



AP9211

#### SINGLE CHIP SOLUTION FOR 1-CELL Li+ BATTERY PACK

### **Description**

The AP9211 is a single chip protection solution specially designed for 1-cell Li+ rechargeable battery pack application.

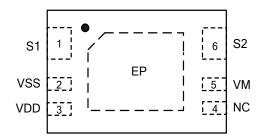
The AP9211 includes a 1-cell Lithium ion battery protection chip and dual N-CH MOSFET with common drain.

The AP9211 provides rich battery protection features and can turn-off the N-CH MOSFET by detecting overcharge voltage/current, over discharge voltage/current, or load short circuit. The AP9211 has built-in fixed delay time to save external components.

The AP9211 is available in U-DFN2030-6 (Type C) package.

### Pin Assignments

#### (Top View)



U-DFN2030-6 (Type C)

### **Features**

- High Voltage CMOS Process, up to 30V (VDD to VM)
- Low Quiescent Current (+25°C)
- In Normal Mode, 3.0μA (Typ.), 4.5μA (Max.) V<sub>DD</sub> = 3.5V
- In Power-Down Mode, 0.1µA (Max.)
- High-Accuracy Voltage Detection Circuit (+25°C)
- Overcharge Detection Voltage: 3.5V to 4.5V (5mV Steps)
   Accuracy ±25mV
- Overcharge Hysteresis Voltage Range: 0.1V to 0.4V (50mV Steps) Accuracy ±50mV
- Overdischarge Detection Voltage: 2.0V to 3.4V (10mV Steps) Accuracy ±35mV
- Overdischarge Hysteresis Voltage Range: 0V to 0.7V (40mV Steps) Accuracy ±65mV
- Discharge Overcurrent Detection Voltage: 0.05V to 0.32V (10mV Steps) Accuracy ±15mV
- Short Current Detection Voltage: 0.45V to 0.7V (50mV Steps) Accuracy ±100mV
- Charge Overcurrent Detection Voltage: -0.2V to -0.05V (10mV Steps) Accuracy ±15mV
- Overcharger Detection Voltage: 8.0V (Fixed) Accuracy ±2V
- Overcharger Release Voltage: 7.3V (Fixed) Accuracy ±2V
- Built-in Fixed Detection Delay Time (+25°C), Accuracy ±20%
- Power-Down Mode Selectable (Yes or No)
- 0V Battery Charge Selectable (Permission or Inhibition)
- Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)
- Halogen and Antimony Free. "Green" Device (Note 3)
- For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/

## **Applications**

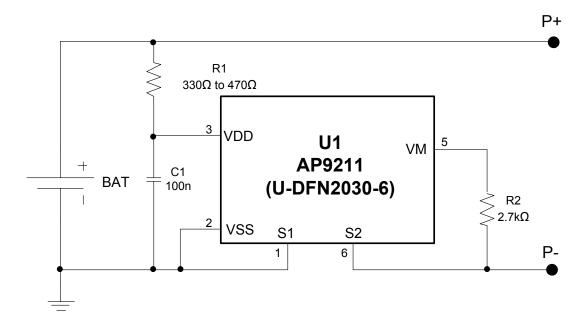
Li+ Rechargeable Battery Pack

Notes:

- 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
- 2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
- 3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.



## **Typical Applications Circuit** (Note 4)



Note: 4. R1 and C1 are used to stabilize the supply voltage of the AP9211. The recommended range of R1 value is 330Ω to 470Ω and C1 value is 10nF to 1000nF, typical value is 100nF. R2 should be connected between P- to V<sub>M</sub> sense terminal to monitor the status of charger and the charge/discharge current. The R2 should be between 300Ω and 4kΩ, typical value is 2.7kΩ. R1 and R2 are also used as current limit resistors if the battery or charger is connected reversely. Polarity reversing may cause the power consumption of R1 and R2 to go over their power dissipation rating, therefore, R1 and R2 values should be selected appropriately for the actual application. If R2 is more than 4kΩ resistor, charge may not be off due to the voltage drop on R2.

For power down mode, when first connecting AP9211 system board to the battery, it is necessary to use charger or to short P- to the battery negative polarity. Once the AP9211 is activated, the charger or connection can be removed, otherwise the battery cannot discharge current through system board.

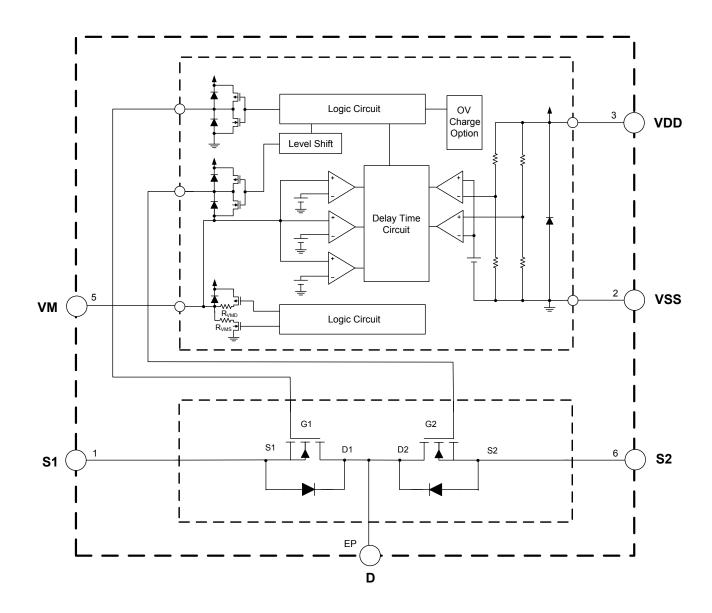
The values selected should follow the recommended typical range mentioned above. It has not been confirmed whether the operation is normal or not in circuits other than the above example of connection. In addition, the example of connection shown above and the typical value do not exactly guarantee proper operation. Please perform the actual application to set the suitable value through your complete evaluation.

### **Pin Descriptions**

Pin Number	Pin Name	Function	
1	S1	Source pin of discharging MOSFET, connecting this pin to battery negative pole.	
2	VSS	Negative power supply pin	
3	VDD	Positive power supply pin, connecting this pin to battery positive pole through R1	
4	NC	Not connected, leave this pin floating	
5	VM	Charger negative input pin, short this pin to S2 pin through R2	
6	S2	Source pin of charging MOSFET, connecting this pin to charge negative input.	
EP	D	Thermal PAD is common drain of charge and discharge MOSFET, so in PCB layout, prefer to use large copper area to cover this pad for better thermal dissipation, then leave it open.	



