Philosophy of Topology and Component Selection for Cost and Performance in Automotive Converters.

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Introduction

"Engineering is a tool

that a company can use

to make profit."

Main Requirements and Conditions for the automotive industry

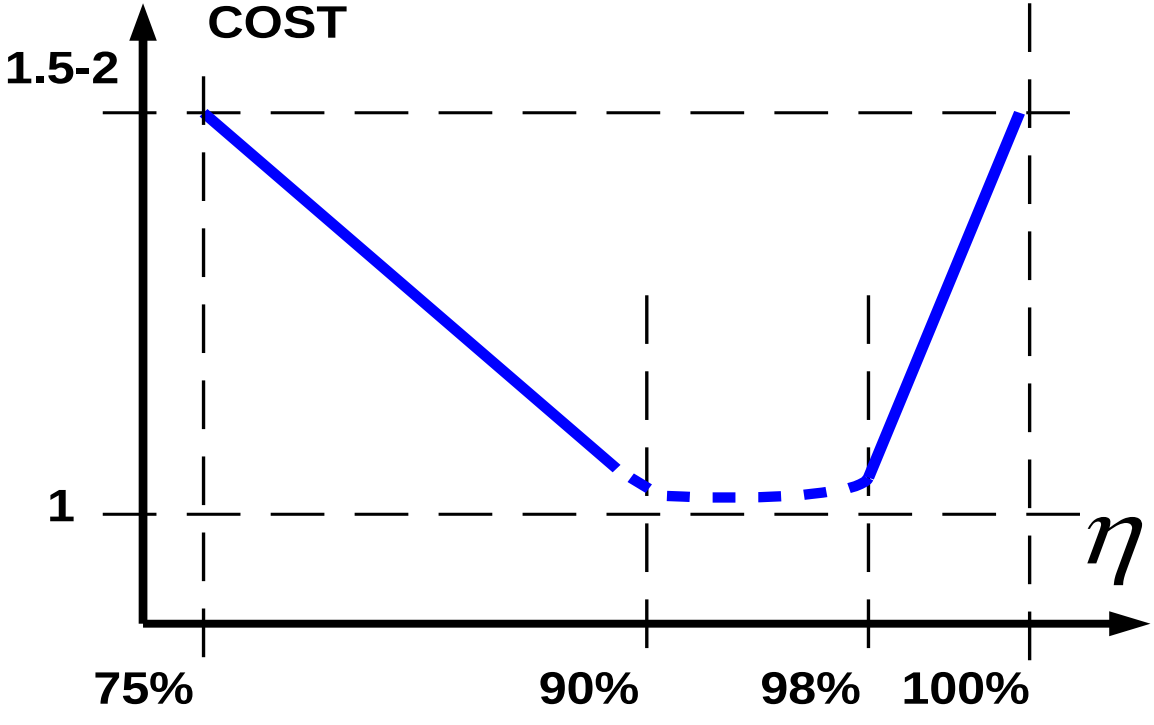
- Reverse polarity protection
- Load Dump Over voltage from alternator
- Sources: battery and alternator
- Over voltage spikes to 800V
- Jump start stresses
- Electromagnetic Compatibility
- Life time, reliability

Main Requirements and Conditions for the automotive industry

- Mechanical challenges: Water resistance and vibration
- CAN-bus communication capability
- High efficiency under light load and low consumption at idle and key off.
- Development cycle time pressures
- Peak currents up to 2900A at 12V
- Operational temperature -40C to +110C
- Electrical air-conditioning drive instead of belt drive
- Optional sources: Electrical grid

