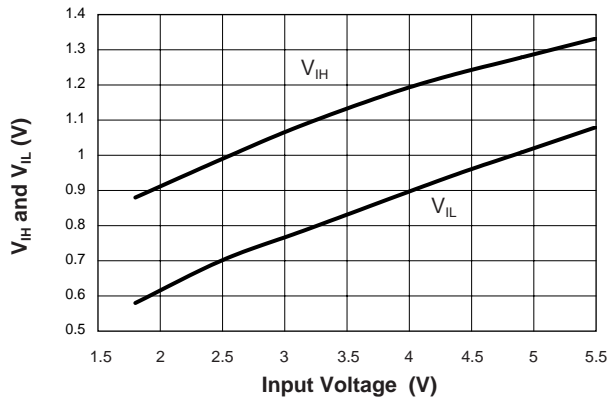
Quiescent Current vs. Temperature



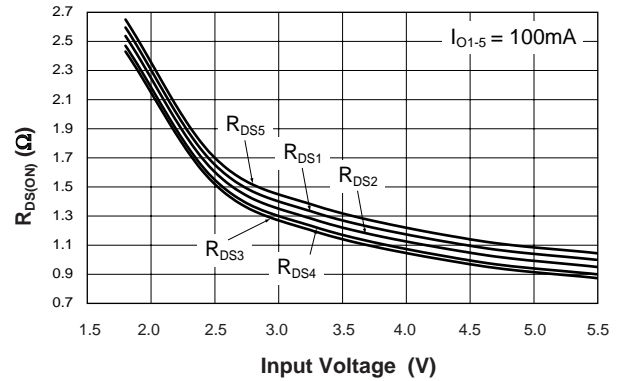
Quiescent Current vs. Input Voltage



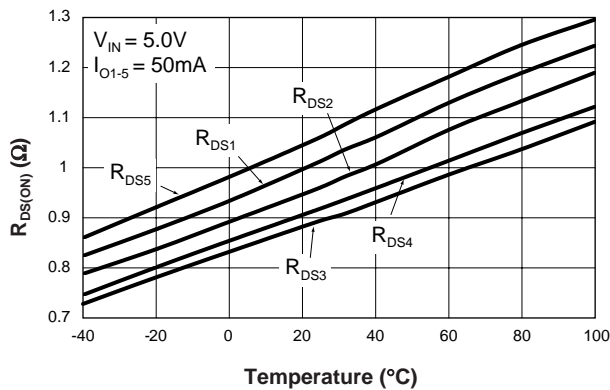
V_{IH} and V_{IL} vs. Input Voltage



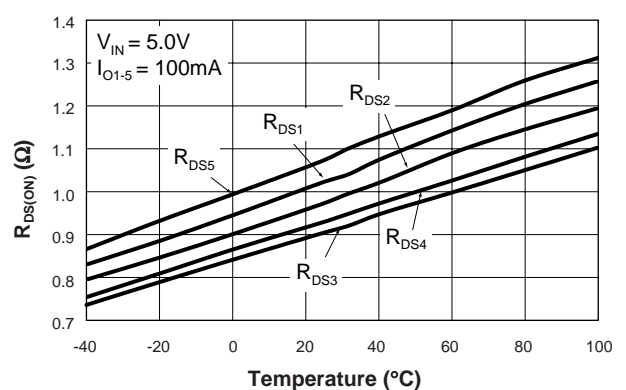
$R_{DS(ON)}$ vs. Input Voltage



$R_{DS(ON)}$ vs. Temperature



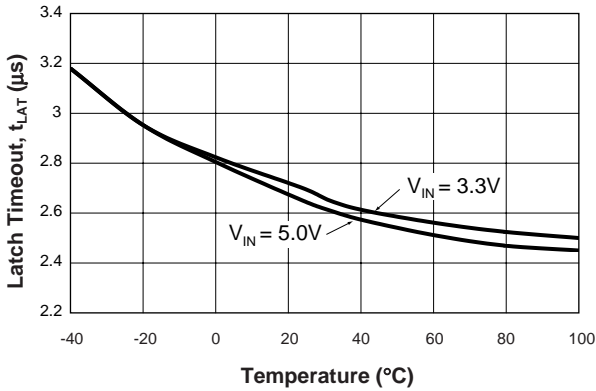
$R_{DS(ON)}$ vs. Temperature



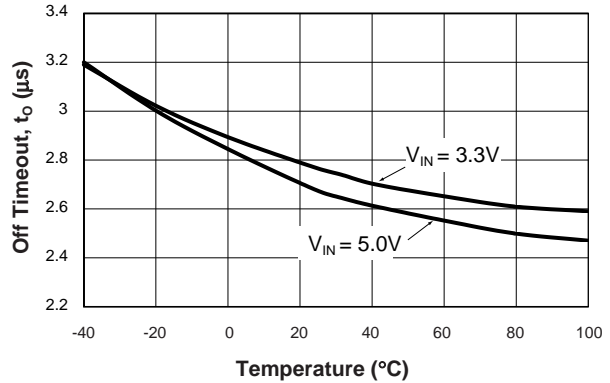
Typical Characteristics

