USER GUIDE
UnitedSiC_UG0001 – September 2021

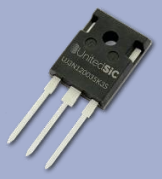
UnitedSiC SiC FET User Guide

By Mike Zhu

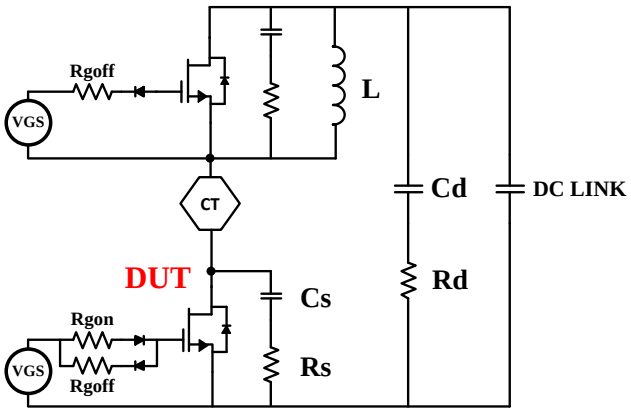
Introduction

This SiC FET user guide presents practical solutions and guidelines for using RC snubbers with fast switching SiC devices. The solution is verified by experimental double pulse tests (DPT) results. The snubber loss is precisely measured to assist users in computing the power rating of the snubber resistor. The beneficial impact of the snubber is analyzed for both hard-switching and soft-switching applications in UnitedSiC_AN0018 “Switching Fast SiC FETs with a Snubber”.

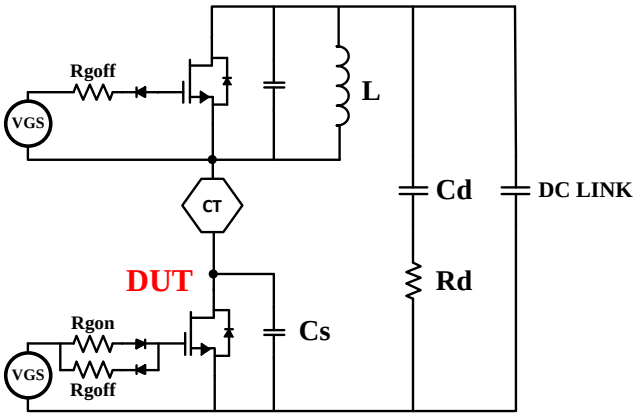
Mike Zhu is an Application Engineer at United Silicon Carbide. Experience includes design of power electronics, EMI mitigation, power device evaluation.



Learn more about power electronic applications at https://unitedsic.com/application-notes/



(a) Hard-switching snubber configuration



(b) Soft-switching snubber configuration

Figure 1. DPT schematic with RC snubbers on both switches for hard-switching (a) and soft-switching (b)

A double pulse tester (DPT) has a half-bridge structure with an inductive load. A simplified schematic is shown in Figure 1. "DPT schematic with RC snubbers on both switches for hard switching (a) and soft switching (b)". When the device under test (DUT) is turning on/off, the bypass capacitor Cd provides transient energy to commutate the high side (HS) and low side (LS) devices. This is the transient power loop. The bypass capacitor should be designed close to the half-bridge layout to reduce the parasitic inductance in the transient power loop. For DUT turn-on transient, once commutation is finished steady-state current flows from the DC LINK capacitors to charge the load inductor L and returns to DC LINK bulk capacitor through the DUT. This is the steady-state power loop. When the DUT is off, the diode becomes forward biased, and the inductor current circulates through the diode and inductor (the freewheeling loop). To avoid high dvdt induced turn-on for fast SiC devices, an isolated gate driver and isolated power supplies are used to suppress high dvdt induced common-mode noise in the gate signal path. Two snubber scenarios are provided here. For more details, please refer to the snubber application note UnitedSiC_AN0018 at https://unitedsic.com/appnotes/Snubber%20AppNotes_V8.pdf.

When designing a bus snubber, Rd designers should pay attention to total energy dissipation in Rd to avoid overheating.