Cost and Efficiency

General Relationship Between Cost and Efficiency

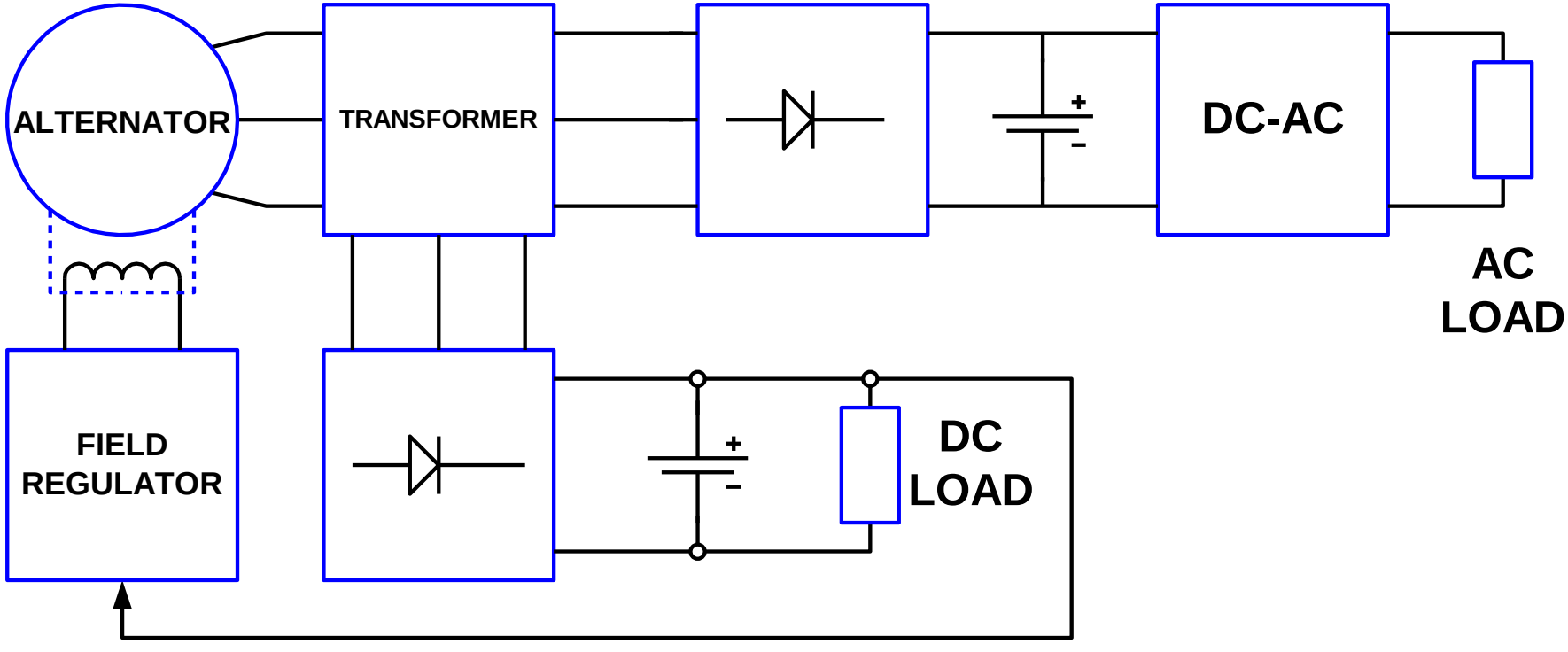


Cost is a strong function of efficiency as we move away from the minimum

$5\%\sim 8\%\Delta Cost \approx \left| 1\%\Delta\eta \right|$

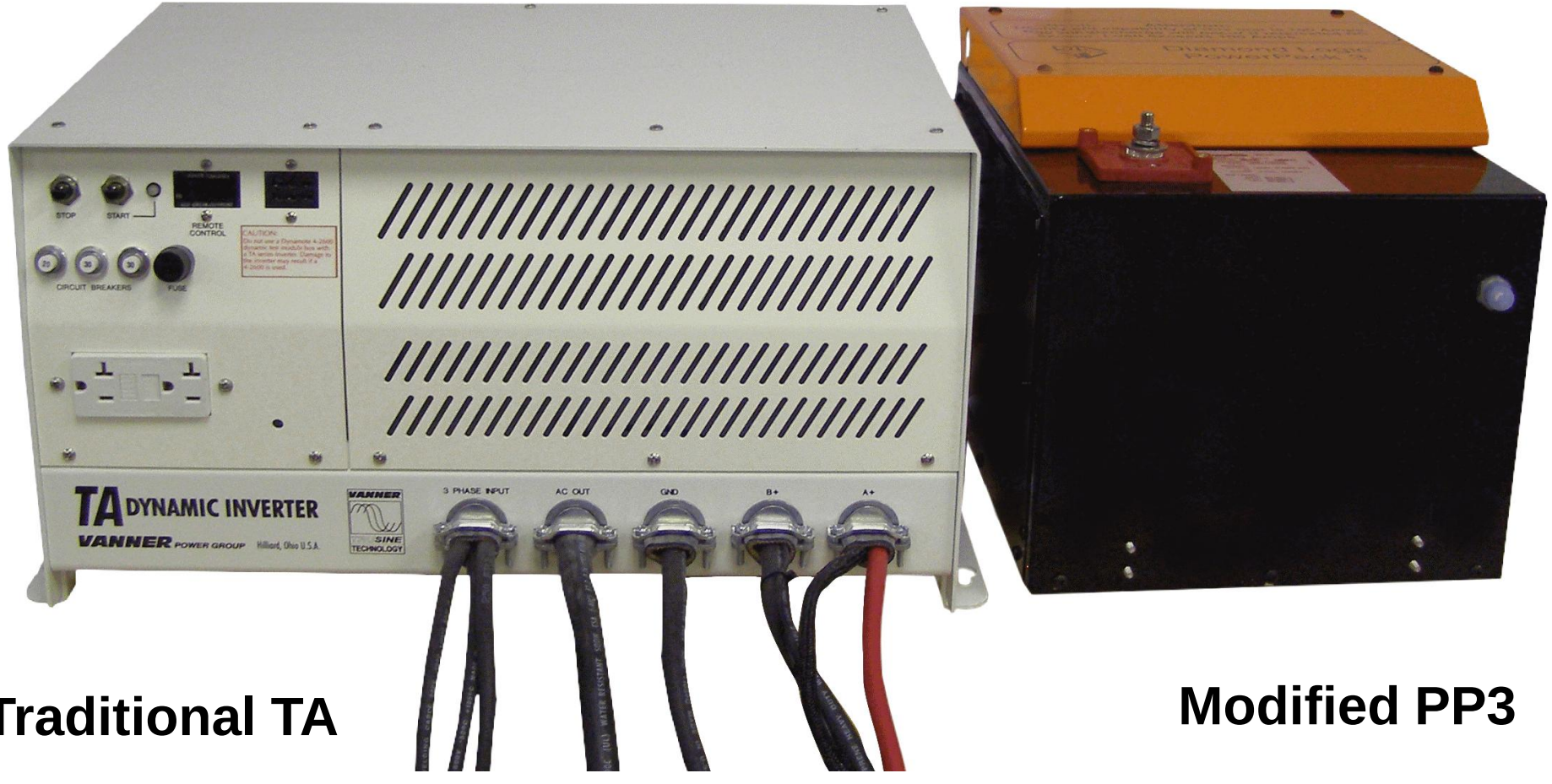
Block Diagram

Block Diagram of a Dynamic Inverter



Comparison between