Unless otherwise noted, $V_{IN} = 5V$, $C_{IN} = 1\mu F$, $C_{OUTX} = 0.1\mu F$, $T_A = 25^\circ C$.

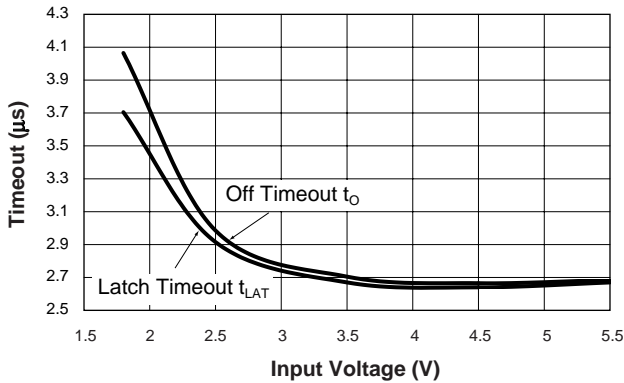
EN/SET Latch Timeout vs. Temperature



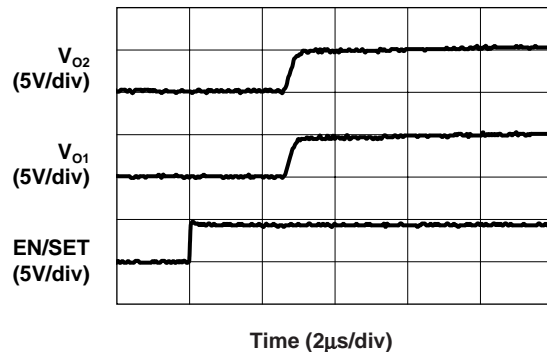
EN/SET Off Timeout vs. Temperature



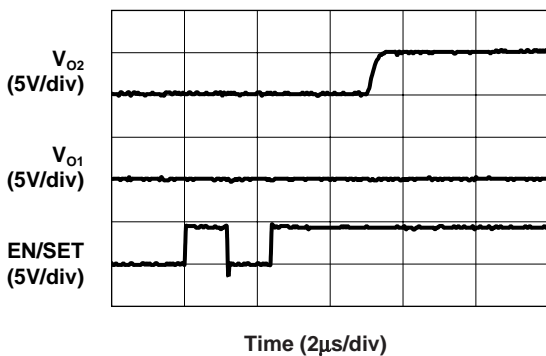
EN/SET Timeout vs. Input Voltage



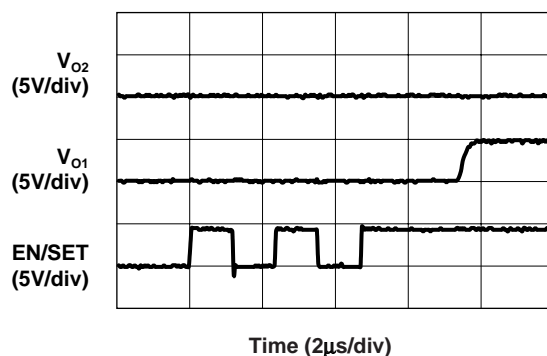
Turn-On Characteristic
($V_{IN} = 5V$, $R_{L1} = R_{L2} = 50\Omega$; $C_{O1} = C_{O2} = 0.1\mu F$)



Turn-On Characteristic
($V_{IN} = 5V$; $R_{L1} = R_{L2} = 50\Omega$; $C_{O1} = C_{O2} = 0.1\mu F$)