UnitedSiC Simply More Efficient

FET-Jet Calculator | Buy Online | Spice Models | Contact Sales | Learn More

SiC FET Usage Table UJ3C and UF3C/SC Devices

									Gate Drive Voltage														Application Type						
									Positive rail RGON				Negative rail RGOFF										Hard switched (Active rectifier, Totem Pole PFC, Full-bridge etc.)			ZVS			
																									LLC		PSFB	
Product Name	Package	Vdsmax	Id (25°C)	Id (100°C)	RthjC (Typ)	$R_{DS(on)}$ (25°C)	$R_{DS(on)}$ (125°C)	$R_{DS(on)}$ (175°C)	10V	12V	15V	20V	0V	-5V	Device RC Snubber	Rsnub	Csnub	Esnub @ 10A	Esnub @ 30A	Esnub @ 50A	Esnub @ 80A	Coss(er)	Up to 20kHz	20-100KHz	>100kHz	50-150kHz	150-500kHz	20-50kHz	50-200kHz
Units		V	A	A	C/W	mΩ	mΩ	mΩ	Ω	Ω	Ω	Ω	Ω	Ω		W	pF	µJ	µJ	µJ	µJ	pF							
650V Devices																													
UJ3C065080T3S	TO220-3L	650	31	23	0.61	80	110	140	5	10	20	30	5	10	Optional	4.7	220						✓			✓		✓	
UJ3C065080K3S	TO247-3L	650	31	23	0.61	80	110	140	5	10	20	30	5	10	Optional	4.7	220						✓			✓		✓	
UJ3C065080B3	D2PAK-3L	650	25	18.2	1	80	110	140	5	10	20	30	5	10	Optional	4.7	220						✓			✓		✓	
UF3C065080T3S	TO220-3L	650	31	23	0.61	80	110	140	5	10	20	30	10	20	Required	4.7	220							✓					
UF3C065080K3S	TO247-3L	650	31	23	0.61	80	110	140	5	10	20	30	10	20	Required	4.7	220							✓					
UF3C065080B3	D2PAK-3L	650	25	18.2	1	80	110	140	5	10	20	30	10	20	Required	4.7	220					77		✓					
UF3C065080B7S	D2PAK-7L	650	27	20	0.83	80	110	140	15	20	30	50	5	10	Recommended	10	115							✓	✓		✓	✓	✓
UF3C065080K4S	TO247-4L	650	31	23	0.61	80	110	140	15	20	30	50	5	10	Recommended	10	115							✓	✓		✓	✓	✓
UF3C065040T3S	TO220-3L	650	54	40	0.35	42	58	78	5	10	20	30	10	20	Required	4.7	330							✓					
UF3C065040K3S	TO247-3L	650	54	40	0.35	42	58	70	5	10	20	30	10	20	Required	4.7	330	16.0	23.0					✓					
UF3C065040B3	D2PAK-3L	650	41	30	0.65	42	58	70	5	10	20	30	10	20	Required	4.7	330							✓					
UF3SC065040B7S	D2PAK-7L	650	43	31.5	0.59	42	58	70	15	20	30	50	5	10	Recommended	10	110					150		✓	✓		✓	✓	✓
UF3C065040K4S	TO247-4L	650	54	40	0.35	42	58	70	15	20	30	50	5	10	Recommended	10	110							✓	✓		✓	✓	✓
UF3SC065040D8S	DFN8x8	650	18	18	0.8	42	58	70	15	20	30	50	5	10	Recommended	10	110							✓	✓		✓	✓	✓
UJ3C065030T3S	TO220-3L	650	85	62	0.26	27	35	43	5	10	20	50	5	10	Optional	4.7	680						✓			✓		✓	
UJ3C065030K3S	TO247-3L	650	85	62	0.26	27	35	43	5	10	20	50	5	10	Optional	4.7	680	13.8	20.3			230	✓			✓		✓	
UJ3C065030B3	D2PAK-3L	650	66	47	0.48	27	35	43	5	10	20	50	5	10	Optional	4.7	680						✓			✓		✓	