# **Functional Block Diagram**





## Absolute Maximum Ratings (Notes 4 & 5)

Symbol	Parameter	Rating	Unit
V <sub>DS</sub>	Supply Voltage (Between VDD and VSS)	-0.3 to 12	V
V <sub>DM</sub>	Charge Input Voltage (Between VDD and VM for Protection Chip)	-0.3 to 24	V
$V_{DSS}$	MOSFET Drain-to-Source Voltage	24	V
V <sub>GSS</sub>	MOSFET Gate-to-Source Voltage	±12	V
	Continuous Drain Current, V <sub>GS</sub> = 4.5V, T <sub>A</sub> = +25°C	9.0	Α
I <sub>D</sub>	Continuous Drain Current, V <sub>GS</sub> = 4.5V, T <sub>A</sub> = +70°C	7.1	Α
$P_D$	Power Dissipation	1000	mW
TJ	Maximum Junction Temperature	+150	°C
T <sub>STG</sub>	Storage Temperature Range	-65 to +150	°C
_	ESD (Machine Model)	300	V
_	ESD (Human Body Model)	3000	V

Notes: 4. Stresses beyond those listed under *Absolute Maximum Ratings* can cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## **Recommended Operating Conditions**

Symbol	Parameter	Min	Max	Unit
V <sub>DS</sub>	Supply Voltage (Between VDD and VSS)	1.5	5.5	V
$V_{DM}$	Charge Input Voltage (Between VDD and VM)	-0.3	5.5	V
TA	Operating Ambient Temperature	-40	+85	°C

<sup>5.</sup> Ratings apply to ambient temperature at +25°C. The JEDEC High-K board design used to derive this data was a 2 inch x 2 inch multilayer board with 2oz internal power and ground planes and 2oz copper traces on the top and bottom of the board.



# $\textbf{Electrical Characteristics} \ (T_{A} = +25^{\circ}\text{C}, V_{DD} = 3.5\text{V}, V_{SS} = 0\text{V}, R1 = 220\Omega, R2 = 1.0\text{k}\Omega, C1 = 100\text{nF}, unless otherwise specified.})$

Symbol	Parameter	Condition	Min	Тур	Max	Unit
V <sub>CU</sub>	Overcharge Detection Voltage	_	V <sub>CU</sub> - 0.025	V <sub>CU</sub>	V <sub>CU</sub> + 0.025	V
		V <sub>CL</sub> ≠V <sub>CU</sub>	V <sub>CL</sub> - 0.050	V <sub>CL</sub>	V <sub>CL</sub> + 0.050	V
V <sub>CL</sub>	Overcharge Release Voltage	V <sub>CL</sub> = V <sub>CU</sub>	V <sub>CL</sub> - 0.025	V <sub>CL</sub>	V <sub>CL</sub> + 0.025	V
$V_{DL}$	Overdischarge Detection Voltage	_	V <sub>DL</sub> - 0.035	$V_{DL}$	V <sub>DL</sub> + 0.035	V
	Overdischere Beleese Valtere	V <sub>DU</sub> ≠V <sub>DL</sub>	V <sub>DU</sub> - 0.100	V <sub>DU</sub>	V <sub>DU</sub> + 0.100	V
V <sub>DU</sub>	Overdischarge Release Voltage	V <sub>DU</sub> = V <sub>DL</sub>	V <sub>DU</sub> - 0.035	V <sub>DU</sub>	V <sub>DU</sub> + 0.035	V
V <sub>DOC</sub>	Discharge Overcurrent Detection Voltage	_	V <sub>DOC</sub> -0.015	$V_{DOC}$	V <sub>DOC</sub> +0.015	V
V <sub>SHORT</sub>	Load Short-Circuiting Detection Voltage	_	V <sub>SHORT</sub> -0.10	V <sub>SHORT</sub>	V <sub>SHORT</sub> +0.10	٧
V <sub>COC</sub>	Charge Overcurrent Detection Voltage	_	V <sub>COC</sub> -0.015	V <sub>COC</sub>	V <sub>COC</sub> +0.015	V
I <sub>CC</sub> (Power D	own Function)					
Icc	Current Consumption During Operation	V <sub>DD</sub> = 3.5V, V <sub>M</sub> = 0V	_	3.0	4.5	μA
I <sub>PDN</sub>	Current Consumption During Power Down Mode	V <sub>DD</sub> = 1.8V, VM Pin Floating	_	-	0.1	μΑ
I <sub>CC</sub> (Auto-Wa	ake Up Function)					
Icc	Current Consumption During Operation	V <sub>DD</sub> = 3.5V, V <sub>M</sub> = 0V	_	3	4.5	μΑ
I <sub>AUTO</sub>	Current Consumption During Auto-Wake Mode	V <sub>DD</sub> = 1.8V, VM Pin Floating	_	3.5	5.5	μΑ
R <sub>VMD</sub>	Resistance Between VM Pin and VDD Pin	V <sub>DD</sub> =1.8V V <sub>M</sub> =0V	150	300	500	kΩ
R <sub>VMS</sub>	Resistance Between VM Pin and VDD Pin	V <sub>DD</sub> =3.5V V <sub>M</sub> =1.0V	10	30	50	kΩ
V <sub>0CHA</sub>	0V Battery Charge Starting Charge Voltage	0V battery charging "available"	1.2	ı	_	V
Voinh	0V Battery Charge Inhibition Battery Voltage	0V battery charging "unavailable"	_		0.45	V
Vovchg	Overvoltage Charge Detection Voltage	V <sub>DD</sub> =3.5V	6.0	8.0	10.0	٧
Vovchgr	Overvoltage Charge Release Voltage	V <sub>DD</sub> =3.5V	5.3	7.3	9.3	V
tcu	Overcharge Detection Delay Time	_	t <sub>CU</sub> * 0.8	tcu	t <sub>CU</sub> * 1.2	ms
tcur	Overcharge Release Delay Time	_	t <sub>CUR</sub> * 0.8	t <sub>CUR</sub>	t <sub>CUR</sub> * 1.2	ms
t <sub>DL</sub>	Overdischarge Detection Delay Time	_	t <sub>DL</sub> * 0.8	t <sub>DL</sub>	t <sub>DL</sub> * 1.2	ms
t <sub>DLR</sub>	Overdischarge Release Delay Time	_	t <sub>DLR</sub> * 0.8	t <sub>DLR</sub>	t <sub>DLR</sub> * 1.2	ms
tDOC	Discharge Overcurrent Detection Delay Time	_	t <sub>DOC</sub> * 0.8	t <sub>DOC</sub>	t <sub>DOC</sub> * 1.2	ms
t <sub>DOCR</sub>	Discharge Overcurrent Release Delay Time	_	t <sub>DOCR</sub> * 0.8	t <sub>DOCR</sub>	t <sub>DOCR</sub> * 1.2	ms
tshort	Load Short Detection Delay Time	_	t <sub>SHORT</sub> * 0.8	tshort	t <sub>SHORT</sub> * 1.2	μs
tcoc	Charge Overcurrent Detection Delay Time	_	t <sub>COC</sub> * 0.8	tcoc	t <sub>COC</sub> * 1.2	ms
tcocr	Charge Overcurrent Release Delay Time	_	t <sub>COCR</sub> * 0.8	tcocr	t <sub>COCR</sub> * 1.2	ms