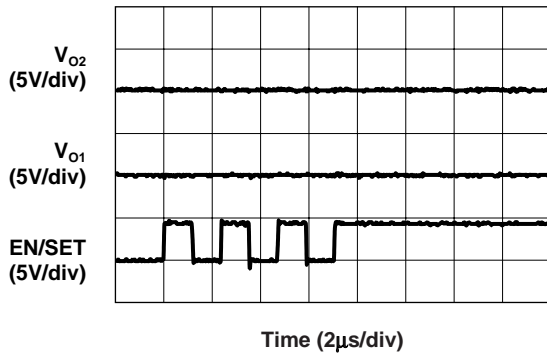
Turn-On Characteristic
($V_{IN} = 5V$; $R_{L1} = R_{L2} = 50\Omega$; $C_{O1} = C_{O2} = 0.1\mu F$)



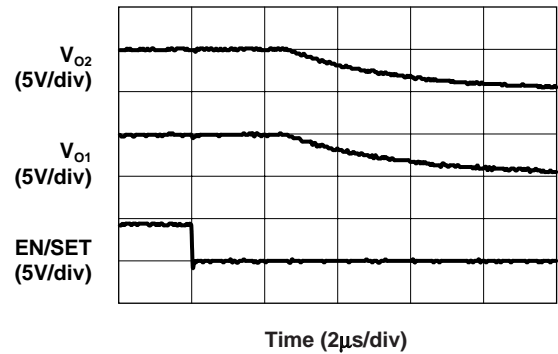
Typical Characteristics

Unless otherwise noted, $V_{IN} = 5V$, $C_{IN} = 1\mu F$, $C_{OUTX} = 0.1\mu F$, $T_A = 25^\circ C$.

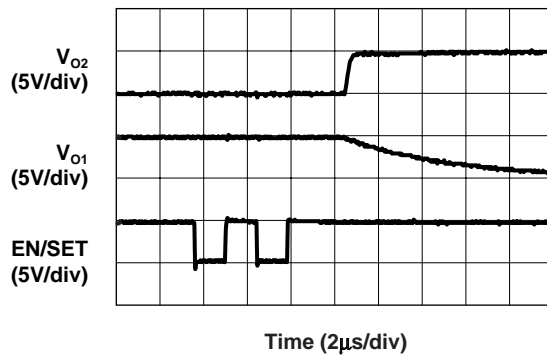
Turn-On Characteristic
 $(V_{IN} = 5V; R_{L1} = R_{L2} = 50\Omega; C_{O1} = C_{O2} = 0.1\mu F)$



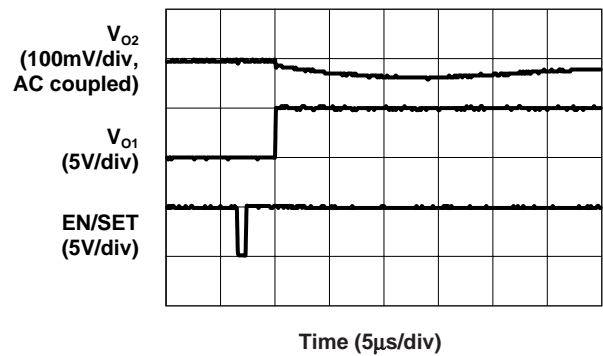
Turn-Off Characteristic
 $(V_{IN} = 5V; R_{L1} = R_{L2} = 50\Omega; C_{O1} = C_{O2} = 0.1\mu F)$



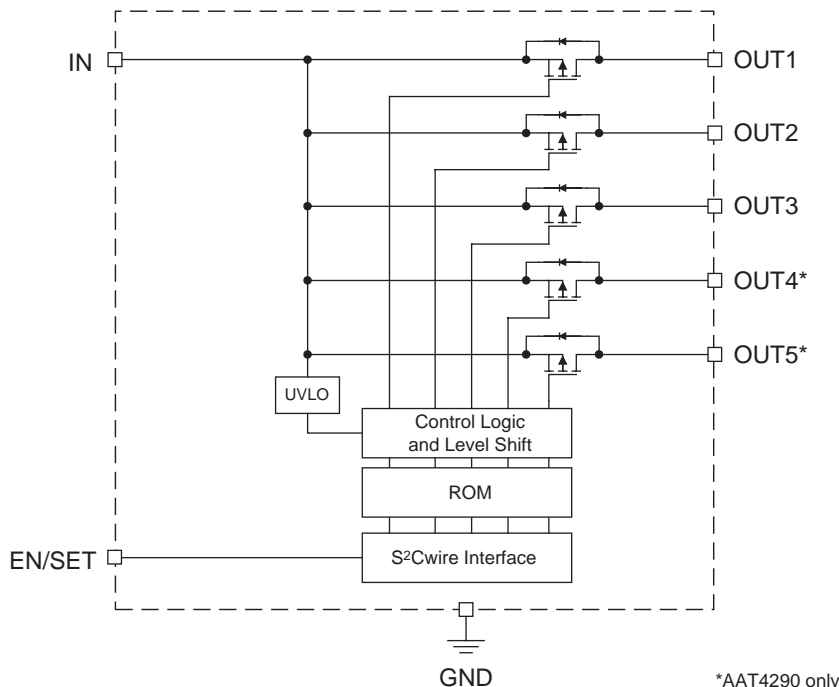
Transition of Outputs
 $(V_{IN} = 5V; R_{L1} = R_{L2} = 50\Omega; C_{O1} = C_{O2} = 0.1\mu F)$