SiC FET Usage Table UJ3C and UF3C/SC Devices

									Gate Drive Voltage														Application Type						
									Positive rail RGON				Negative rail RGOFF										Hard switched (Active rectifier, Totem Pole PFC, Full-bridge etc.)			ZVS			
																										LLC		PSFB	
Product Name	Package	Vdsmax	Id (25°C)	Id (100°C)	RthjC (Typ)	$R_{DS(on)}$ (25°C)	$R_{DS(on)}$ (125°C)	$R_{DS(on)}$ (175°C)	10V	12V	15V	20V	0V	-5V	Device RC Snubber	Rsnub	Csnub	Esnub @ 10A	Esnub @ 30A	Esnub @ 50A	Esnub @ 80A	Coss(er)	Up to 20kHz	20-100KHz	> 100kHz	50-150kHz	150-500kHz	20-50kHz	50-200kHz
Units		V	A	A	C/W	mΩ	mΩ	mΩ	Ω	Ω	Ω	Ω	Ω	Ω		W	pF	µJ	µJ	µJ	µJ	pF							
UF3C065030T3S	TO220-3L	650	85	62	0.26	27	35	43	5	10	20	30	10	20	Required	4.7	680							✓					
UF3C065030K3S	TO247-3L	650	85	62	0.26	27	35	43	5	10	20	30	10	20	Required	4.7	680	15.8	22.5					✓					
UF3C065030B3	D2PAK-3L	650	66	47	0.48	27	35	43	5	10	20	30	10	20	Required	4.7	680					230		✓					
UF3SC065030B7S	D2PAK-7L	650	62	44	0.54	27	35	43	15	20	30	50	5	10	Recommended	10	220							✓	✓		✓	✓	✓
UF3C065030K4S	TO247-4L	650	85	62	0.26	27	35	43	15	20	30	50	5	10	Recommended	10	220							✓	✓		✓	✓	✓
UF3SC065030D8S	DFN8x8	650	18	18	0.54	27	35	43	15	20	30	50	5	10	Recommended	10	220							✓	✓		✓	✓	✓
UF3SC065007K4S	TO247-7L	650	180	130	0.15	6.7	9.3	11.8	3	4	5	7	3	5	Recommended	10	680					856	✓			✓		✓	✓
1200V Devices																													
UF3C120400K3S	TO247-3L	1200	7.6	5.9	1.2	410	780	1070	5	10	20	30	10	20	No Need							17.5		✓	✓		✓	✓	✓
UF3C120400B7S	D2PAK-7L	1200	6.7	5	1.7	410	780	1070	15	20	30	50	5	10	No Need									✓	✓		✓	✓	✓
UJ3C120150K3S	TO247-3L	1200	18.4	13.8	0.7	150	255	330	5	10	20	30	5	10	Optional	4.7	100					34	✓			✓		✓	
UF3C120150K3S	TO247-3L	1200	18.4	13.8	0.7	150	255	330	5	10	20	30	10	20	Required	4.7	100							✓					
UF3C120150B7S	D2PAK-7L	1200	18.4	13.8	0.7	150	255	330	15	20	30	50	5	10	Recommended	10	47							✓	✓		✓	✓	✓
UF3C120150K4S	TO247-4L	1200	18.4	13.8	0.7	150	255	330	15	20	30	50	5	10	Recommended	10	47							✓	✓		✓	✓	✓
UJ3C120080K3S	TO247-3L	1200	33	24	0.45	80	136	172	5	10	20	30	5	10	Optional	4.7	150	5.0	8.0			59	✓			✓		✓	
UF3C120080K3S	TO247-3L	1200	33	24	0.45	80	136	172	5	10	20	30	10	20	Required	4.7	150							✓					
UF3C120080B7S	D2PAK-7L	1200	28.8	21	0.61	80	136	172	15	20	30	50	5	10	Recommended	10	68							✓	✓		✓	✓	✓
UF3C120080K4S	TO247-4L	1200	33	24	0.45	80	136	172	15	20	30	50	5	10	Recommended	10	68							✓	✓		✓	✓	✓