## **Electrical Characteristics** (Cont.)

 $(T_A = -40^{\circ}\text{C to } +85^{\circ}\text{C}, V_{DD} = 3.5\text{V}, V_{SS} = 0\text{V}, R1 = 220\Omega, R2 = 1.0k\Omega, C1 = 100nF, unless otherwise specified.)$ 

V <sub>CU</sub>   Overcharge Detection Voltage	Symbol	Parameter	Condition	Min	Тур	Max	Unit
VcL         Overcharge Release Voltage         VcL = VcU         - 0.080         VcL = VcD         + 0.080         VcL = VcD         VcD = VcD         VcD = VcD         + 0.040         VcL + 0.040         VcL + 0.040         VcD + 0.080         VcL + 0.040         VcD + 0.080         VcD + 0.080         VcD + VcD + 0.080         VcD	V <sub>CU</sub>	Overcharge Detection Voltage	_		V <sub>CU</sub>		٧
V <sub>CL</sub> Overcharge Release Voltage         V <sub>CL</sub> = V <sub>CU</sub> V <sub>CL</sub> = V <sub>CL</sub> V			V <sub>CL</sub> ≠V <sub>CU</sub>	_	V <sub>CL</sub>		٧
Voi.	V <sub>CL</sub>	Overcharge Release Voltage	V <sub>CL</sub> = V <sub>CU</sub>	V <sub>CL</sub>	V <sub>CL</sub>	V <sub>CL</sub>	V
Vou	V <sub>DL</sub>	Overdischarge Detection Voltage	_	$V_{DL}$	V <sub>DL</sub>	$V_{DL}$	V
V <sub>DU</sub> <			V <sub>DU</sub> ≠ V <sub>DL</sub>	$V_{DU}$	V <sub>DU</sub>	$V_{DU}$	V
Voc	$V_{DU}$	Overdischarge Release Voltage	V <sub>DU</sub> = V <sub>DL</sub>	$V_{DU}$	V <sub>DU</sub>	$V_{DU}$	V
VSHORT         Load Short-Circuiting Detection Voltage         —         VSHORT -0.34 -0.34 (0.34)         VSHORT +0.34 (0.34)         V SHORT +0.34 (0.34)         V COC +0.040         V COC +0.040 <t< td=""><td>V<sub>DOC</sub></td><td>Discharge Overcurrent Detection Voltage</td><td>_</td><td><math>V_{DOC}</math></td><td>V<sub>DOC</sub></td><td><math>V_{DOC}</math></td><td>V</td></t<>	V <sub>DOC</sub>	Discharge Overcurrent Detection Voltage	_	$V_{DOC}$	V <sub>DOC</sub>	$V_{DOC}$	V
Vocc         Charge Overcurrent Detection Voltage         —         Vccc (-0.040)         Vccc (-0.040)         V coc (-0	V <sub>SHORT</sub>	Load Short-Circuiting Detection Voltage	_	V <sub>SHORT</sub>	V <sub>SHORT</sub>	V <sub>SHORT</sub>	V
Icc (Power Down Function)           Icc (Cyment Consumption During Operation         VoD = 3.5V, VM = 0V         —         3.0         7.0         μA           Ipon (Light)         Current Consumption During Power Down Mode (VDD = 1.8V, VM Pin Floating)         —         1.0         μA           Icc (Auto-Wake Up Function)         User (Courrent Consumption During Operation (VDD = 1.8V, VM Pin Floating)         —         3         4.5         μA           Icut Current Consumption During Auto-Wake Mode (VDD = 1.8V, VM Pin Floating (VDD Pin VM Pin Floating)          —         6         8         μA           Rymid Resistance between VM Pin and VDD Pin (VDD Pin VM Pin Floating)         VDD = 1.8V VM Pin Floating         —         6         8         μA           VOCHAD (VDCHA)         Resistance between VM Pin and VDD Pin VM Pin Floating (VDD Pin VM Pin Floating)         —         6         8         μA           VOCHAD (VDCHA)         QV Battery Charge Starting Charge Voltage (VDD Pin VM Pin Floating)         1.0         300 (PDD Pin VM Pin Floating)         5         30 (PDD Pin VM Pin Floating)         4         4         4         4         4         4         5         4         4         4         4         4         4         4         4         4         4         5         30 (PD Pin VM Pin Floating)         4         5	V <sub>coc</sub>	Charge Overcurrent Detection Voltage	_	Vcoc	V <sub>COC</sub>	Vcoc	V
PDN   Current Consumption During Power Down Mode   VDD = 1.8V, VM Pin Floating   —   —   1.0   µA	I <sub>CC</sub> (Power D	own Function)			I		
Coc (Auto-Wake Up Function)   Coc (Auto-Wake Up Function)   Coc (Current Consumption During Operation   Vode 3.5V, VM = 0V   - 3	Icc	Current Consumption During Operation	V <sub>DD</sub> = 3.5V, V <sub>M</sub> = 0V	_	3.0	7.0	μΑ
IccCurrent Consumption During Operation $V_{DD} = 3.5V$ , $V_{M} = 0V$ —34.5μAI_{AUTO}Current Consumption During Auto-Wake Mode $V_{DD} = 1.8V$ , VM Pin Floating—68μAR_{VMD}Resistance between VM Pin and VDD Pin $V_{DD} = 1.8V$ , VM Pin Floating—68μAR_{VMS}Resistance between VM Pin and VDD Pin $V_{DD} = 1.8V$ , VM Pin Floating100300650kΩ $V_{OCHA}$ 0V Battery Charge Starting Charge Voltage0V battery charging "available"1.2———V $V_{OINH}$ 0V Battery Charge Inhibition Battery Voltage0V battery charging "available"——0.3V $V_{OVCHG}$ Overvoltage Charge Detection Voltage $V_{DD} = 3.5V$ 5.58.010.5V $V_{OVCHGR}$ Overvoltage Charge Release Voltage $V_{DD} = 3.5V$ 5.07.39.5V $V_{OVCHGR}$ Overcharge Detection Delay Time— $t_{CU}$ *0.6 $t_{CU}$ * $t_{CU}$ *1.4ms $t_{CUR}$ Overdischarge Detection Delay Time— $t_{CUR}$ *0.6 $t_{CUR}$ *1.4ms $t_{DL}$ Overdischarge Release Delay Time— $t_{DL}$ *0.6 $t_{DL}$ * $t_{DL}$ *1.4ms $t_{DOC}$ Discharge Overcurrent Detection Delay Time— $t_{DCC}$ *0.6 $t_{DOC}$ * $t_{DOC}$ *1.4ms $t_{DOCR}$ Discharge Overcurrent Release Delay Time— $t_{DOCR}$ *0.6 $t_{DOCR}$ *1.4ms $t_{DOCR}$ Discharge Overcurrent Detection Delay Time <td>I<sub>PDN</sub></td> <td>Current Consumption During Power Down Mode</td> <td>V<sub>DD</sub> = 1.8V, VM Pin Floating</td> <td>_</td> <td>_</td> <td>1.0</td> <td>μA</td>	I <sub>PDN</sub>	Current Consumption During Power Down Mode	V <sub>DD</sub> = 1.8V, VM Pin Floating	_	_	1.0	μA
Nauto   Current Consumption During Auto-Wake Mode   V_DD = 1.8V, VM Pin Floating   — 6 8 8	I <sub>CC</sub> (Auto-Wa	ke Up Function)				1	
RVMD Resistance between VM Pin and VDD Pin $V_{DD}=1.8V$ $V_{M}=0V$ 100 300 650 k $\Omega$ RVMS Resistance between VM Pin and VDD Pin $V_{DD}=3.5V$ $V_{M}=1.0V$ 5 30 65 k $\Omega$ VOCHA OV Battery Charge Starting Charge Voltage Overburge available 1.2 — — V $V_{DD}=3.5V$ $V_{DD}=3.5V$ $V_{DD}=3.5V$ $V_{DD}=3.5V$ 1.2 — — V $V_{DD}=3.5V$ OV battery charging available 1.2 — — 0.3 V $V_{DD}=3.5V$ 0.5 8.0 10.5 V $V_{DD}=3.5V$ 5.5 8.0 10.5 V $V_{DD}=3.5V$ 5.5 8.0 10.5 V $V_{DD}=3.5V$ 5.0 7.3 9.5 V $V_{DD}=3.5V$ 5.0 T $V_{DD}=$	Icc	Current Consumption During Operation	V <sub>DD</sub> = 3.5V, V <sub>M</sub> = 0V	_	3	4.5	μA
Resistance between VM Pin and VDD Pin $V_{M=0V}$ $V_{D=3.5V}$ $V_{M=1.0V}$ $V_{D=3.5V}$ $V_{M=1.0V}$ $V_{D=3.5V}$ $V_{M=1.0V}$ $V_{D=3.5V}$ $V_{M=1.0V}$ $V_{D=3.5V}$ $V_{D=3$	I <sub>AUTO</sub>	Current Consumption During Auto-Wake Mode	V <sub>DD</sub> = 1.8V, VM Pin Floating	_	6	8	μA
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	R <sub>VMD</sub>	Resistance between VM Pin and VDD Pin		100	300	650	kΩ
