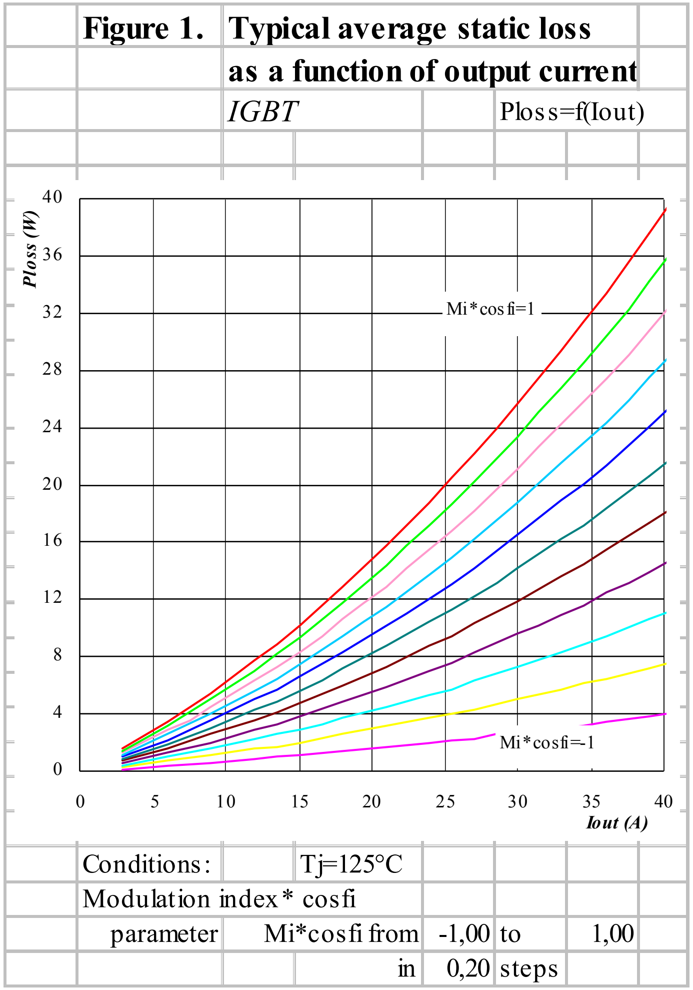
Interpretation of Curves for Motor Drive Applications

Typical average static loss as a function of output current

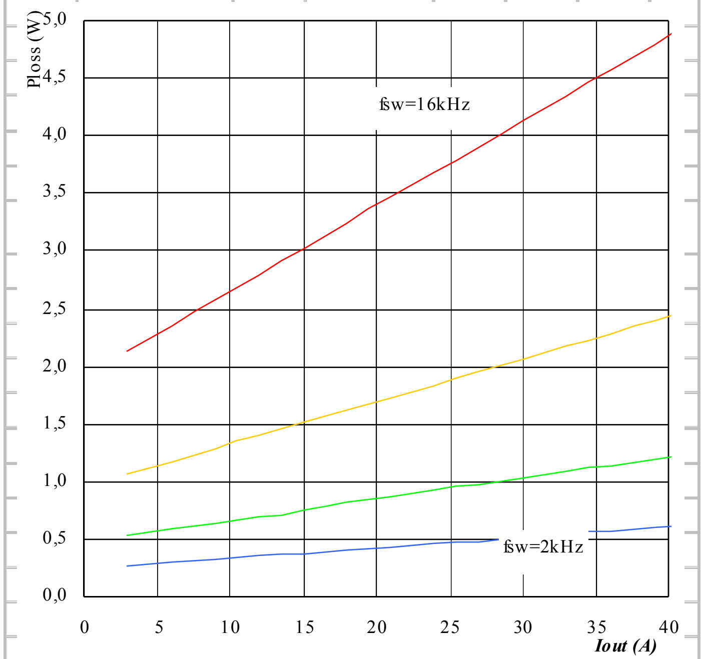
- These diagrams give estimation for the IGBT and FRED static losses as a function of output RMS phase current
- The curves are given with different Mi*cosfi parameters
- Mi defines the ratio of phase peak output voltage to half of DC link voltage
- Mi is positive for motoring and negative for braking mode
- In motoring mode the IGBT in braking mode the FRED have high dissipation
- Cosfi is the cosines of delay of phase current to phase output voltage
- The diagram gives average losses that might have high swings at low FC frequencies