traditional and modified dynamic inverter



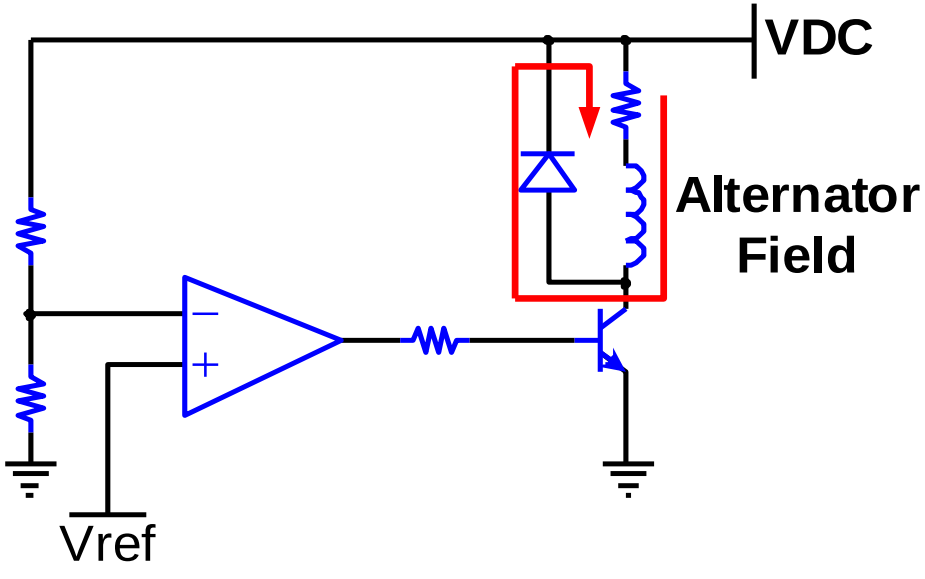
Traditional TA

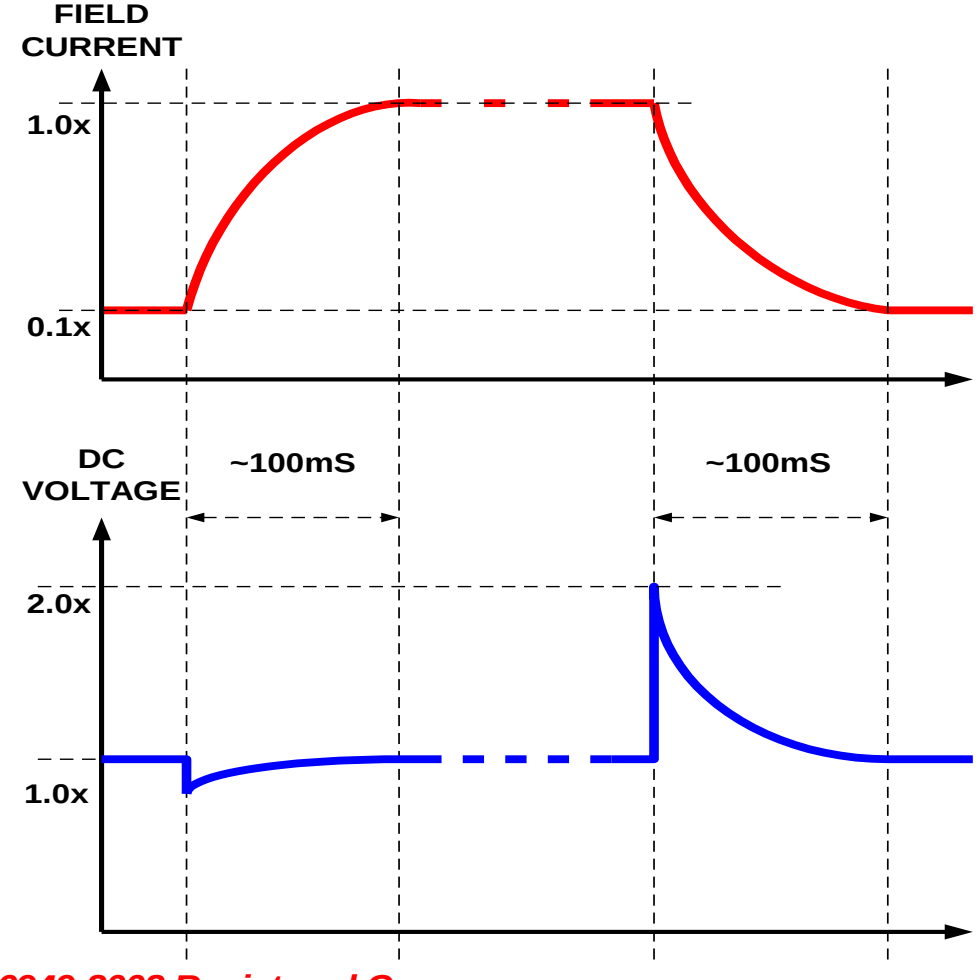
Modified PP3

The cost of the modified inverter
is 17% lower relative to
the cost of the traditional inverter

Simplified Field Regulator

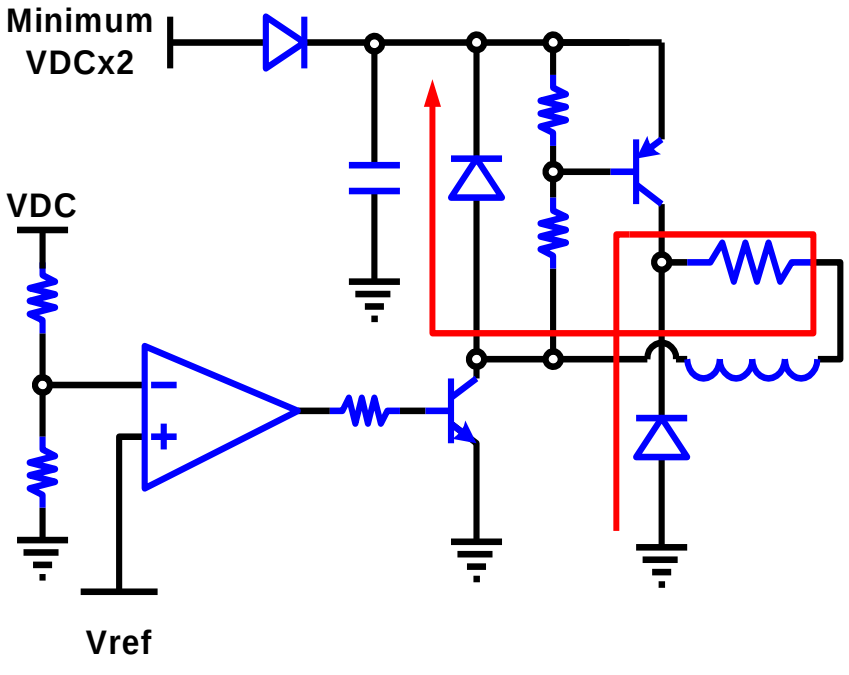
Observed in most cars and traditional inverter