VOCHA       OV Battery Charge Starting Charge Voltage       OV battery charging "available"       1.2       —       —       V         VOINH       OV Battery Charge Inhibition Battery Voltage       OV battery charging "unavailable"       —       —       —       0.3       V         VOVCHG       Overvoltage Charge Detection Voltage       VDD=3.5V       5.5       8.0       10.5       V         VOVCHGR       Overvoltage Charge Release Voltage       VDD=3.5V       5.0       7.3       9.5       V         tcu       Overcharge Detection Delay Time       —       tcu* 0.6       tcu       tcu* 1.4       ms         tcuR       Overdischarge Detection Delay Time       —       tcu* 0.6       tcuR       tcuR* 1.4       ms         tDLR       Overdischarge Release Delay Time       —       tcuR* 0.6       tcuR       tcuR* 1.4       ms         tDC       Discharge Overcurrent Detection Delay Time       —       tcuR* 0.6       tcuR* 1.4       ms         tDCC       Discharge Overcurrent Release Delay Time       —       tcuR* 0.6       tcoc* 1.4       ms         tDCCR       Discharge Overcurrent Detection Delay Time       —       tcoc* 0.6       tcoc* 1.4       ms         tCCC       Charge Overcurrent Detection Delay Time	R <sub>VMS</sub>	Resistance between VM Pin and VDD Pin	V <sub>DD</sub> =3.5V	5	30	65	kΩ
VoINH       OV Battery Charge Inhibition Battery Voltage       "unavailable"       —       —       —       0.3       V         VoVCHG       Overvoltage Charge Detection Voltage       V <sub>DD</sub> =3.5V       5.5       8.0       10.5       V         VoVCHGR       Overvoltage Charge Release Voltage       V <sub>DD</sub> =3.5V       5.0       7.3       9.5       V         t <sub>CU</sub> Overcharge Detection Delay Time       —       t <sub>CU</sub> * 0.6       t <sub>CU</sub> t <sub>CU</sub> * 1.4       ms         t <sub>CUR</sub> Overdischarge Release Delay Time       —       t <sub>DL</sub> * 0.6       t <sub>DL</sub> t <sub>DL</sub> * 1.4       ms         t <sub>DLR</sub> Overdischarge Release Delay Time       —       t <sub>DLR</sub> * 0.6       t <sub>DLR</sub> t <sub>DLR</sub> * 1.4       ms         t <sub>DOC</sub> Discharge Overcurrent Detection Delay Time       —       t <sub>DOC</sub> * 0.6       t <sub>DOC</sub> * 1.4       ms         t <sub>SHORT</sub> Load Short Detection Delay Time       —       t <sub>SHORT</sub> * 0.6       t <sub>SHORT</sub> * 1.4       ms         t <sub>COC</sub> Charge Overcurrent Detection Delay Time       —       t <sub>COC</sub> * 0.6       t <sub>COC</sub> * 1.4       ms	V <sub>0CHA</sub>	0V Battery Charge Starting Charge Voltage	0V battery charging	1.2	_	_	V
VOVCHGR       Overvoltage Charge Release Voltage       VDD=3.5V       5.0       7.3       9.5       V         tcu       Overcharge Detection Delay Time       —       tcu* 0.6       tcu       tcu* 1.4       ms         tcuR       Overcharge Release Delay Time       —       tcuR* 0.6       tcuR       tcuR* 1.4       ms         tbL       Overdischarge Detection Delay Time       —       tbL* 0.6       tbL       tbL* 1.4       ms         tbLR       Overdischarge Release Delay Time       —       tbLR* 0.6       tbLR       tbLR* 1.4       ms         tbOC       Discharge Overcurrent Detection Delay Time       —       tbOC* 0.6       tbOC       tbOC* 1.4       ms         tbHORT       Load Short Detection Delay Time       —       tsHORT* 0.6       tsHORT       tsHORT* 1.4       ms         tcoc       Charge Overcurrent Detection Delay Time       —       tcoc* 0.6       tcoc       tcoc* 1.4       ms	Voinh	0V Battery Charge Inhibition Battery Voltage	0V battery charging	_	_	0.3	V
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	V <sub>OVCHG</sub>	Overvoltage Charge Detection Voltage	V <sub>DD</sub> =3.5V	5.5	8.0	10.5	V
$t_{CUR}$ Overcharge Release Delay Time— $t_{CUR} * 0.6$ $t_{CUR} * 1.4$ ms $t_{DL}$ Overdischarge Detection Delay Time— $t_{DL} * 0.6$ $t_{DL}$ $t_{DL} * 1.4$ ms $t_{DLR}$ Overdischarge Release Delay Time— $t_{DLR} * 0.6$ $t_{DLR}$ $t_{DLR} * 1.4$ ms $t_{DOC}$ Discharge Overcurrent Detection Delay Time— $t_{DOC} * 0.6$ $t_{DOC}$ $t_{DOC} * 1.4$ ms $t_{DOCR}$ Discharge Overcurrent Release Delay Time— $t_{DOCR} * 0.6$ $t_{DOCR} * 0.6$ $t_{DOCR} * 1.4$ ms $t_{SHORT}$ Load Short Detection Delay Time— $t_{SHORT} * 0.6$ $t_{SHORT} * 0.6$ $t_{SHORT} * 1.4$ $t_{SHORT} * 1.4$ $t_{SHORT} * 1.4$ $t_{COC}$ Charge Overcurrent Detection Delay Time— $t_{COC} * 0.6$ $t_{COC} * 1.4$ $t_{COC} * 1.4$ $t_{COC} * 1.4$	Vovchgr	Overvoltage Charge Release Voltage	V <sub>DD</sub> =3.5V	5.0	7.3	9.5	V
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	t <sub>CU</sub>	Overcharge Detection Delay Time	_	t <sub>CU</sub> * 0.6	t <sub>CU</sub>	t <sub>CU</sub> * 1.4	ms
$t_{DLR}$ Overdischarge Release Delay Time— $t_{DLR} * 0.6$ $t_{DLR} * 1.4$ ms $t_{DOC}$ Discharge Overcurrent Detection Delay Time— $t_{DOC} * 0.6$ $t_{DOC} * 0.6$ $t_{DOC} * 1.4$ ms $t_{DOCR}$ Discharge Overcurrent Release Delay Time— $t_{DOCR} * 0.6$ $t_{DOCR} * 0.6$ $t_{DOCR} * 1.4$ ms $t_{SHORT}$ Load Short Detection Delay Time— $t_{SHORT} * 0.6$ $t_{SHORT} * 1.4$ $t_{SHORT} * 1.4$ $t_{SHORT} * 1.4$ $t_{COC}$ Charge Overcurrent Detection Delay Time— $t_{COC} * 0.6$ $t_{COC} * 1.4$ $t_{COC} * 1.4$ $t_{COC} * 1.4$	t <sub>CUR</sub>	Overcharge Release Delay Time	_	t <sub>CUR</sub> * 0.6	t <sub>CUR</sub>	t <sub>CUR</sub> * 1.4	ms
t <sub>DOC</sub> Discharge Overcurrent Detection Delay Time — t <sub>DOC</sub> * 0.6 t <sub>DOC</sub> * 1.4 ms  t <sub>DOCR</sub> Discharge Overcurrent Release Delay Time — t <sub>DOCR</sub> * 0.6 t <sub>DOCR</sub> * 1.4 ms  t <sub>SHORT</sub> Load Short Detection Delay Time — t <sub>SHORT</sub> * 0.6 t <sub>SHORT</sub> t <sub>SHORT</sub> * 1.4 μs  t <sub>COC</sub> Charge Overcurrent Detection Delay Time — t <sub>COC</sub> * 0.6 t <sub>COC</sub> * 1.4 ms	t <sub>DL</sub>	Overdischarge Detection Delay Time	_	t <sub>DL</sub> * 0.6	t <sub>DL</sub>	t <sub>DL</sub> * 1.4	ms
t <sub>DOCR</sub> Discharge Overcurrent Release Delay Time — t <sub>DOCR</sub> * 0.6 t <sub>DOCR</sub> * 1.4 ms  t <sub>SHORT</sub> Load Short Detection Delay Time — t <sub>SHORT</sub> * 0.6 t <sub>SHORT</sub> t <sub>SHORT</sub> * 1.4 μs  t <sub>COC</sub> Charge Overcurrent Detection Delay Time — t <sub>COC</sub> * 0.6 t <sub>COC</sub> * 1.4 ms	t <sub>DLR</sub>	Overdischarge Release Delay Time	_	t <sub>DLR</sub> * 0.6	t <sub>DLR</sub>	t <sub>DLR</sub> * 1.4	ms
t <sub>SHORT</sub> Load Short Detection Delay Time — t <sub>SHORT</sub> * 0.6 t <sub>SHORT</sub> * 1.4 μs t <sub>COC</sub> Charge Overcurrent Detection Delay Time — t <sub>COC</sub> * 0.6 t <sub>COC</sub> * 1.4 ms	t <sub>DOC</sub>	Discharge Overcurrent Detection Delay Time	_	t <sub>DOC</sub> * 0.6	t <sub>DOC</sub>	t <sub>DOC</sub> * 1.4	ms
t <sub>COC</sub> Charge Overcurrent Detection Delay Time — t <sub>COC</sub> * 0.6 t <sub>COC</sub> * 1.4 ms	t <sub>DOCR</sub>	Discharge Overcurrent Release Delay Time	_	t <sub>DOCR</sub> * 0.6	t <sub>DOCR</sub>	t <sub>DOCR</sub> * 1.4	ms
	t <sub>SHORT</sub>	Load Short Detection Delay Time	_	t <sub>SHORT</sub> * 0.6	t <sub>SHORT</sub>	t <sub>SHORT</sub> * 1.4	μs
	tcoc	Charge Overcurrent Detection Delay Time	_	t <sub>COC</sub> * 0.6	t <sub>COC</sub>	t <sub>COC</sub> * 1.4	ms
	t <sub>COCR</sub>	Charge Overcurrent Release Delay Time	_		t <sub>COCR</sub>		ms