Typical average switching loss as a function of output current

- These diagrams give estimation for the IGBT and FRED switching losses as a function of output RMS phase current
- The curves are given with different fsw switching frequency parameters
- The switching losses are always linear with fsw but more curves are given for easy reading
- The losses at low currents indicate the capacitive switching losses
- The losses are proportional with DC link voltage for smaller variations
- The diagram gives average losses that might have high swings at low FC frequencies

Figure 4.	**Typical avarage switching loss as a function of output current**	
	FRED	Ploss=f(Iout)



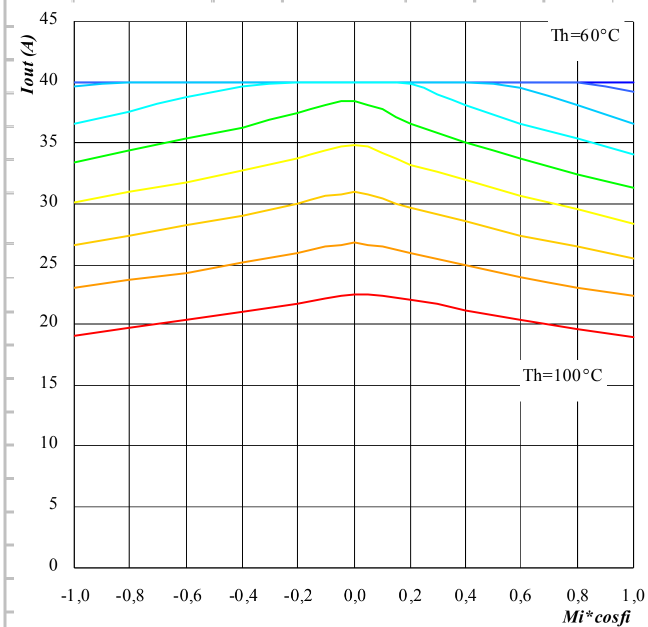
Conditions:	Tj=125°C				
	DC link=	320	V		
Switching freq.	fsw from	2	kHz to	16	kHz
parameter	in	* 2	steps		

Typical available 50Hz output current as a function of Mi*cosfi

- This diagram gives estimation for the value of output RMS phase current as a function of Mi*cosfi
- The curves are given with different Th heat sink temperature parameters.
- Heat sink temperature is to be interpreted heat sink temperature just bellow thermal grease
- The lower the heat sink temperature the higher the available current but at low heat sink temperatures the current is limited by wire bonding
- Typically the positive Mi*cosfi motoring range is limited by the IGBT while the negative braking range by the FRED
- The component sizing is best if the curves are symmetrical to Mi*cosfi=0
- The fsw switching frequency is fixed typically to 16kHz for 600V and to 4kHz for 1200V parts

Figure 5. **Typical available 50Hz output curr as a function of Mi*cosfi**

Phase Iout=f(Mi*cosfi)