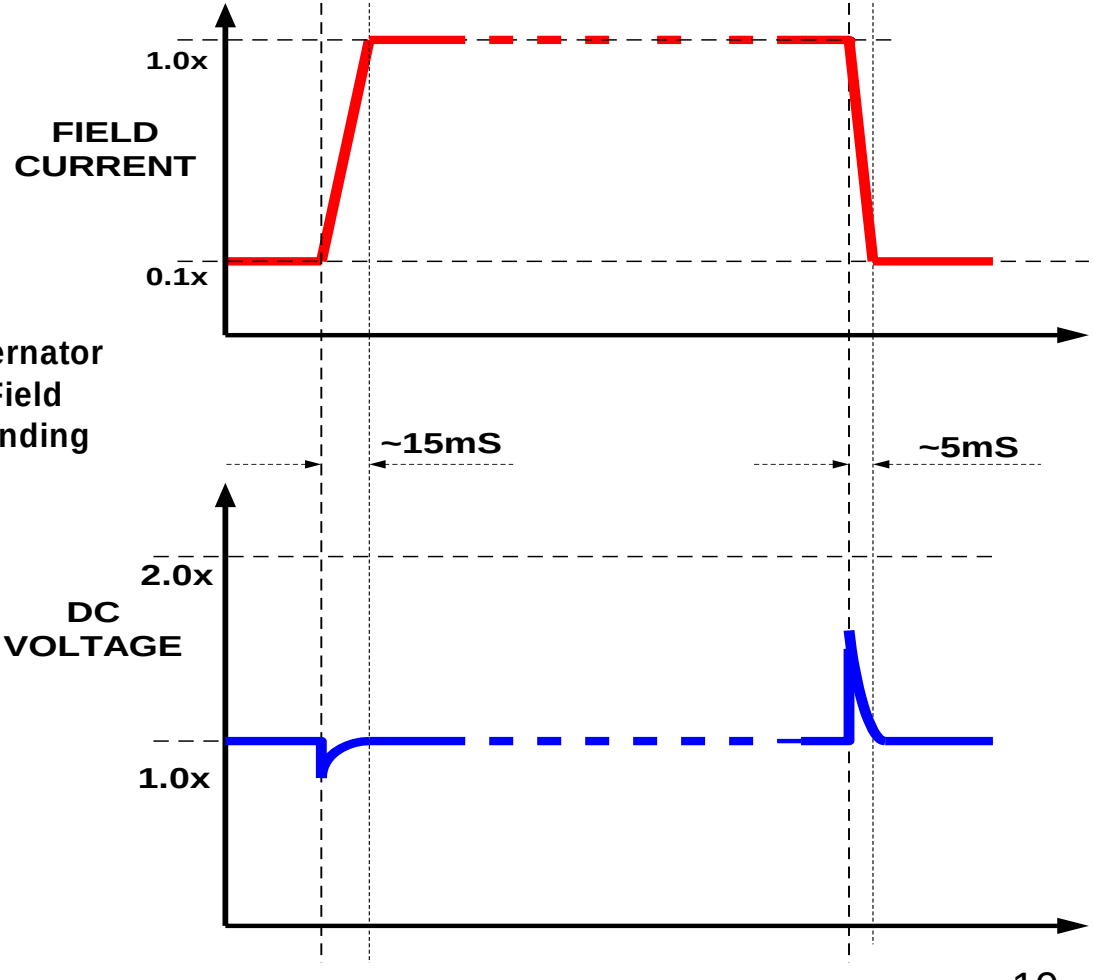




Simplified Field Regulator

Modified Field Regulator





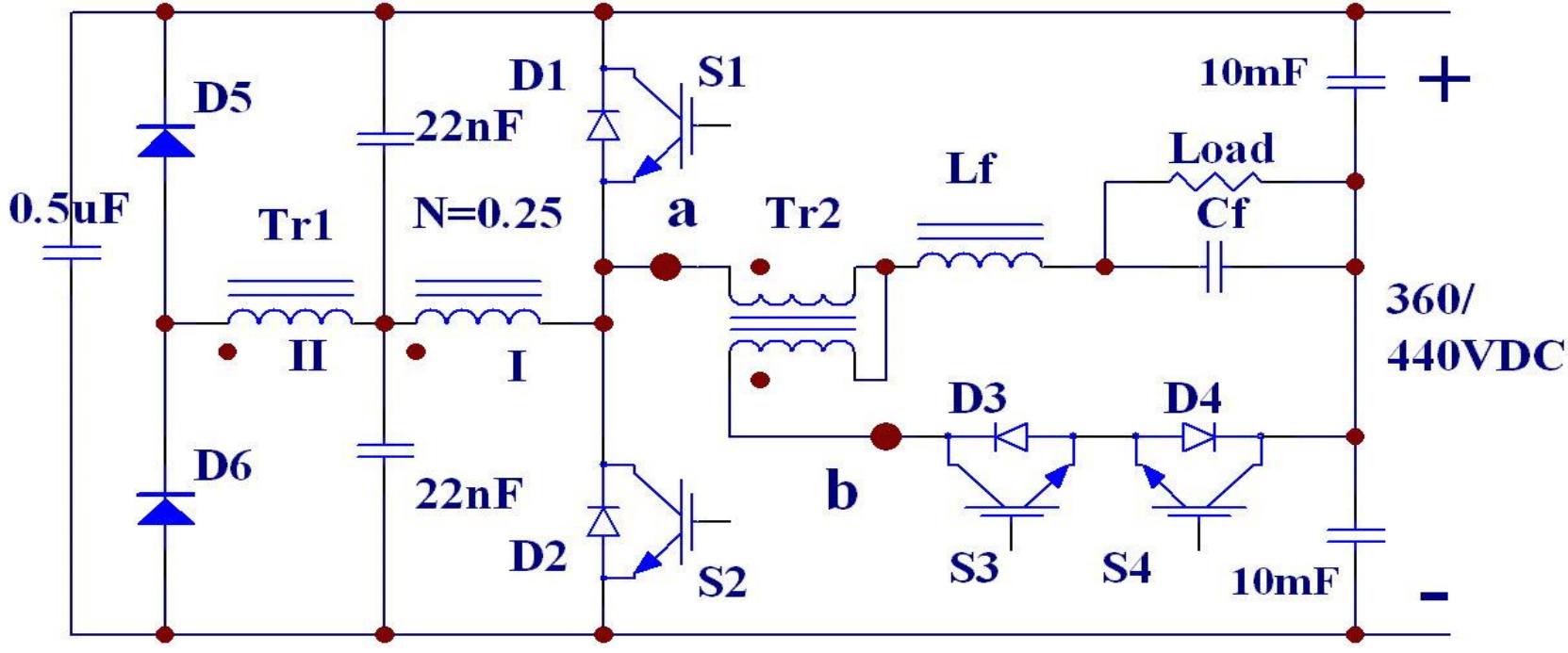
US Patent 7,106,030

Summary of Benefits

- Reduced electrical stress
- Improved response
- Reduced rating for same performance