SiC FET Usage Table UJ3C and UF3C/SC Devices

									Gate Drive Voltage														Application Type						
									Positive rail RGON				Negative rail RGOFF										Hard switched (Active rectifier, Totem Pole PFC, Full-bridge etc.)			ZVS			
																										LLC		PSFB	
Product Name	Package	Vdsmax	Id (25°C)	Id (100°C)	RthjC (Typ)	$R_{DS(on)}$ (25°C)	$R_{DS(on)}$ (125°C)	$R_{DS(on)}$ (175°C)	10V	12V	15V	20V	0V	-5V	Device RC Snubber	Rsnub	Csnub	Esnub @ 10A	Esnub @ 30A	Esnub @ 50A	Esnub @ 80A	Coss(er)	Up to 20kHz	20-100KHz	> 100kHz	50-150kHz	150-500kHz	20-50kHz	50-200kHz
Units		V	A	A	C/W	mΩ	mΩ	mΩ	Ω	Ω	Ω	Ω	Ω	Ω		W	pF	µJ	µJ	µJ	µJ	pF							
UJ3C120040K3S	TO247-3L	1200	65	47	0.27	35	56	73	5	10	20	30	5	10	Optional	4.7	330	14.7	21.6				✓			✓		✓	
UF3C120040K3S	TO247-3L	1200	65	47	0.27	35	56	73	5	10	20	30	10	20	Required	4.7	330	16.1	23.5					✓					
UF3SC120040B7S	D2PAK-7L	1200	47	34	0.54	35	56	73	15	20	30	50	5	10	Recommended	10	110	6.9	11.4			112		✓	✓		✓	✓	✓
UF3C120040K4S	TO247-4L	1200	65	47	0.27	35	56	73	15	20	30	50	5	10	Recommended	10	110							✓	✓		✓	✓	✓
UF3SC120016K3S	TO247-3L	1200	107	77	0.22	16	26	34	5	8	10	15	5	10	Required	10	470					243	✓			✓		✓	
UF3SC120016K4S	TO247-4L	1200	107	77	0.22	16	26	34	6	8	10	15	5	10	Recommended	10	470						✓	✓		✓		✓	
UF3SC120009K4S	TO247-4L	1200	180	130	0.15	8.6	13.8	18.2	3	4	5	7	3	5	Recommended	10	680					395	✓			✓		✓	
1700V Devices																													
UF3C170400K3S	TO247-3L	1700	7.6	5.9	1.2	410	780	1070	5	10	20	30	10	20	No Need							15.5		✓	✓		✓	✓	✓
UF3C170400B7S	D2PAK-7L	1700	6.7	5	1.7	410	780	1070	15	20	30	50	5	10	No Need									✓	✓		✓	✓	✓

Notes for Gen 3 products in hard-switching half-bridge applications:

1. UF3CxxxyyyK4S gives the highest efficiency. Snubber is recommended to improve EMI.
2. UF3CxxxyyyK3S with snubber is a fast solution for 3L applications. UF series in 3 terminal packages **MUST** use a snubber for hard-switching.

Notes for Gen 3 products in soft-switching half-bridge applications (LLC, PSFB, etc.):

3. DFN8x8, D2PAK-7L, TO247-4L has highest efficiency even with snubber capacitors (No Rs)
4. UJ3CxxxyyyK3S does not require snubber. For $R_{DS(on)}$ >80m, UJ3CxxxyyyK3S show good balance of EMI & efficiency.
5. A bus snubber with a Cds capacitor generally provides the best performance and waveforms

SiC FET Usage Table UJ4C/SC Devices

									Gate Drive Voltage															Application Type						
									Positive rail RGON				Negative rail RGOFF											Hard switched (Active rectifier, Totem Pole PFC, Full-bridge etc.)			ZVS			
																										LLC		PSFB	
Product Name	Package	Vdsmax	Id (25°C)	Id (100°C)	RthjC (Typ)	$R_{DS(on)}$ (25°C)	$R_{DS(on)}$ (125°C)	$R_{DS(on)}$ (175°C)	10V	12V	15V	20V	0V	-5V	RC snubber	Rsnub	Csnub	Esnub @ 10A	Esnub @ 30A	Esnub @ 50A	Esnub @ 80A	Coss(er)	Up to 20kHz	20-100KHz	>100kHz	50-150kHz	150-500kHz	20-50kHz	50-200kHz
Units		V	A	A	C/W	mΩ	mΩ	mΩ	Ω	Ω	Ω	Ω	Ω	Ω		W	pF	µJ	µJ	µJ	µJ	pF							
750V Devices																													
UJ4SC075006K4S	TO247-4L	750	120	120	0.16	5.9	9.8	12.9	1	1	1		5	10	Required	5	680	18.0	21.0	32.0	60.0	475	✓	✓	✓				
															Recommended		680									✓	✓	✓	✓
UJ4SC075009K4S	TO247-4L	750	106	86	0.31	9	14.8	19.4	1	1	1		5	10	Required	5	560	15.0	25.0	33.0	60.0	286	✓	✓	✓				
															Recommended		560									✓	✓	✓	✓
UJ4SC075011K4S	TO247-4L	750	104	75	0.33	11	18.4	24.2	1	1	1		5	10	Required	10	390	15.0	20.0	26.0	43.0	225	✓	✓	✓				
															Recommended		390									✓	✓	✓	✓
UJ4C075018K4S	TO247-4L	750	81	60	0.3	18	31	41	1	1	1		5	10	Recommended	10	300					150	✓	✓	✓				
															Recommended		300									✓	✓	✓	✓
UJ4C075018K3S	TO247-3L	750	81	60	0.3	18	31	41	15	20	30		50	50	Recommended	10	300					150	✓	✓	✓				
															Recommended		300									✓	✓	✓	✓
UJ4C075023K4S	TO247-4L	750	66	49	0.38	23	39	50	1	1	1		5	10	Recommended	10	200	8.0	17.0	25.0		116	✓	✓	✓				
															Recommended		200									✓	✓	✓	✓
UJ4C075023K3S	TO247-3L	750	66	49	0.38	23	39	50	15	20	30		50	50	Recommended	10	200	7.0	12.0	17.0		116	✓	✓	✓				
															Recommended		200									✓	✓	✓	✓
UJ4C075033K4S	TO247-4L	750	47	39	0.48	33	57	75	1	1	1		5	10	Recommended	10	100	7.0	12.0	24.0		83	✓	✓	✓				
															Recommended		100									✓	✓	✓	✓