## Electrical Characteristics (Cont.) (Notes 7 & 8)

 $(T_A = +25^{\circ}C, V_{DD} = 3.5V, V_{SS} = 0V, R1 = 220\Omega, R2 = 1.0k\Omega, C1 = 100nF, unless otherwise specified.)$ 

Symbol	Parameter	Conditions	Min	Тур	Max	Unit
I <sub>DSS</sub>	Zero Gate Voltage Drain Current	V <sub>DS</sub> = 20V, V <sub>GS</sub> =0	_	_	1.0	μA
R <sub>SS(ON)1</sub>	Static Source-Source On-Resistance 1	V <sub>DD</sub> = 4.0V I <sub>D</sub> = 1.0A	20	27	30	mΩ
R <sub>SS(ON)2</sub>	Static Source-Source On-Resistance 2	V <sub>DD</sub> = 3.9V I <sub>D</sub> = 1.0A	21	27	31	mΩ
R <sub>SS(ON)3</sub>	Static Source-Source On-Resistance 3	V <sub>DD</sub> = 3.0V I <sub>D</sub> = 1.0A	21	28	33	mΩ
V <sub>SD</sub>	Diode Forward Voltage	V <sub>GS</sub> = 0V (Note 6) I <sub>S</sub> = 1A	_	0.75	1.0	٧

Notes:

<sup>6.</sup> In case of Gate-Source voltage of charging MOSFET is 0V. In case of Gate-Source voltage of discharging MOSFET is 0V. 7. These specifications are guaranteed by design - will not be tested in production.



