SynQor
Advancing The Power Curve®

Paralleling Capability of SynQor® Converters and Power Supplies

Application Note

Summary

This application note provides an overview of the paralleling capabilities of the different SynQor power converter families.

Introduction

Many SynQor® power converters have built-in paralleling capability. This functionality allows increased total load power and often redundancy with the addition of output OR'ing FETs or diodes. The table that follows on pages 4-8 provides a summary of whether paralleling is built into the design for a given converter family. It also includes some additional information about how the converter design implements the current sharing feature. For converters that do not have built-in paralleling capability, the table indicates whether they may be made to operate in parallel with the addition of an external current-sharing circuit that makes adjustment to the converter's output voltage Remote-Sense or Trim inputs.

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Types of Current-Share Methods

Different current-share methods are implemented in SynQor converters and power supplies. These include the analog method, digital method and droop method. Following is a brief description of each method.

Analog Method:

Converters using an analog current-share method have a “share” control bus with a voltage that represents the average load current per paralleled converter connected. With this current-share method, all the converters operate without any single converter being in overall control, i.e., there is no master. An advantage of analog current-sharing is that an individual converter in a power system can stop working and the remaining converters will continue to provide power to the load without interruption or shutdown. The load sharing effectiveness between paralleled units decreases as the number of units in the parallel group increases. As the number of units increase, the output current-share disparity increases between the unit that delivers the most amount of current and the unit that delivers the least amount of current. This causes the unit that delivers the most amount of current to exceed its maximum operating current before most of the other units in the group. This effectively limits the amount of current that an analog parallel system can deliver without any one unit exceeding its operational current limit.

However, for converters that are designed to work in current limit indefinitely, the current-share algorithm can help achieve maximum output power without any one unit exceeding its maximum operating current limit. These converters act as current sources when their current limit is exceeded. They have a configurable current limit. These converters can load share by simply connecting their outputs in parallel or in conjunction with the analog paralleling method to improve load sharing effectiveness at near full load. In general, the converter with the highest output voltage will supply most of the current until the current limit is reached. As the load increases, the output voltage of the converter will droop as it tries to maintain constant current. This output voltage droop will then cause the other converters in the system to increase their output currents and reduce the current mismatch among the units. This method can be used in conjunction with the analog method, if available in the converters being paralleled to enhance paralleling effectiveness.

Digital Method:

The digital current-share method utilizes a high-speed, two-wire serial communication bus to implement current share. With this method, on initial startup one converter automatically becomes the master and all the remaining converters become slaves. The master unit then broadcasts its control state over the shared serial bus on a cycle-by-cycle basis. The slave units interpret and implement the control commands sent by the master, mirroring every action of the master unit. If the master is disabled or encounters a fault condition, all units will immediately shut down, and if the master unit is unable to restart, then one of slave unit will become master. If a slave unit is disabled or encounters a fault condition, all other units can continue to run assuming that the load does not exceed the combined output power of the units. The slave unit which shutdown, may attempt to restart seamlessly if not disabled or damaged. The accuracy of current-share among the paralleled converters will depend on a symmetrical layout that ensures the same input and output impedances from each converter to the common connected point and not the number of converters being paralleled.

Droop Method:

The droop load share method is very scalable and requires no active communication between the units. The output voltage of the droop share units droop as output current increases. Systems designed for the droop current-share method reduce their output voltage as the output current increases. At lighter loads, the output voltage is higher and at heavier loads it is lower. This is graphically represented as output voltage vs. output current, known as a load-line, and it slopes downward as current is increased. Converters connected in parallel using the droop share method will share the current in accordance with how well their load-lines are matched and also how well the external output impedances between the converters and the common connected points are matched. You can find the load-line graph in the datasheet of each of the system products. The advantage of this method of paralleling is ease of implementation since there is no share bus or serial communication between modules.

External Analog Current Sharing:

Some of the converters without built-in paralleling capabilities can be paralleled by using an external current sharing circuit, as indicated in the table below. There are many third party, high performance load-share controllers available that provide all the necessary functions needed to parallel multiple DC-DC modules to current share within 1% at full load. You can search for these controllers from reputable IC manufactures on the web. A good example of a load share controller is Texas Instrument's UCC29002/39002.

For the best parallel operation and performance, please refer to the application guidelines in the product datasheet. There you will find helpful suggestions and sample application circuits for the specific module.

The tables below show for each converter family whether it has built-in current sharing capability or whether it can be controlled to current share with external components. Often there are several models with different performance features available within a converter family. To determine the specific model of converter that includes built-in current sharing, please check the ordering section of the individual product datasheet which is located on the last page of the datasheet.