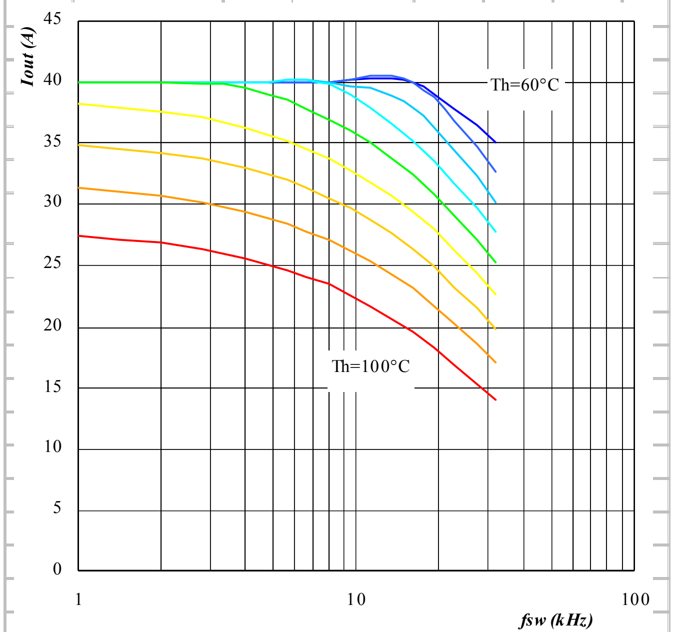


Conditions:	Tj=125°C				
	DC link=	320	V		
	fsw=	16	kHz		
Heatsink temp.	Th from	60	°C to	100	°C
parameter	in	5	°C	steps	

Typical available 50Hz output current as a function of switching frequency

- This diagram gives estimation for the value of output RMS phase current as a function of fsw switching frequency
- The curves are given with different Th heat sink temperature parameters
- The lower the heat sink temperature the higher the available current but at low heat sink temperatures the current is limited by wire bonding
- In most cases the available current is reduced due to IGBT switching loss limitation but too slow FRED can also cause reduction
- The –3dB point gives an approximate speed performance of the device for comparison
- Mi*cosfi is fixed to a typical 0,8 value

Figure 6.	**Typical available 50Hz output curr**			
	as a function of switching frequen			
	Phase		Iout=f(fsw)	



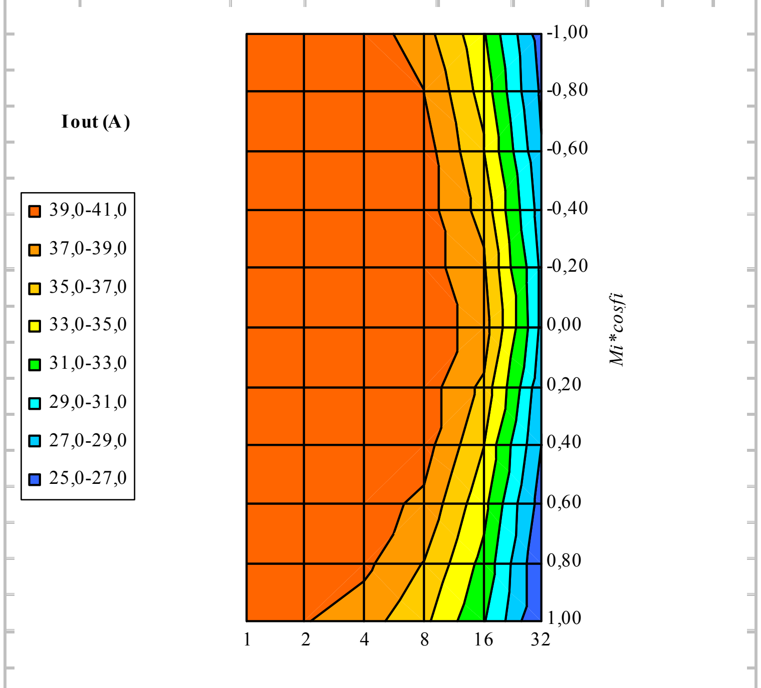
Conditions:	Tj=125°C				
	DC link=	320	V		
	Mi*cosfi=	0,8			
Heatsink temp.	Th from	60	°C to	100	°C
parameter	in	5	°C	steps	

Typical available 50Hz output current as a function of Mi*cosfi and fsw

- This surface diagram gives help for the selection of the operating parameters to meet the output RMS phase current requirement
- The surfaces are given at fixed Th = 80°C heat sink temperature

Figure 7. Typical available 50Hz output curren as a function of Mi*cosfi and fsw

Phase Iout=f(fsw,Mi*cosfi)