## **Application Information**

#### **Operation Mode**

#### 1. Normal Status

The AP9211 monitors the battery voltage between the VDD pin and VSS pin as well as the voltage difference between the VM pin and VSS pin to control battery charging and discharging. When the battery voltage is between overdischarge detection voltage ( $V_{CU}$ ) as well as when the VM pin voltage is between the charge overcurrent detection voltage ( $V_{COC}$ ) and discharge overcurrent detection voltage ( $V_{DOC}$ ), the AP9211 turns on discharging and charging MOSFET. In these conditions, the battery can charge and discharge freely. Also,  $R_{VMD}$  does not connect to VDD pin, and  $R_{VMS}$  does not connect to VSS pin in this status.

#### 2. Overcharge Status

If the battery voltage is more than  $V_{CU}$  during charging status for the overcharge detection delay time ( $t_{CU}$ ) or longer, the AP9211 turns off the charging MOSFET to stop charging.  $R_{VMD}$  and  $R_{VMS}$  are not connected in overcharge status.

When VM pin voltage is lower than  $V_{DOC}$  and battery voltage falls below  $V_{CL}$ , the AP9211 releases from overcharge status. When VM pin voltage is equal or more than  $V_{DOC}$  and battery voltage falls below  $V_{CU}$ , the AP9211 releases from overcharge status.

#### 3. Overdischarge Status

If the battery voltage is less than  $V_{DL}$  during discharging status for the overdischarge detection delay time ( $t_{DL}$ ) or longer, the AP9211 turns off the discharging MOSFET to stop discharging. In overdischarge status,  $R_{VMD}$  is connected to  $V_{DD}$  and VM pin voltage is pulled up to  $V_{DD}$  by  $R_{VMD}$ , but  $R_{VMS}$  is not connected. For power-down mode version, the AP9211 recovers normal status from overdischarge status only by charging the battery through the charger.

When VM pin voltage to VSS pin voltage is less than typical -0.7V, and the battery voltage rises over  $V_{DL}$ , the AP9211 releases from overdischarge status. If  $V_{M}$  pin voltage to  $V_{SS}$  pin voltage is higher than typical -0.7V, the AP9211 releases from overdischarge status until the battery voltage rises over  $V_{DL}$ .

For auto-wakeup version AP9211SA, the device recovers to normal status from overdischarge status if either of these two conditions are satisfied:

If charger is connected: The AP9211SA overdischarge status is released in the same way as described above in AP9211S Overdischarge Status

section.

If no charger is connected:

1) The battery voltage reaches the overdischarge release voltage (V<sub>DU</sub>) or higher.

2) Maintains continuous time more than overdischarge release delay time t<sub>DLR</sub>.

### 4. Discharge Overcurrent and Short-Current Status

When battery is in discharge overcurrent status, if the voltage of the VM pin to VSS pin is equal or more than  $V_{DOC}$  to  $V_{SHORT}$  and detection lasts for the discharge overcurrent detection delay time ( $t_{DOC}$ ) or longer, the AP9211 turns off the discharging MOSFET to stop discharging.

When the battery is in short-current status, if the voltage of the VM pin to VSS pin is equal to or more than  $V_{SHORT}$ , and the detection lasts for the short current detection delay time or longer, the AP9211 turns off the discharge MOSFET to stop discharging.

In discharge overcurrent or short-current status,  $R_{VMS}$  is connected to  $V_{SS}$ , but  $R_{VMD}$  is not connected. The voltage of VM pin is almost equal to  $V_{DD}$  as long as the load is connected. When the load is disconnected, the voltage of VM pin becomes almost equal to  $V_{SS}$  (due to  $R_{VMS}$  being connected) and then the AP9211 releases from discharge overcurrent or short current status.

### 5. Charge Overcurrent Status

When the battery is in charge current status, if the voltage of the VM pin to VSS pin is equal to or less than  $V_{COC}$ , and the detection continues for the charge overcurrent detection delay time ( $t_{COC}$ ) or longer, the AP9211 turns off the charging MOSFET to stop charging.



## **Application Information (Cont.)**

### 6. 0V Battery Charging Function (Option)

This function is available as an option and can be factory set internally. AP9211 has this function built in. 0V charging function permits charge to recharge the battery whose voltage is 0V due to self-discharge. If 0V charging function is not present, the device prevents the charger to recharge the battery whose voltage is 0V due to self-discharge. If a device without 0V charging function is required, contact Diodes sales team.

#### 7. Overvoltage Charger Detection Circuit

This function is used to monitor the charger voltage between the VDD pin and VM pin, and when this voltage exceeds overvoltage charger detection voltage (8.0V Typ.), the AP9211 turns off charging MOSFET. When this voltage drops below overvoltage charger release voltage (7.3V Typ.), it then turns on charging MOSFET. There are no delay times set for detection and release.

### 8. Power-Down Mode or Auto-Wakeup Function Option

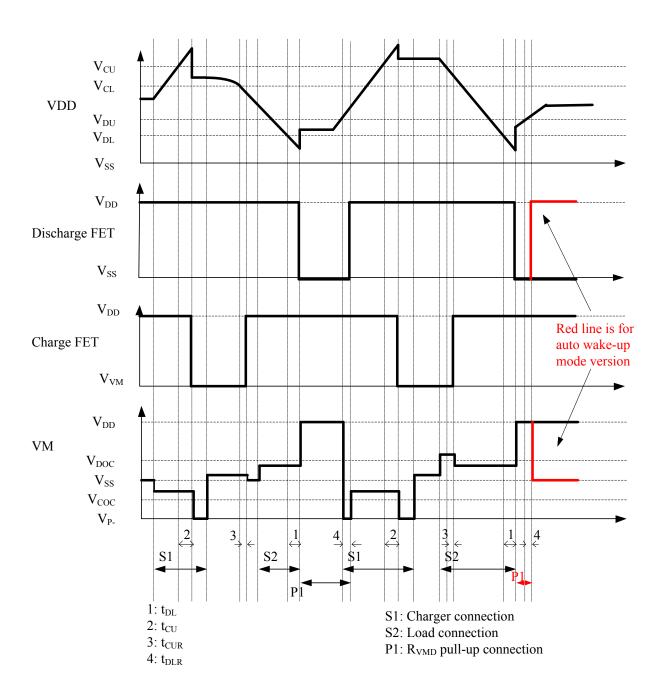
In a device with power-down function, during power-down mode, the device enters the overdischarge status. The IC enters sleep mode and the current consumption becomes very low, typically 0.1µA. To release from power-down status to the normal status, charger connection is required.