Quick Reference Guide to Paralleling Capabilities of SynQor Products

SynQor Converter Family	Converter Brick Size					Built-In Paralleling Capability	Paralleling Capability with External Circuit
	Sixteenth	Eighth	Quarter	Half	Full		
PowerQor							
PQ24			QB			No	Yes, except PQ24xxxQEx
PQ30		EB	QB			No	Yes
PQ40			QB			No	Yes
PQ48			QB			No	Yes
				HB		Yes, Analog Method	n/a
PQ60	SB	EB	QB			No	Yes, except PQ60xxxQEx and PQ60xxxQZx
				HB		Yes, Digital Method,(PQ60xxxHZxxxF) No, (PQ60xxxHEx) Yes, Analog Method, (PQ60xxxHxxxxF, most other non-HZ, consult datasheets)	n/a, Yes, n/a, Yes
PQ50			QB	HB		No	Yes
PQ55				HB		No	Yes, except PQ55xxxHEx
PQ65			QB			No	Yes
DualQor							
DQ61, 62, 63, 65			QB			No	No
BusQor							
BQ50			QB			Yes, Droop Method	n/a
BQ55, BQ57		EB	QB			Yes, Droop Method	n/a
PQ60120QEx17 PQ60120QEx25 PQ60120QZx33			QB			No	No
BQ60120HEx30				HB		No	No
PQ60120HZx50				HB		Yes, Droop Method	n/a
BQ35		EB				Yes, Droop Method	n/a
BQ4H		EB		HB	FB	Yes, Droop Method	n/a
SQ60		EB	QB	HB		Yes, Droop Method, except SQ60120QEx25	n/a
NiQor							
NQ04, NQ16	SIP and SMT					No	Yes
NQ15	SMT					Yes, Analog Method	No
NQ20		EB	QB			No	No
NQ40, NQ60, NQ90		EB	QB	HB		Yes, Analog Method, NQxxxxxHGx, No all others	No
iQor, ATCA							
IQ65			QB			No	No

Note: *This chart is intended as a quick reference guide to the paralleling capabilities of SynQor converters.*

Please feel free to contact SynQor technical support for further assistance when paralleling any specific SynQor converter.

SynQor Converter Family	Converter Brick Size					Built-In Paralleling Capability	Paralleling Capability with External Circuit
	Sixteenth	Eighth	Quarter	Half	Full		
InQor							
IQ12, IQ18	SB		QB	HB		No	Yes
IQ24	SB		QB			No	Yes
				HB		Yes for IQ24xxxHZxxxNRF Digital Method, No all others	Yes, except IQ24xxxHEx and IQ24xxxHZx
IQ32			QB			No	Yes
				HB		Yes for IQ32xxxHZxxxNRF Digital Method, No all others	Yes, except IQ24xxxHZx
IQ36	SB		QB	HB		No	Yes
IQ48	SB		QB			No	Yes
				HB		Yes for IQ48xxxHZxxxNRF Digital Method, No all others	Yes, except IQ24xxxHZx
IQ64, IQ68, IQ70, IQ72, IQ90, IQ1B			QB	HB		No	Yes
IQ2H			QB			No	Yes
IQ4H			QB			No	Yes
				HB	FB	Yes, Analog Method	Yes
InQor DC Filters							
IQxxxPFQT			QB			No	No
RailQor							
RQ18, RQ24, RQ36, RQ68, RQ72, RQ90 RQ1B			QB	HB		Yes for RQxxxxxHEx, Analog Method Yes for RQxxxxxHZx, Analog Method	Yes, except RQxxxxxHEx and RQxxxxxHZx
CFQor							
CF12, CF24, CF48			QB			No	Yes
ACuQor							
G-Series AQ0800-AQ1400	All					No, all Medical Grade, Yes, Industrial Grade 24V, 28V, 48V only, ending in “INP”, Droop Method, No all others	No
E-Series AQ0300 - AQ0500	All					Yes, Droop Method	n/a
PFCQor							
PFCU390xPxxx			QB	HB		Yes for Half Brick Analog Method, No for Quarter Brick	No
PFICQor							
PFICUxxHTxxxNRS				HB		No	No
PFICUxxHTxxxNRD				HB		Yes, Droop Method	n/a
AC Filters							
ACLFxxxHT ACLFxxxET		EB		HB		No	No

Note: *This chart is intended as a quick reference guide to the paralleling capabilities of SynQor converters.*

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SynQor Converter Family	Converter Size	Built-In Paralleling Capability	Paralleling Capability with External Circuit
Hi-Rel Single Output			
MQFL-28, MQFL-28E, MQFL-28V, MQFL-28VE	FL Package	Yes, Analog Method	n/a
MQFL-270, MQFL-270L	FL Package	Yes, Analog Method	n/a
MQHL-28, MQHL-28E	HL Package	No	Yes
MQBL-28, MQBL-28E	BL Package	No	Yes
MQSA-28, MQSA-28E	SA Package	No	Yes
Hi-Rel Dual Output			
MQFL-28, MQFL-28E, MQFL-28V, MQFL-28VE	FL Package	Yes, Analog Method	n/a
MQFL-270	FL Package	Yes, Analog Method	n/a
MQHL-28, MQHL-28E	HL Package	No	No
MQBL-28, MQBL-28E	BL Package	No	No
MQSA-28, MQSA-28E	SA Package	No	No
Hi-Rel BusQor			
MQBQ-28, MQBQ-270	FL Package	Yes, Droop Method	n/a
Hi-Rel DC Filters			
MQME-28, MQME-28E, MQME-270, MQME-270L	FL Package	No	No
MQHE-28, MQHE-28E, MQHE-270, MQHE-270L	HL Package	No	No