- These result in reduced cost for the customer

Proposed DC-AC

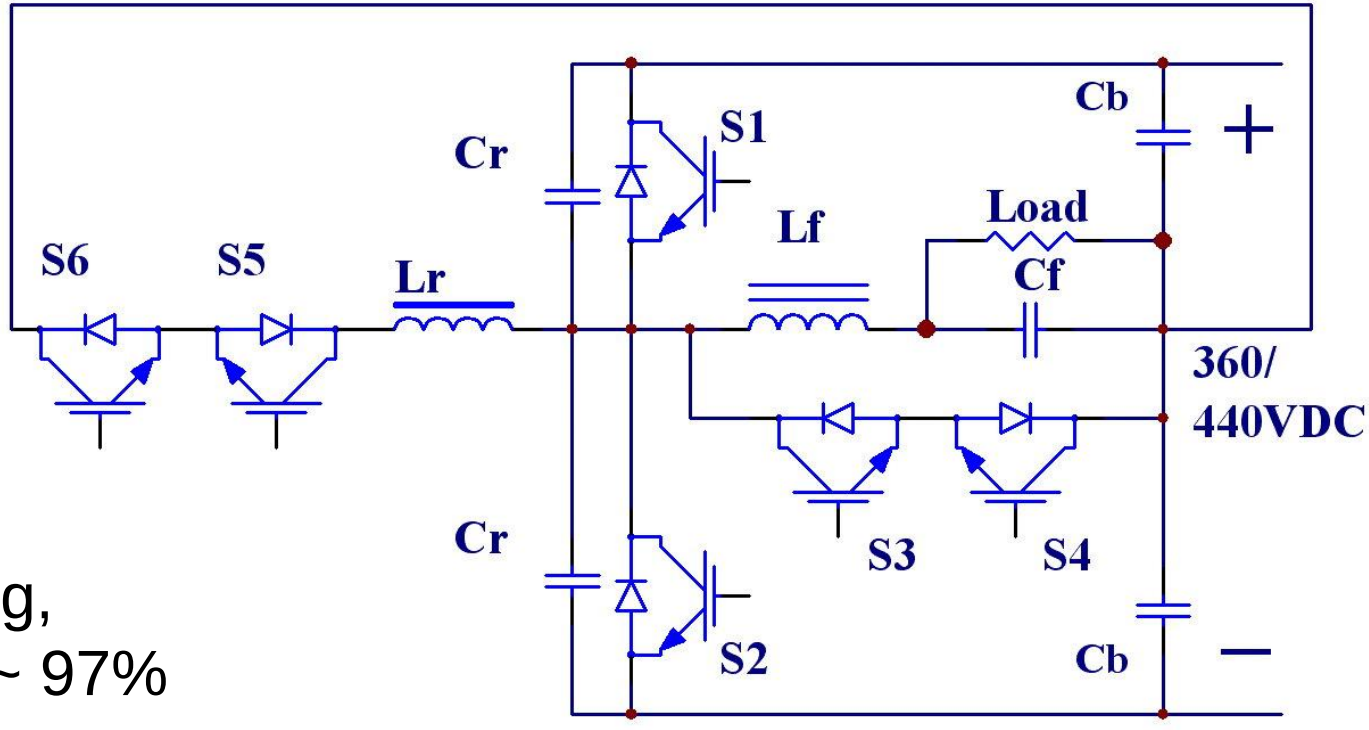


12kW rating, efficiency ~ 97%

Presented APEC2008

Conventional

Single phase DC-AC inverter with ARCP



12kW rating,
Efficiency ~ 97%

Cost comparison Table

For our Described Implementation

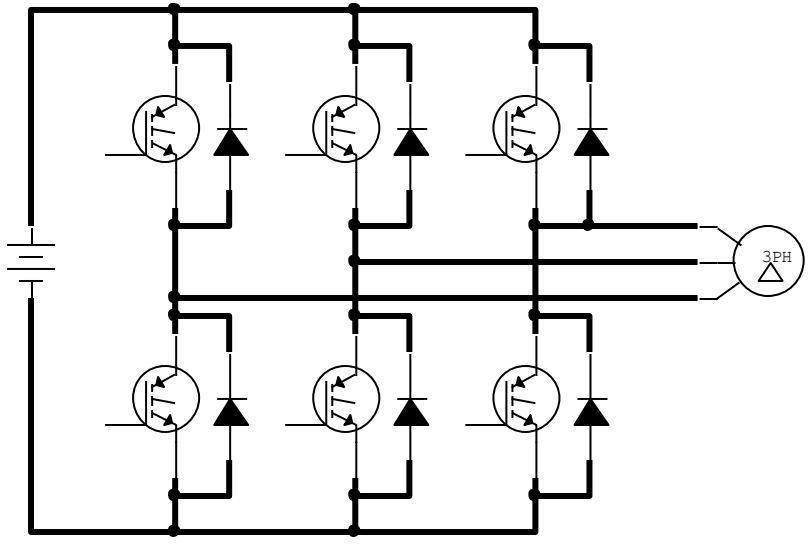
	Inverter with ARCP	New inverter
Cost	Add 2-3%	Basis
Efficiency	equal	equal
EMI	equal	equal
Reliability	Reduced	Basis

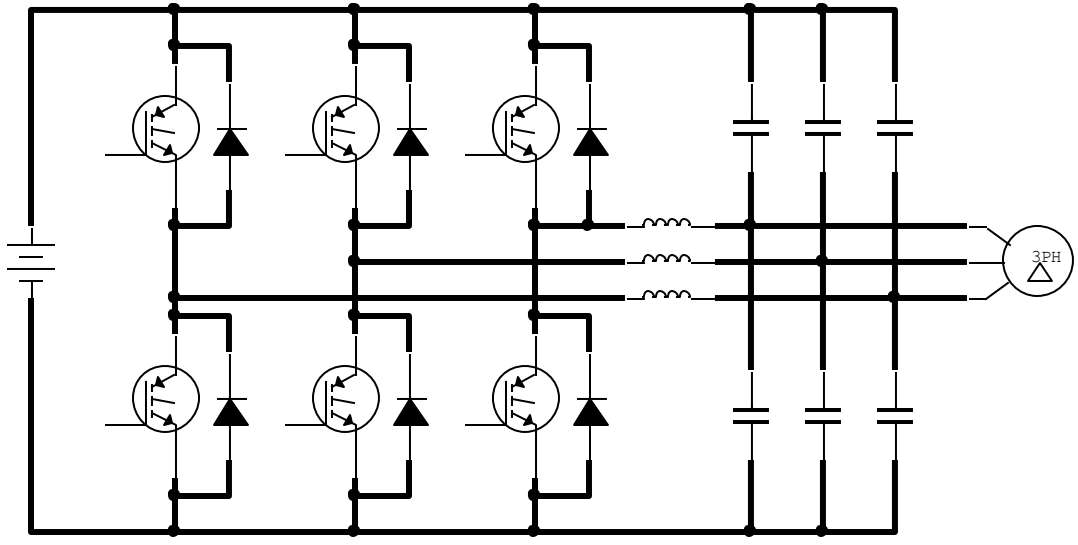
Summary

- Modern components require the use of new technology and philosophies for automotive applications of power converters

Block Diagrams

Motor drive DC-AC Converters without and with LC Filters





System with a filter has higher efficiency under light load,

This point very important for EV vehicle.

Conclusion

The converter and motor should be looked at as **one integrated power stage.** We need to see the whole picture from the start to the end. **Only this way can we get a good cost with optimal performance**.