In device with auto-wakeup mode, the IC remains active in the overdischarge state. The IC is released into the normal state by the operation that increases the battery voltage more than overdischarge release voltage.



# **Application Information (Timing Chart)**

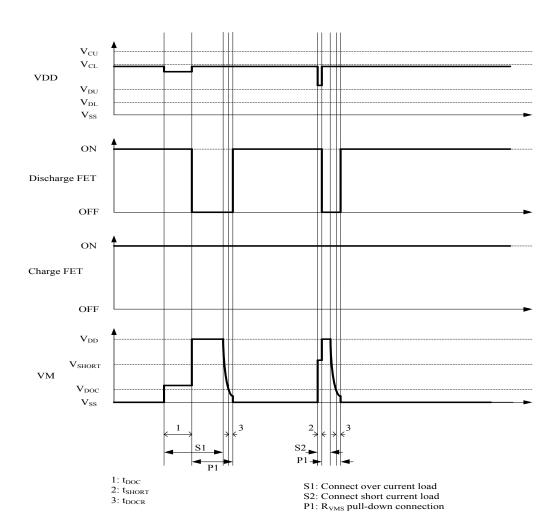
## 1. Overcharge and Overdischarge Detection





# **Application Information (Timing Chart) (Cont.)**

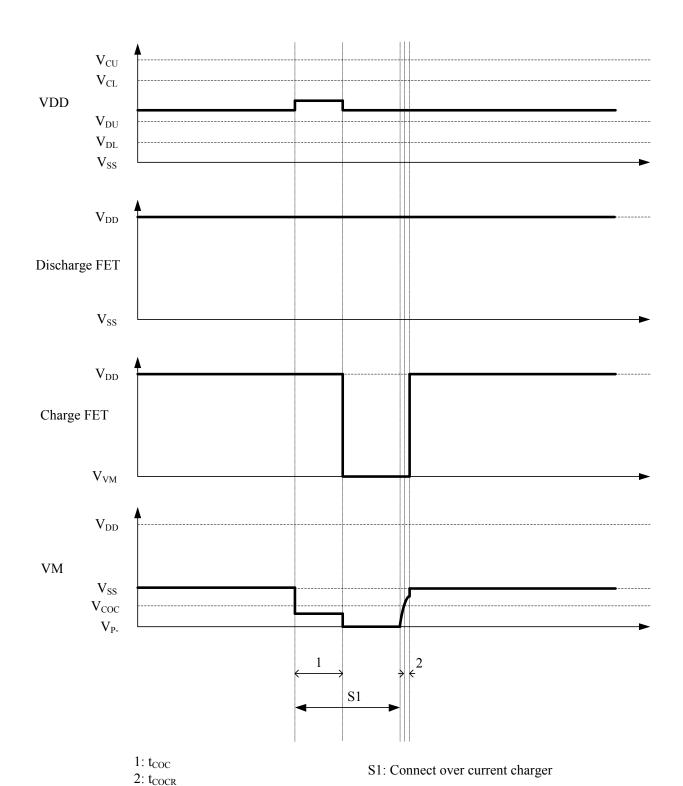
## 2. Discharge Overcurrent Detection





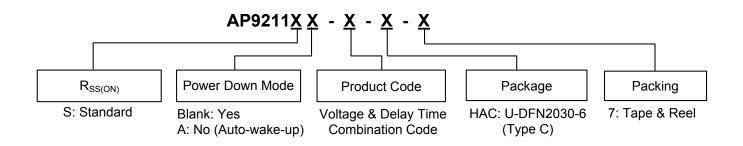
# **Application Information (Timing Chart) (Cont.)**

## 3. Charge Overcurrent Detection





## **Ordering Information**



Part Number	Package Code	Packaging	7" Tape and Reel Quantity
AP9211XX-XX-HAC-7	HAC	U-DFN2030-6 (Type C)	3000/Tape & Reel



# Ordering Information (Note 9) (Cont.)

## **Voltage Combination**

Part Number	Overcharge Detection Voltage V <sub>CU</sub>	Overcharge Release Voltage V <sub>CL</sub>	Over- discharge Detection Voltage V <sub>DL</sub>	Over- discharge Release Voltage V <sub>DU</sub>	Discharge Overcurrent Detection Voltage V <sub>DOC</sub>	Load Short Detection Voltage V <sub>SHORT</sub>	Charge Overurrent Detection Voltage V <sub>COC</sub>	Over Voltage Charger Detection Voltage Vovche	Over Voltage Charger Release Voltage V <sub>OVCHGR</sub>	Power-down Function	Overcharge Protection Mode	0V Battery Charge Function
AP9211XX- AA-HAC-7	4.375V	4.175V	2.500V	2.900V	0.150V	0.700V	-0.150V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AB-HAC-7	4.425V	4.225V	2.500V	2.900V	0.150V	0.700V	-0.150V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AC-HAC-7	4.375V	4.175V	2.500V	2.900V	0.095V	0.700V	-0.095V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AD-HAC-7	4.375V	4.175V	2.500V	2.900V	0.120V	0.700V	-0.120V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AE-HAC-7	4.200V	4.100V	2.500V	3.000V	0.300V	0.550V	-0.100V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AF-HAC-7	4.375V	4.175V	2.500V	2.900V	0.180V	0.700V	-0.180V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AG-HAC-7	4.375V	4.175V	2.500V	2.900V	0.075V	0.700V	-0.075V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AH-HAC-7	4.425V	4.225V	2.500V	2.900V	0.075V	0.700V	-0.075V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- Al-HAC-7	4.500V	4.300V	2.400V	2.800V	0.150V	0.700V	-0.075V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AJ-HAC-7	4.375V	4.175 V	2.400V	2.800V	0.125V	0.700V	- 0.125V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AK-HAC-7	4.250V	4.050 V	2.400V	3.000V	0.150V	0.700V	- 0.150V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AL-HAC-7	4.275V	4.175V	2.300V	2.400V	0.180V	0.700V	-0.180V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AM-HAC-7	4.375V	4.175V	2.300V	2.400V	0.180V	0.700V	-0.180V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- AN-HAC-7	4.225V	4.025V	3.200V	3.400V	0.060V	0.450V	-0.060V	8.0V	7.3V	Selectable	Auto Release	Permission
AP9211XX- DD-HAC-7	4.375V	4.175V	2.500V	2.900V	0.120V	0.700V	-0.120V	8.0V	7.3V	Selectable	Auto Release	Prohibition
AP9211XX- DH-HAC-7	4.425V	4.225V	2.500V	2.900V	0.075V	0.700V	-0.075V	8.0V	7.3V	Selectable	Auto Release	Prohibition
AP9211XX- DL-HAC-7	4.275V	4.175V	2.300V	2.400V	0.180V	0.700V	-0.180V	8.0V	7.3V	Selectable	Auto Release	Prohibition
AP9211XX- CR-HAC-7	4.425V	4.225V	2.800V	3.000V	0.130V	0.500V	0.130V	8.0V	7.3V	Selectable	Auto Release	Prohibition
AP9211XX- EA-HAC-7	4.475V	4.275V	2.500V	2.900V	0.150V	0.500V	-0.150V	8.0V	7.3V	Selectable	Auto Release	Permission