Turn-On Transient Characteristic
 $(V_{IN} = 5V; R_{L1} = R_{L2} = 50\Omega)$



Functional Block Diagram



Functional Description

The AAT4290 consists of five P-channel MOSFET power switches designed for I/O expansion applications. The AAT4291 has all of the features offered in the AAT4290, but integrates three switches instead of five. It operates with input voltages ranging from 1.8V to 5.5V which, along with its extremely low operating current, makes it ideal for battery-powered applications. In cases where the input voltage drops below 1.8V, the AAT4290 MOSFETs are protected from entering the linear region of operation by automatically shutting down. In addition, the TTL-compatible EN/SET pin makes the AAT4290 an ideal level-shifted load switch. An optional slew rate controlling feature eliminates inrush current when a MOSFET is turned on, allowing the AAT4290 to be implemented with a small input capacitor or no capacitor at all, while maintaining isolation between channels. During slewing, the current ramps linearly until it reaches the level required for the output load condition. The proprietary control method works by careful control

and monitoring of the MOSFET gate voltage. When the device is switched ON, the gate voltage is quickly increased to the threshold level of the MOSFET. Once at this level, the current begins to slew as the gate voltage is slowly increased until the MOSFET becomes fully enhanced. Once it has reached this point, the gate is quickly increased to the full input voltage and $R_{DS(ON)}$ is minimized.

The ON/OFF state of the five MOSFET switches are controlled by the EN/SET serial data input. An internal control counter is clocked on the rising edge of the EN/SET pin and is decoded into the 32 possible states of the MOSFET (see Table 1). The counter rolls over after 32 clocks and the table repeats. The counter can be clocked at speeds up to 1MHz, but the count value is not latched until clocking has stopped and the EN/SET pin has remained high for approximately 2.6 μ s. The first rising edge of EN/SET enables the AAT4290 and is counted as the first clock. To change states, additional low going clock pulses may be asserted on the EN/SET pin with the resulting change taking

effect after the EN/SET pin has remained in a high state for T_{LAT} . The AAT4290 is disabled after the EN/SET pin has transitioned and remained in a logic low state for T_O .

| Clock | OUT5 | OUT4 | OUT3 | OUT2 | OUT1 |
|-------|------|------|------|------|------|
| 1 | on | on | on | on | on |
| 2 | on | on | on | on | off |
| 3 | on | on | on | off | on |
| 4 | on | on | on | off | off |
| 5 | on | on | off | on | on |
| 6 | on | on | off | on | off |
| 7 | on | on | off | off | on |
| 8 | on | on | off | off | off |
| 9 | on | off | on | on | on |
| 10 | on | off | on | on | off |
| 11 | on | off | on | off | on |
| 12 | on | off | on | off | off |
| 13 | on | off | off | on | on |
| 14 | on | off | off | on | off |
| 15 | on | off | off | off | on |
| 16 | on | off | off | off | off |
| 17 | off | on | on | on | on |
| 18 | off | on | on | on | off |
| 19 | off | on | on | off | on |
| 20 | off | on | on | off | off |
| 21 | off | on | off | on | on |
| 22 | off | on | off | on | off |
| 23 | off | on | off | off | on |
| 24 | off | on | off | off | off |
| 25 | off | off | on | on | on |
| 26 | off | off | on | on | off |
| 27 | off | off | on | off | on |
| 28 | off | off | on | off | off |
| 29 | off | off | off | on | on |
| 30 | off | off | off | on | off |
| 31 | off | off | off | off | on |
| 32 | off | off | off | off | off |

Table 1: AAT4290 Output Settings.