SiC FET Usage Table UJ4C/SC Devices

									Gate Drive Voltage														Application Type						
									Positive rail RGON				Negative rail RGOFF										Hard switched (Active rectifier, Totem Pole PFC, Full-bridge etc.)			ZVS			
																									LLC		PSFB	
Product Name	Package	Vdsmax	Id (25°C)	Id (100°C)	RthjC (Typ)	$R_{DS(on)}$ (25°C)	$R_{DS(on)}$ (125°C)	$R_{DS(on)}$ (175°C)	10V	12V	15V	20V	0V	-5V	RC snubber	Rsnub	Csnub	Esnub @ 10A	Esnub @ 30A	Esnub @ 50A	Esnub @ 80A	Coss(er)	Up to 20kHz	20-100KHz	> 100kHz	50-150kHz	150-500kHz	20-50kHz	50-200kHz
Units		V	A	A	C/W	mΩ	mΩ	mΩ	Ω	Ω	Ω	Ω	Ω	Ω		W	pF	µJ	µJ	µJ	µJ	pF							
UJ4C075033K3S	TO247-3L	750	47	39	0.48	33	57	75	15	20	30		50	50	Recommended	10	100	5.0	9.0	9.0		83	✓	✓	✓				
															Recommended		100									✓	✓	✓	✓
UJ4C075044K4S	TO247-4L	750	37.4	27.6	0.57	44	75	101	1	1	1		5	10	Recommended	10	68	3.2	6.8			66	✓	✓	✓				
															Recommended		68									✓	✓	✓	✓
UJ4C075044K3S	TO247-3L	750	37.4	27.6	0.57	44	75	101	15	20	30		50	50	Recommended	10	68	4.0	5.5			66	✓	✓	✓				
															Recommended		68									✓	✓	✓	✓
UJ4C075060K4S	TO247-4L	750	28	20.6	0.75	58	106	147	1	1	1		5	10	Recommended	10	95	1.7				50	✓	✓	✓				
															Recommended		95									✓	✓	✓	✓
UJ4C075060K3S	TO247-3L	750	28	20.6	0.75	58	106	147	15	20	30		50	50	Recommended	10	95	1.4				50	✓	✓	✓				
															Recommended		95									✓	✓	✓	✓

Notes for Gen 4 products in hard-switching half-bridge applications:

1. All UJ4C devices are measured with a 2.5Ω, 100nF Bus snubber
2. All UJ4CxxxK3S devices **requires** either a 2.5Ω, 100nF Bus snubber or a recommended device snubber.
3. For switching currents above 20A, a device snubber is **required**. A bus snubber with a pure capacitive snubber is also an option but results in higher overshoot.