Note: 9. If any other voltage combinations are needed, please contact the local sales office.



# Ordering Information (Cont.)

## **AP9211 Delay Time Combination**

Part Number	Overcharge Detection Delay Time tcu	Overcharge Release Delay Time tcur	Overdischarge Detection Delay Time t <sub>DL</sub>	Overdischarge Release Delay Time t <sub>DLR</sub>	Discharge Overcurrent Detection Delay Time tDOC	Discharge Overcurrent Release Delay Time tDOCR	Charge Overcurrent Detection Delay Time tcoc	Charge Overcurrent Release Delay Time tCOCR	Load Short Detection Delay Time tshort
AP9211XX-XX-HAC- 7	1.0s	2.0ms	115ms	2.0ms	10.0ms	2.0ms	10.0ms	2.0ms	360µs



# **Marking Information**

## (Top View)

<u>XX</u>   $\underline{XX}$  : Identification Code

Y: Year: 0~9
W: Week: A~Z: 1~26 week;
a~z: 27~52 week; z represents
52 and 53 week

X: A~Z: Internal Code

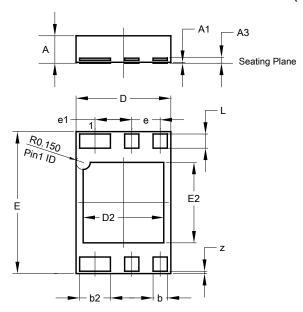
Part Number	Package	Identification Code
AP9211S-AA-HAC-7	U-DFN2030-6 (Type C)	P5
AP9211S-AB-HAC-7	U-DFN2030-6 (Type C)	P6
AP9211S-AC-HAC-7	U-DFN2030-6 (Type C)	6B
AP9211S-AD-HAC-7	U-DFN2030-6 (Type C)	6C
AP9211S-AE-HAC-7	U-DFN2030-6 (Type C)	6D
AP9211S-AF-HAC-7	U-DFN2030-6 (Type C)	6E
AP9211S-AG-HAC-7	U-DFN2030-6 (Type C)	6F
AP9211S-AH-HAC-7	U-DFN2030-6 (Type C)	6G
AP9211S-AI-HAC-7	U-DFN2030-6 (Type C)	6H
AP9211S-AJ-HAC-7	U-DFN2030-6 (Type C)	6Y
AP9211S-AK-HAC-7	U-DFN2030-6 (Type C)	6Z
AP9211S-AL-HAC-7	U-DFN2030-6 (Type C)	5T
AP9211S-AM-HAC-7	U-DFN2030-6 (Type C)	5U
AP9211S-AN-HAC-7	U-DFN2030-6 (Type C)	5V
AP9211S-CR-HAC-7	U-DFN2030-6 (Type C)	5W
AP9211S-DD-HAC-7	U-DFN2030-6 (Type C)	5Z
AP9211S-DH-HAC-7	U-DFN2030-6 (Type C)	8A
AP9211S-DL-HAC-7	U-DFN2030-6 (Type C)	8B
AP9211SA-AA-HAC-7	U-DFN2030-6 (Type C)	M3
AP9211SA-AB-HAC-7	U-DFN2030-6 (Type C)	M4
AP9211SA-AC-HAC-7	U-DFN2030-6 (Type C)	M6
AP9211SA-AD-HAC-7	U-DFN2030-6 (Type C)	M7
AP9211SA-AE-HAC-7	U-DFN2030-6 (Type C)	M8
AP9211SA-AF-HAC-7	U-DFN2030-6 (Type C)	N3
AP9211SA-AG-HAC-7	U-DFN2030-6 (Type C)	N4
AP9211SA-AH-HAC-7	U-DFN2030-6 (Type C)	N6
AP9211SA-AI-HAC-7	U-DFN2030-6 (Type C)	N7
AP9211SA-AJ-HAC-7	U-DFN2030-6 (Type C)	N8
AP9211SA-AK-HAC-7	U-DFN2030-6 (Type C)	NE
AP9211SA-AL-HAC-7	U-DFN2030-6 (Type C)	7X
AP9211SA-AM-HAC-7	U-DFN2030-6 (Type C)	P7
AP9211SA-AN-HAC-7	U-DFN2030-6 (Type C)	P8
AP9211SA-CR-HAC-7	U-DFN2030-6 (Type C)	7Y
AP9211SA-DD-HAC-7	U-DFN2030-6 (Type C)	7Z
AP9211SA-DL-HAC-7	U-DFN2030-6 (Type C)	7V



## **Package Outline Dimensions**

Please see http://www.diodes.com/package-outlines.html for the latest version.

### U-DFN2030-6 (Type C)

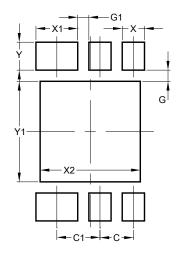


	U-DFN2030-6 (Type C)						
Dim	Min	Max	Тур				
Α	0.50	0.60					
A1	0.00	0.05	0.02				
A3			0.127				
b	0.25	0.35	0.30				
b2	0.60	0.70	0.65				
D	1.90	2.10	2.00				
D2	1.60	1.80	1.70				
Е	2.90	3.10	3.00				
E2	1.60	1.80	1.70				
е			0.60				
e1		-	0.775				
L	L 0.25 0.35 0.30						
<b>z</b> 0.0500 Ref							
All	All Dimensions in mm						

# **Suggested Pad Layout**

Please see http://www.diodes.com/package-outlines.html for the latest version.

### U-DFN2030-6 (Type C)



Dimensions	Value (in mm)
С	0.600
C1	0.775
G	0.200
G1	0.200
Х	0.400
X1	0.750
X2	1.800
Y	0.500
Y1	1.800



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  - 2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.
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