Note: *This chart is intended as a quick reference guide to the paralleling capabilities of SynQor converters.*

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SynQor Converter Family	Converter Brick Size					Built-In Paralleling Capability	Paralleling Capability with External Circuit
	Sixteenth	Demi	Quarter	Half	Full		
MilQor MCOTS							
MCOTS-C-28	SB	DB	QB			No	Yes, except -28-xx-QE, and -28-xxD-DM
				HB	FB	Yes, Digital Method, -28-xx-HZ-xxF, No all others	Yes, except -28-xx-xZ
MCOTS-C-28E		DB		HB		Yes, Digital Method, -28E-xx-HZ-xxF, No all others	No, except -28E-xxS-DM
MCOTS-C-28V, -28VE			QB			No	Yes
				HB		Yes, Digital Method, -28V-xx-HZ-xxF and -28VE-xx-HZ-xxF, No all others	Yes, except -28V-xx-HZ and -28VE-xx-HZ
MCOTS-C-48	SB		QB			No	Yes
				HB		Yes, Digital Method, -48-xx-HZ-xxF, No all others	Yes, except -48-xx-HZ
MCOTS-C-150			QB			No	Yes
MCOTS-C-270			QB			No	Yes
				HB	FB	Yes, Analog Method	Yes
MCOTS-C-270N				HB		Yes, Analog Method	Yes
MCOTS-C-270H					FB	Yes, Analog Method	Yes
MCOTS BusQor							
MCOTS-B-xxx				HB	FB	Yes, Droop Method	n/a
MCOTS Non-Isolated							
MCOTS-N-28V-60			QB	HB		Yes, Analog Method, MCOTS-N-28V-60-HG-x, No all others	No
MCOTS-N-28VE-90			QB	HB		Yes, Analog Method, MCOTS-N-28VE-90-HG-x No all others	No
MCOTS-N-12-Q3P1N-QT			QB			No	No
MPFCQor							
MPFC-U-390			QB			No	No
				HB		Yes, Analog Method	No
MPFC-115-270			QB			No	No
				HB		Yes, Analog Method	No
MPFC-115-3PH-270-FP					FB	No	No
MPFC-115-3PH-270P-FP					FB	Yes, Droop Method	No

Continued on the next page.

SynQor Converter Family	Converter Brick Size					Built-In Paralleling Capability	Paralleling Capability with External Circuit
	Sixteenth	Demi	Quarter	Half	Full		
MPFICQor							
MPFIC-U-xx-HT-x-x MPFIC-U-xx-FT-x-x MPFIC-U-xx-FG-x-x-H MPFIC-115-3PH-xxR				HB	FB	No	No
MPFIC-U-xx-HT-x-x-D MPFIC-U-xx-FT-x-x-D MPFIC-U-xx-FG-x-x-DH MPFIC-115-3PH-xxD				HB	FB	Yes, Droop Method	n/a
MPFC-440-3PH-400-LE	LE					Yes, Droop Method	No
MCOTS DC Filter							
MCOTS -F-28, -48, -270		DB	QB	HB		No	No
MCOTS AC Filter							
MACF-xxx-230				HB		No	No
MACF-115-3PH-UNV			QB	HB		Yes, MACF-115-3PH-UNVD-QT No, all others	No
MACF-U-230		EB	QB			No	No
MACF-440-3PH-UNV	MP					No	No
AeroQor AC Filter							
ACF-U-230 ACF-U-115-3PH			QB	HB		No	No
AeroQor PFIC							
APFIC-U-xxR APFIC-115-3PH-xxR				HB	FB	No	No
APFIC-U-xxD APFIC-115-3PH-xxD				HB	FB	Yes, Droop Method	n/a

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SynQor Power Supplies:

SynQor Converter Family	Built-In Paralleling Capability	Paralleling Capability with External Circuit
MultiQor		
MTQ-Px-DC28T	Yes for P3 only, digital method, paralleling only for two or three -28-xx-HZ-x half bricks within the assembly but not with other MTQ assemblies. (No for P1, P2, and P4)	No
MTQ-Px-DC28	No	No
MTQ-Px-AC115-1	No	No
VPX		
VPX-3U-DC28P-00x VPX-3U-DC48P-00x	Yes, +12V Main (Digital Method), +5V and +3.3V Main (Analog Method)	No for Auxillary Outputs
VPX-xU-DC270P-001 VPX-3U-DC270P-002 VPX-xU-ACUNV-1-C-001 VPX-3U-ACUNV-1-CH-001	Yes, +12V Main, +5V and +3.3V Main (Analog Method)	No for Auxillary Outputs
VPX-3U-ACUNV-1-C-N01	No	No
VPX-6U-DC28x-001	Yes, +12V Main (Digital Method), +5V Main (Analog Method)	No for Auxillary Outputs
VPX-3U-AC115-3-C-001	Yes, Main output (Droop Method)	No for Auxillary Output