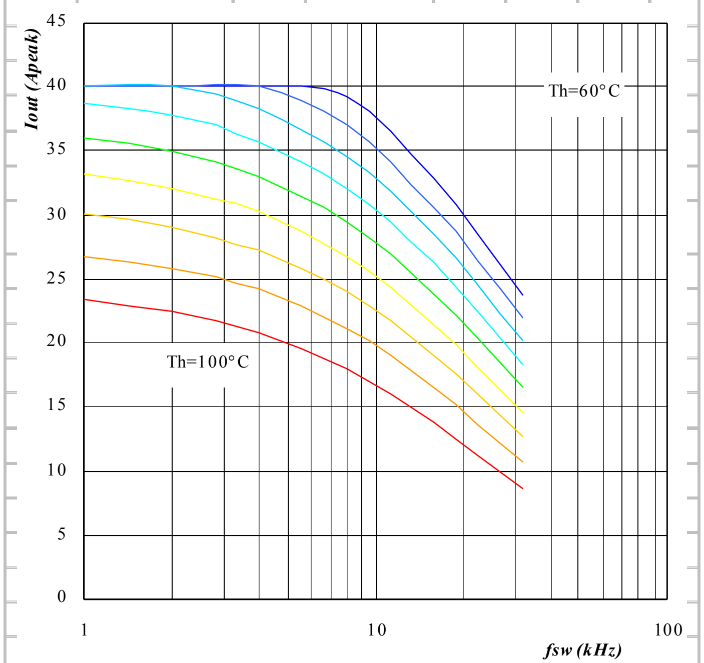
Conditions:	Tj=125°C	
DC link=	320	V
Th=	80	°C

Typical available 0Hz output current as a function of switching frequency

- This diagram gives estimation for the value of output phase current peak as a function of fsw switching frequency at 0Hz of FC
- This operation mode of FC is entered when starting a motor from still position or applying DC braking
- It is important to note that the available 0Hz current value can be much less than at 50Hz
- Some of the IGBTs and some of the FREDs are under DC switching conditions that is DC current chopped to about 50% duty cycle at fsw switching frequency

Figure 8. **Typical available 0Hz output curre as a function of switching frequenc**

Phase Ioutpeak=f(fsw)



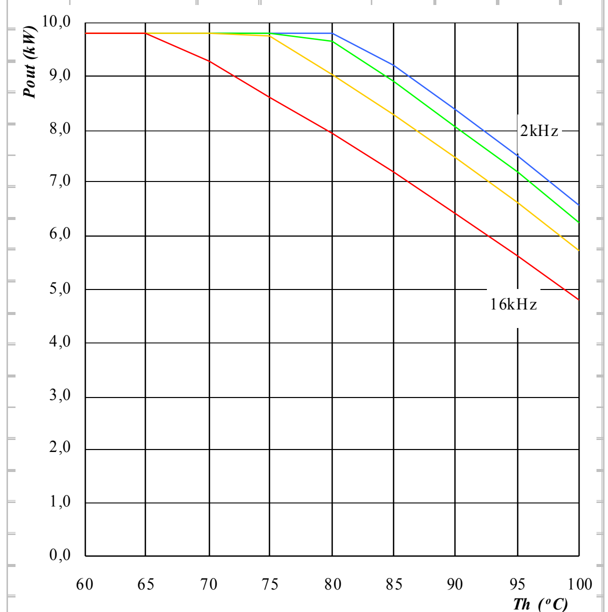
Conditions:		Tj=125°C			
		DC link=	320	V	
Heatsink temp.		Th from	60	°C to	100 °C
parameter		in	5	°C	steps

Typical available electric peak output power as a function of heat sink temperature

- This diagram gives estimation for the value of output 3 phase output power calculated from 50Hz RMS current
- The power is calculated as real and undistorted that is taking into account the given cosfi and leaving a 10% spare space for voltage drop from supply. The drop is for covering DC voltage ripple and switch efficiency
- The modulation index Mi=1 condition includes that the PWM has built in compensation for DC link ripple for maximum undistorted output voltage
- The power at low heat sink temperatures can be limited by current capability of wire bonds

Figure 9. Typical available electric peak output power as a function of heatsink temperature

Inverter Pout=f(Th)