With the exception of three channel power switches, the AAT4291 has a similar function to the AAT4290. The ON/OFF state of the three MOSFET switches are controlled by the EN/SET serial data input. An internal control counter is clocked on the rising edge of the EN/SET pin and is decoded into the eight possible states of the MOSFET (see Table 2). The counter rolls over after eight clocks and the table repeats.

| Clock | OUT3 | OUT2 | OUT1 |
|-------|------|------|------|
| 1 | on | on | on |
| 2 | on | on | off |
| 3 | on | off | on |
| 4 | on | off | off |
| 5 | off | on | on |
| 6 | off | on | off |
| 7 | off | off | on |
| 8 | off | off | off |

Table 2: AAT4291 Output Settings.

Applications Information

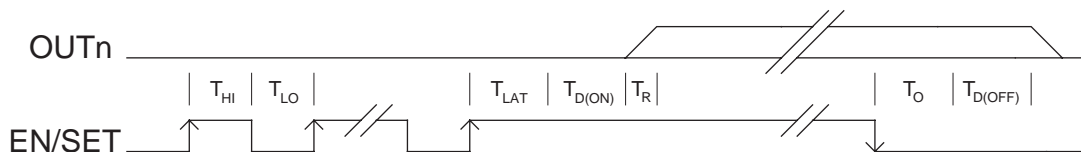
Thermal Considerations

The AAT4290 is designed to deliver continuous output load currents. Due to its high level of integration, care must be taken in designing for higher load conditions. If greater loads are required, outputs can be tied together to deliver higher power to a given load.

At 25°C ambient, the AAT4290 is capable of dissipating 440mW of power, or 1.14A at 5.0V, for an average current of 228mA per output.

At 85°C ambient, the AAT4290 is capable of dissipating 178mW of power, or 0.72A at 5.0V, for an average current of 145mA per output.

Timing Diagram



Output Sequencing

If output sequencing is not necessary, then all of the outputs will be switched on simultaneously on the first rising edge of the EN/SET pin. However, if output sequencing is desired, then a series of pulses on the EN/SET pin will accomplish this. Each time a new group of pulses is asserted on EN/SET, the AAT4290/91 internal control is reset. For example,

to sequence the outputs in order from OUT5 to OUT1, five clocks bursts are input on the EN/SET pin. From Table 1, the first burst of 16 clocks turns on OUT5. A following burst of 8 clocks (as the counter resets) will add OUT4, followed by 4 clocks to add OUT3, 2 clocks to add OUT2, and 1 clock to add OUT1. Likewise, the outputs can be turned off in any order by adding more clock bursts.

Applications Circuits

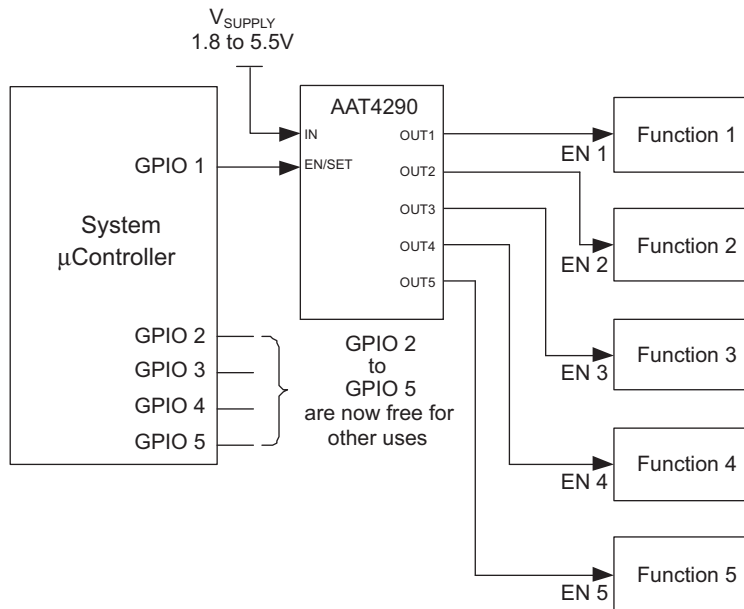


Figure 1: GPIO I/O Expander
(condense five GPIO control lines to one).