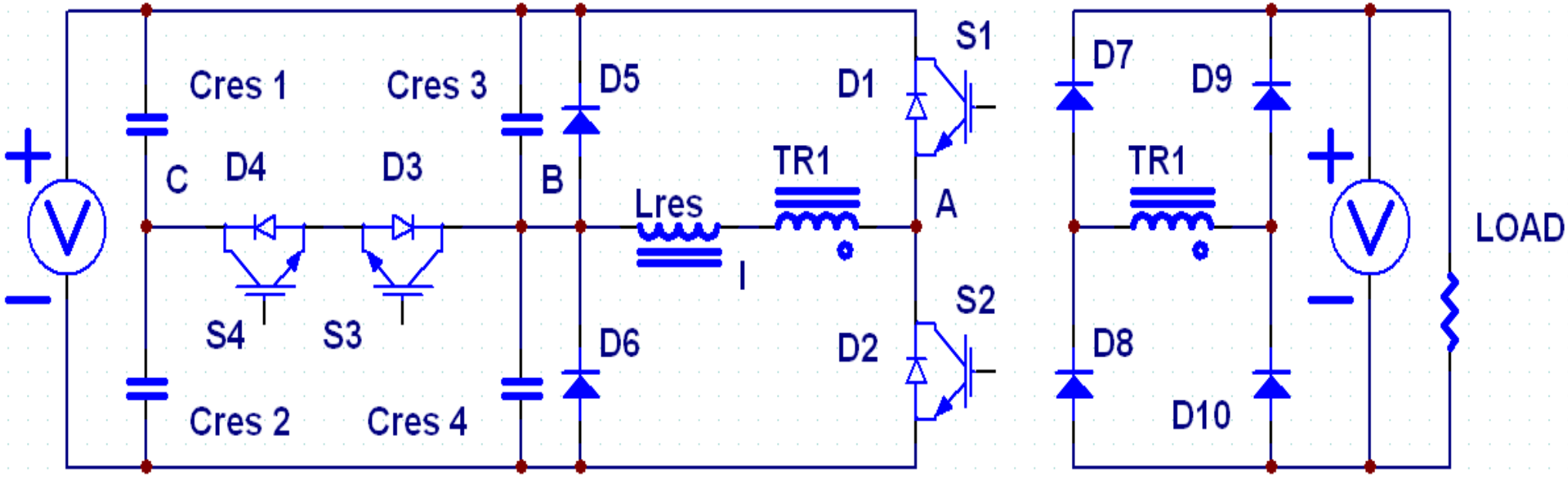
Main Data

9kW Bi-directional DC-DC converter

- High voltage side: 500VDC-800VDC
- Low voltage side: 20VDC-30VDC @300A
- Operational temperature: -40C to +70C @ full power
- Efficiency 94% excluding reverse polarity protection and pre-charge (93% with)
- Efficiency 84% @ 5% load
- Consumption @ idle 60W
- Life time minimum 20 years
- Cost for customer equivalent to conventional alternator

New Topology

DC-DC Converter in Step-down Mode



Presented APEC2006

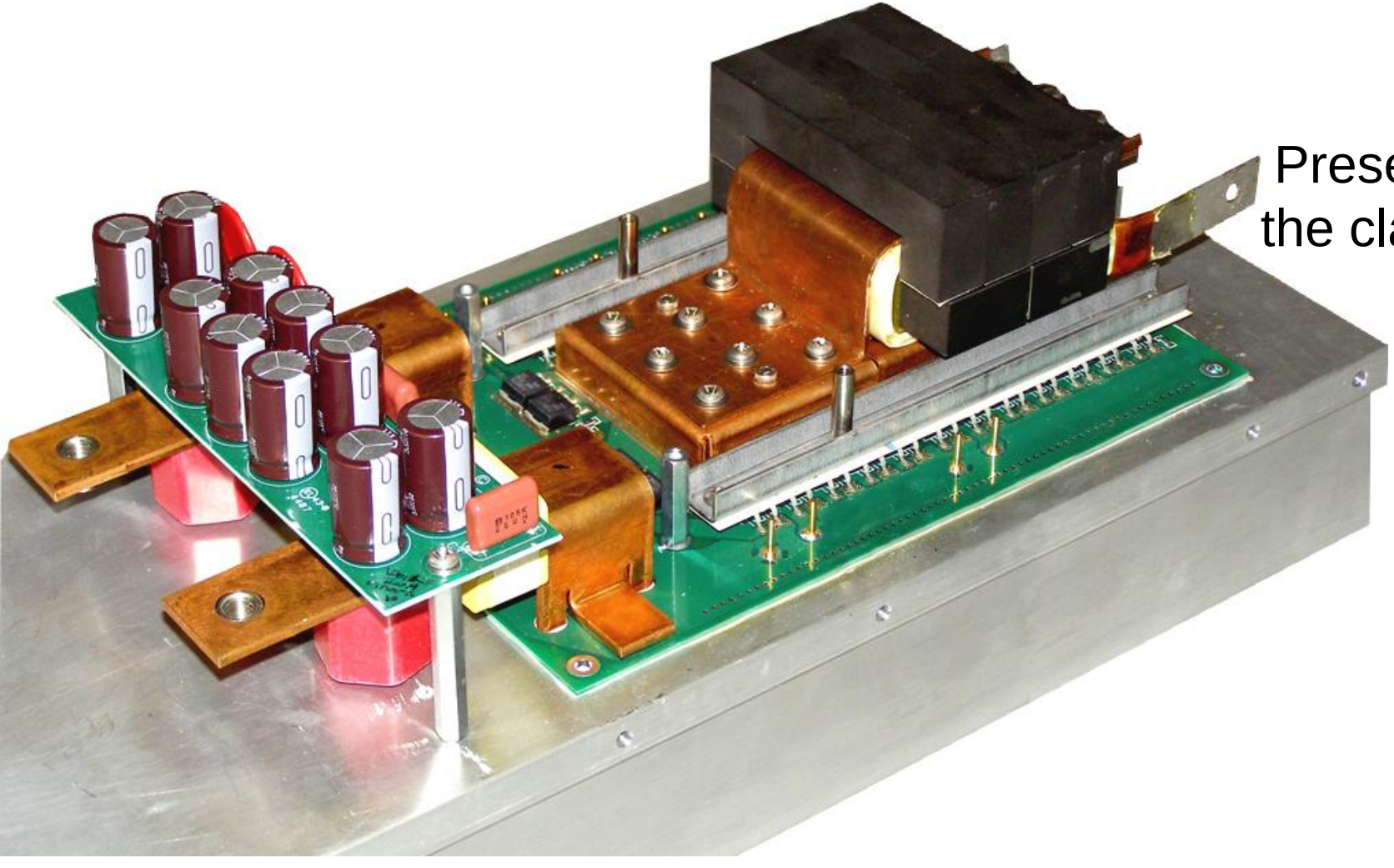
Patent US 6,483,731

Comparisons

PARAMETERS	PHASE-SHIFT	NEW
Max. com. freq.	1x	2x
Load range	Limited	Unlimited
Commutation	ZVS	ZVS ZCS
Rectifier recovery	Recovery losses	Simple and soft
Paralleling of stages	Requires additional control	Simple
Transformer	Not optimal	Optimal
DC-bias	Yes	No
Control	Standard	Special
Idle losses	1.5%	0.15%
COST	**Basis**	**Basis minus >10%**

The both have the same performance.