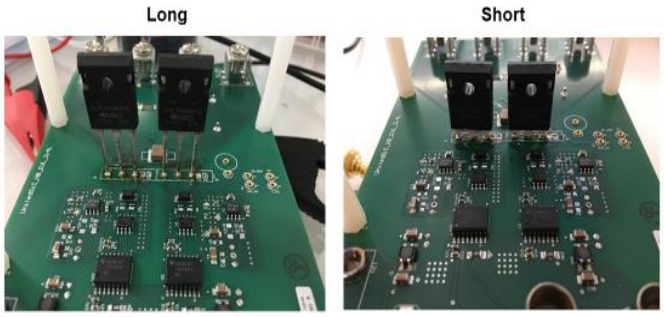


Figure 2: Long Lead vs. Short Lead - through-hole devices must have leads fully inserted to minimize inductance

Snubber Design Guidelines

This SiC FET user guide presents practical solutions and guidelines for using RC snubbers with fast switching SiC devices. The solution is verified by experimental double pulse tests (DPT) results. The snubber loss is precisely measured to assist users in computing the power rating of the snubber resistor. The beneficial impact of the snubber is analyzed for both hard switching and soft switching applications. An application note entitled "Switching fast SiC FETs with a snubber" complements this user guide and can be found at https://unitedsic.com/wp-content/uploads/2019/11/Snubber-AppNotes_V8.pdf.

More snubber guidance is available at: https://info.unitedsic.com/fet-design-tips

Basic assumptions:

1. Rgon: minimize Qrr to reduce Eon.
2. Rgoff: Small value gives better VGS waveform. UFK3S needs higher Rgoff to avoid oscillation. 0 is possible.
3. Cascode Rg has big impact on turn on didt while limited effect on dvdt.
4. dvdt is affected by snubber.

Guidelines:

Snubber Rule	UF3CxxxyyyK3S	UF3CxxxyyyK4S
Cs (>80m $R_{DS(on)}$)	3xCoss(er)	2xCoss(er)
Cs (<30m $R_{DS(on)}$)		Coss(er)
Rs (Ω)	See datasheet	See datasheet

Note: Using snubber Cs can greatly reduce Eoff for soft switching (ZVS) applications.

BOM:

Cs (pF)	Series	Part Number	Package	Rated V
47	C0G	202R18N470JV4E	1206	2000V
68		C1206C680JGGAC7800	1206	
100		202R18N101JV4E	1206	

Cs (pF)	Series	Part Number	Package	Rated V
150	C0G	C1206C151JGGAC7800	1206	2000V
220		C1206C221JGGAC7800	1206	
330		C1210C331JGGACTU	1210	
680		C1808C681JGGAC7800	1808	

Notes:

1. "C0G" ceramic capacitors have most stable capacitance over temperature and voltage variation.
2. KEMET's X8G HV Class I dielectric features a 150°C maximum operating temperature, offering the latest in high temperature dielectric technology and reliability for extreme temperature applications and under the hood applications. X8G exhibits no change in capacitance with respect to voltage and boasts a minimal change in capacitance with reference to ambient temperature. It is a suitable replacement for higher capacitance and larger footprint devices that fail to offer capacitance stability. Capacitance change is limited to ±30ppm/°C from -55°C to +150°C. KEMET X8R is available with flexible termination technology which inhibits the transfer of board stress to the rigid ceramic body, therefore mitigating flex cracks which can result in low IR or short circuit failures.

Rs (Ω)	Power Rating (W)	Part Number	Package
4.7	0.25	KTR18EZPF4R70	1206
	0.5	SR1206FR-7W4R7L	1206
	1	CRCW20104R70JNEFHP	2010
	1.5	CRCW25124R70JNEGHP	2512
10	0.25	KTR18EZPF10R0	1206
	0.5	SR1206FR-7W10RL	1206
	1	CRCW201010R0JNEFHP	2010
	1.5	CRCW251210R0JNEGHP	2512

Notes:

1. For "KTR18" resistor is rated at 500V and the overload voltage is 1000V.
2. For "SR1206" resistor is rated at 200V, the overload voltage is 400V, the dielectric withstanding voltage is 500V.
3. TE Connectivity offers 3540 series of SMD resistors that can handle 4W at 70°C in 2817 size package.

Angst+Pfister
Sensors and Power

We are here for you. Addresses and Contacts.

Headquarter Switzerland:

Angst+Pfister Sensors and Power AG
Thurgauerstrasse 66
CH-8050 Zurich
Phone +41 44 877 35 00
sensorsandpower@angst-pfister.com

Office Germany:

Angst+Pfister Sensors and Power Deutschland GmbH
Edisonstraße 16
D-85716 Unterschleißheim
Phone +49 89 374 288 87 00
sensorsandpower.de@angst-pfister.com

Scan here and get an overview of personal contacts!

sensorsandpower.angst-pfister.com