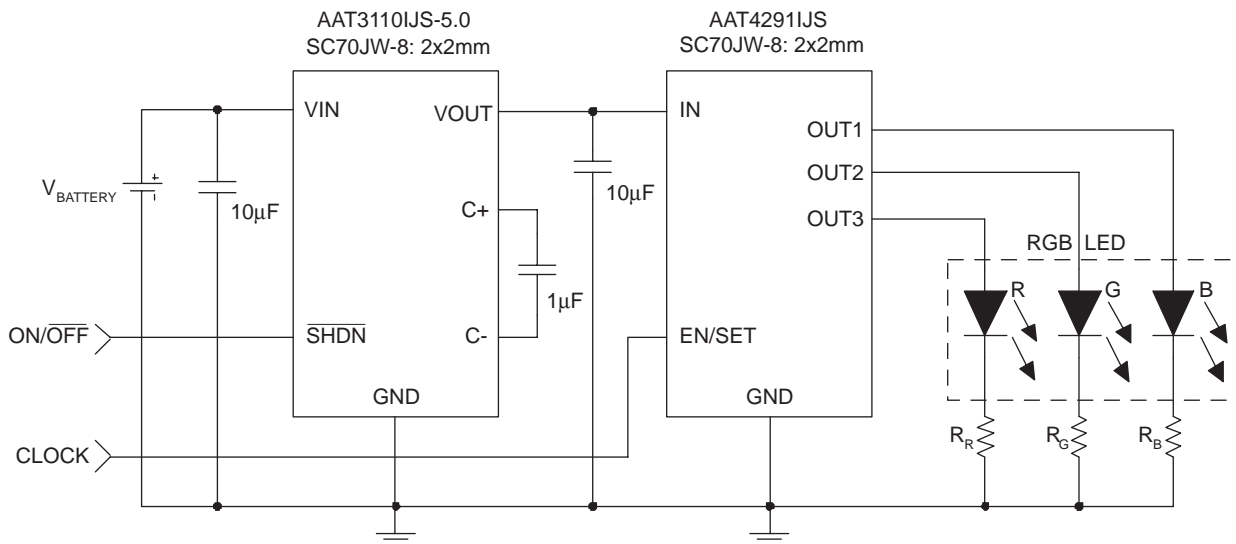


Figure 2: RGB LED Control
(eliminates three discrete MOSFET switches).

Ordering Information

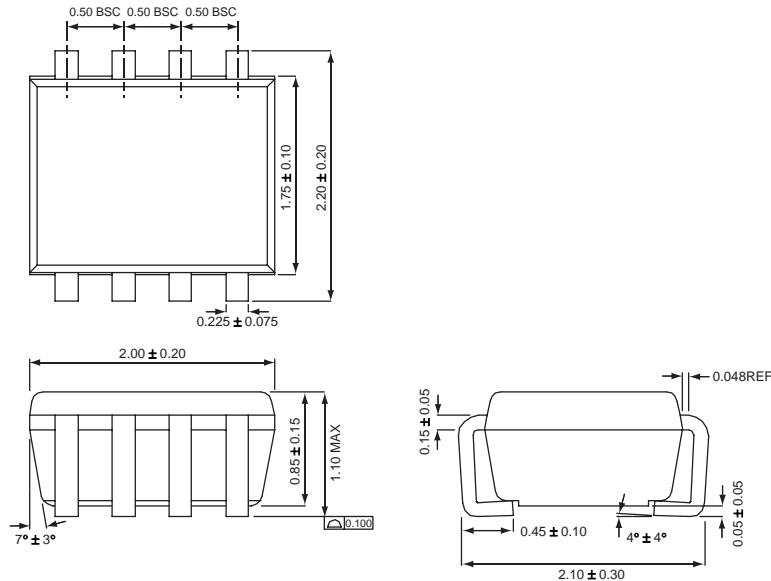
| Package | Marking ¹ | Part Number (Tape and Reel) ² |
|----------|----------------------|--|
| SC70JW-8 | HSXYY | AAT4290IJS-1-T1 |
| SC70JW-8 | HCXYY | AAT4291IJS-1-T1 |



All AnalogicTech products are offered in Pb-free packaging. The term “Pb-free” means semiconductor products that are in compliance with current RoHS standards, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. For more information, please visit our website at <http://www.analogictech.com/pbfree>.

Package Information

SC70JW-8



All dimensions in millimeters.

1. XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.

© Advanced Analogic Technologies, Inc.

AnalogicTech cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in an AnalogicTech product. No circuit patent licenses, copyrights, mask work rights, or other intellectual property rights are implied. AnalogicTech reserves the right to make changes to their products or specifications or to discontinue any product or service without notice. Customers are advised to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability. AnalogicTech warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with AnalogicTech's standard warranty. Testing and other quality control techniques are utilized to the extent AnalogicTech deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed.

Advanced Analogic Technologies, Inc.
 830 E. Arques Avenue, Sunnyvale, CA 94085
 Phone (408) 737-4600
 Fax (408) 737-4611