Low voltage side power stage with integrated power transformer



Presented without the clamping frame

Patent US 7,123,123

Comparisons

Cost and efficiency of the low-voltage side power stage with two types of transformers

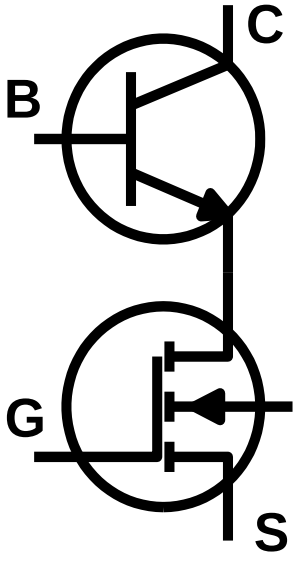
Power Stage Incorporating:	Product Cost	System Efficiency
Integrated transformer	1	94%
Planar transformer	1+20%	92%

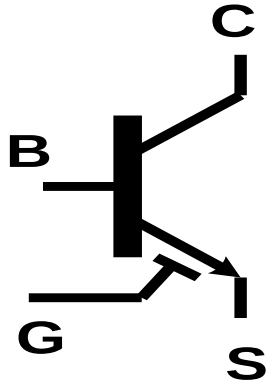
Commutation frequency 110kHz
Low voltage side rating 280A

To use a topology where the transformer works under **optimal conditions**

The transformer itself cannot be useful alone. It can be used only as **part** of the whole power stage

Emitter Switched Bipolar Transistor





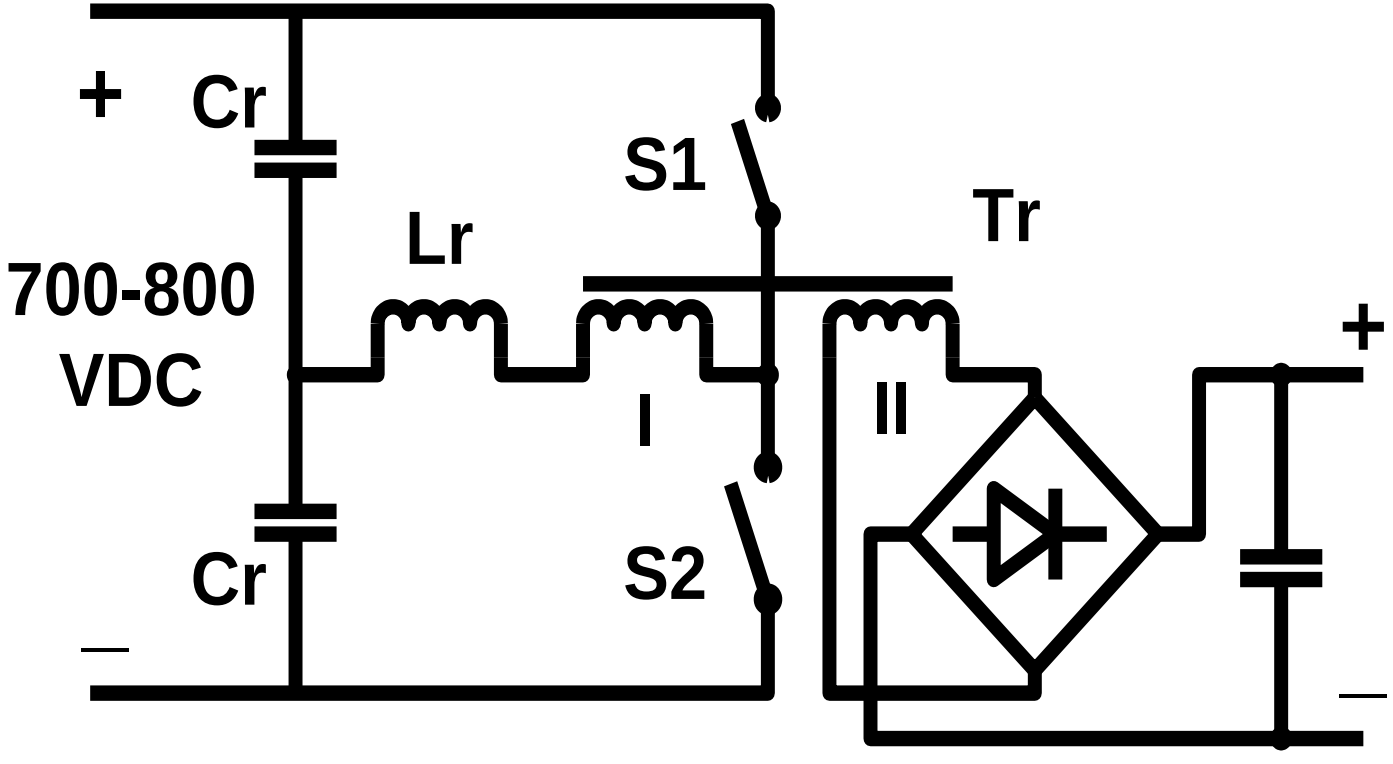
ESBT symbol and equivalent circuit, cascade connection

Comparison:

	ESBT total	SiC
Cost	1	3

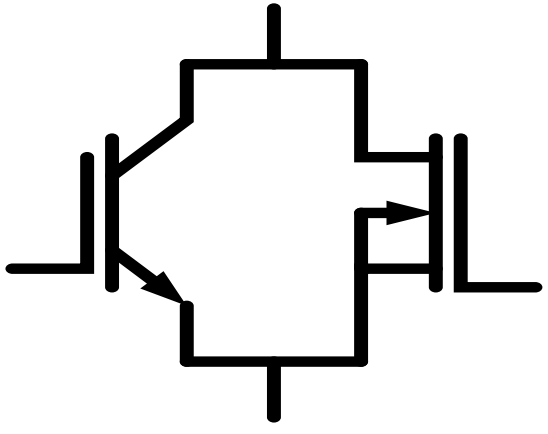
ESBT-STE70IE120 and SiC-SAS100H12AM1 The both have the same performance.