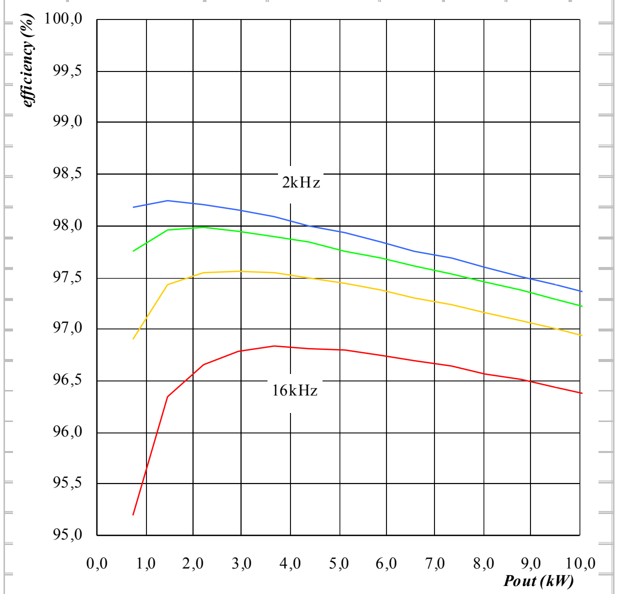
Conditions:	Tj=125°C		
	DC link=	320	V
	Modulation index Mi=	1	
	cosfi=	0,80	
Switching freq.	fsw from	2	kHz to 16 kHz
parameter	in	* 2	steps

Typical efficiency as a function of output power

- The diagram is an estimation for the efficiency of the inverter with switches working under worst Tj=125°C conditions.
- If the switches are operated at lower Tj junction temperature the efficiency is higher due to the positive temperature coefficient of static and switching losses
- The degradation of efficiency at low loads is a consequence of capacitive switching losses

Figure 10. Typical efficiency as a function of output power

Inverter efficiency=f(Pout



Conditions:	Tj=125°C			
	DC link=	320	V	
	Modulation index Mi=	1		
	cosfi=	0,80		
Switching freq.	fsw from	2	kHz to	16 kHz
parameter	in	* 2	steps	

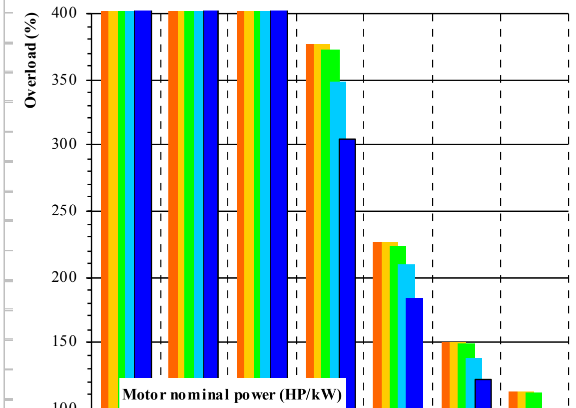
Typical available overload factor as a function of motor power and switching frequency

- The overload factor is calculated as typical electrical output power relative to the electrical power requirement of standard sized motors with 0,85% motor efficiency.
- The standard ratings of motors are mechanical power at rated voltage and RPM
- When the inverter uses special modulation techniques like 3th harmonic or flat-top instead of the simple SPWM to get 10-15% output voltage increase then output power and overload factor can also be higher.

All fixed parameters of the calculations can be changed to immediately get diagrams with specific conditions

Figure 11. Typical available overload factor as a function of motor power and switching frequency

Inverter Ppeak/Pnom=f(Pr



Switching frequency (kHz)	1,00 / 0,74	1,50 / 1,10	2,00 / 1,47	3,00 / 2,21	5,00 / 3,68	7,50 / 5,52	10,00 / 7,36
1	1130	753	565	377	226	151	113
2	1130	753	565	377	226	151	113
4	1115	743	558	372	223	149	112
8	1043	695	522	348	209	139	0
16	915	610	458	305	183	122	0

Conditions:	Tj=125°C			
	DC link=	320	V	
	Modulation index Mi=	1		
	cos fi=	0,8		
Switching freq.	fsw from	1	kHz to	16 kHz
parameter	in	* 2	steps	
	Heatsink temperature=	80	°C	
	Motor efficiency=	0,85		

Selection Guide

- Diagrams of the selection guide are a subset of the diagrams of the application guides to compare the available power graphs within a family
- The power surface plots make the selection easy for a given electric power level at known heating and switching frequency conditions
- The overload factor comparison charts help the selection if the motor to be driven and the required overload factor are both known at standard conditions