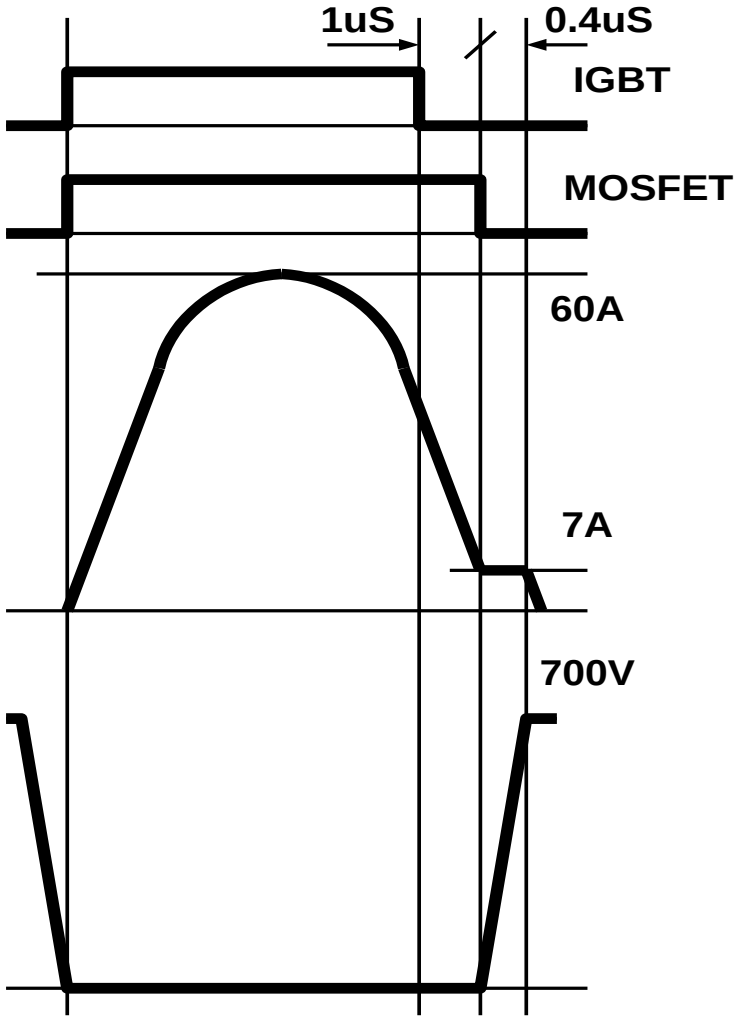
IGBT and MOSFET in Parallel



Commutation Friqency-80kHz Current via Primary winding of transformer is sinusoidal with peak 60A and duty cycle 90-95%

IGBT and MOSFET in Parallel





Simplified waveforms of S2 :
Gate signals
Current and Voltage

Comparison between different combinations of IGBT and MOSFETs.

IGBT-IXEN60120 MOSFET-IXFN32N120

	IGBT	IGBT & MOSFET	Two MOSFET's	Three MOSFET's
COST	N/A	1	1.2	1.9
Power losses per switch	N/A	109W	158W	105W

Compatibility

During the last 15 years the EMI requirements for electronic units for automotive applications has become more stringent,
from CISPR25 class 2 to class 4.
The main reason is the demand for

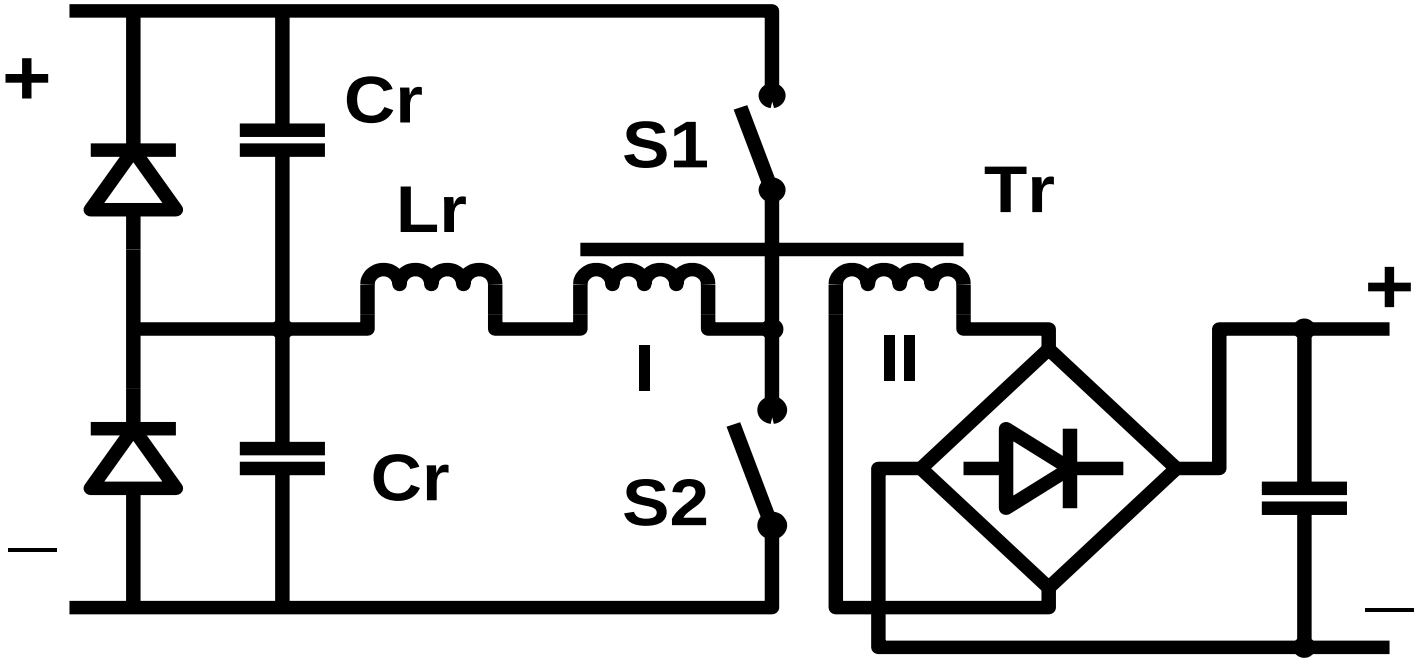
COMPATIBILITY.

The key for this point are soft-switching and maximum slew-rate 2500V/uS

Total cost of ownership considerations

- Product cost
- Diagnostic
- Removal and replacement cost
- Availability (stock) cost
- Loss of use

High cost of automotive maintenance calls for high reliability



Resonant topologies with clamp diodes provide passive power limiting.

Conclusion

- Efficiency target: 92-98% The efficiency itself is not the target, rather the low cost and superior performance
- Use soft-switch technology
- Minimum of active components
- Reduced quantity, and simply constructed, magnetic components
- Use integrated magnetic components
- Use SMA where possible
- Use multi-level topology only when voltage is above 1000VDC
- Limit slew rate to 2500V/uS
- Keep operating frequency high to minimize the filter

Maximize board mounting, minimize chassis mounting

In other words packaging is key to realizing the benefits of the topology

Thank You for Your Attention.