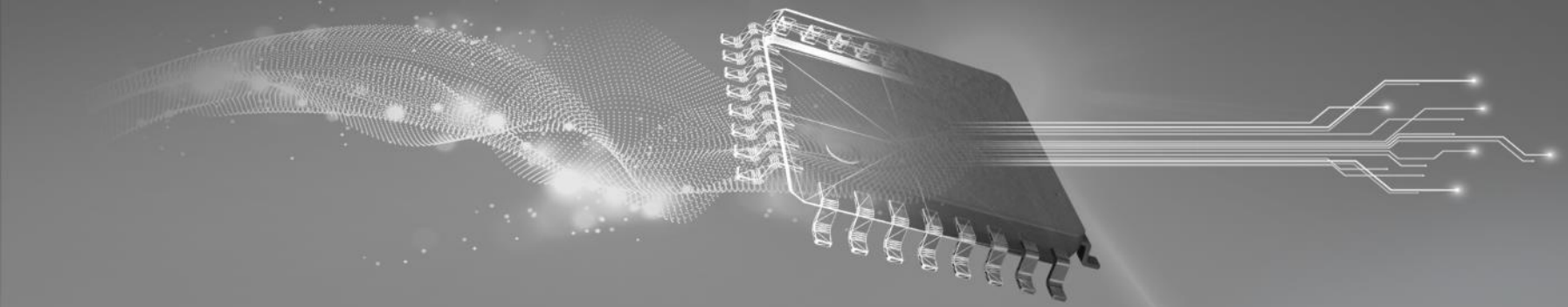
TI TECH DAYS



High-voltage contactor control

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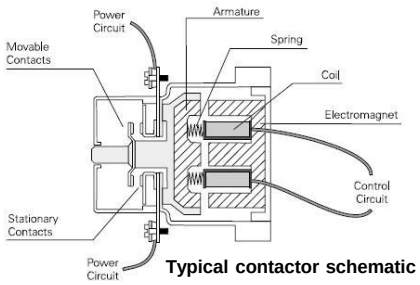
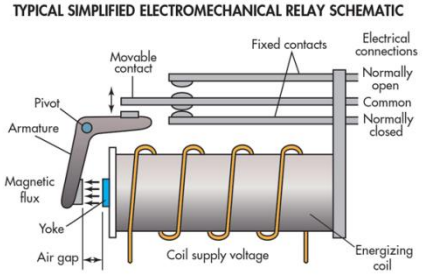
“Relay” and “Contactor”

- **The industry uses the terms ‘High-voltage relay’, ‘high-voltage contactor’ interchangeably and often without distinction for EV/HEV switches**.
- **In general**, both terms designate an electromechanical switching device, working on the same physical principle, where a coil is used to generate a magnetic force that mechanically operates an electric contact.
- **For simplicity,** we can consider the term relay for low and medium power device while the term contactor for high power device.
- **For coil structure perspective,** the magnetic “motor” is typically realized with a plunger in the center of the coil body for contactors, as opposed to a hinged armature design, which is normally used for relays.



Typical contactor schematic



Contents

- ❑ Contactor configuration in EV/HEV
- ❑ Main contactors & sequence
- ❑ Contactor information & control requirement
- ❑ Contactor control principle
- ❑ Contactor control proposal
- ❑ Semiconductor switch trend

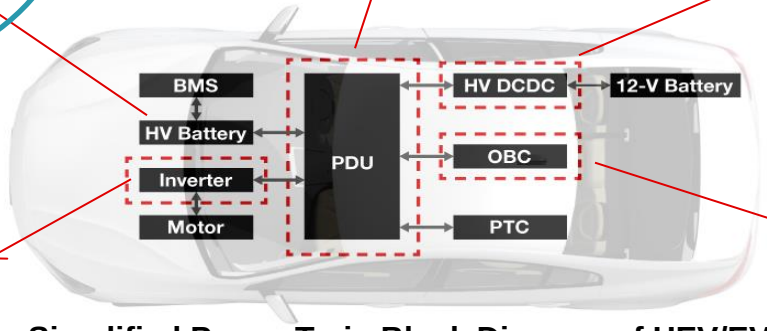
Separate end equipment

HV Battery

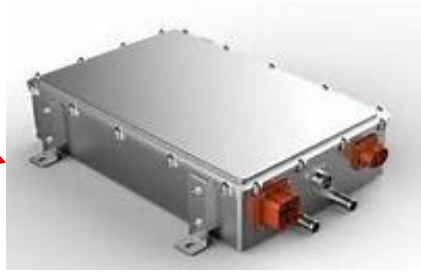
PDU

HV DCDC

Inverter



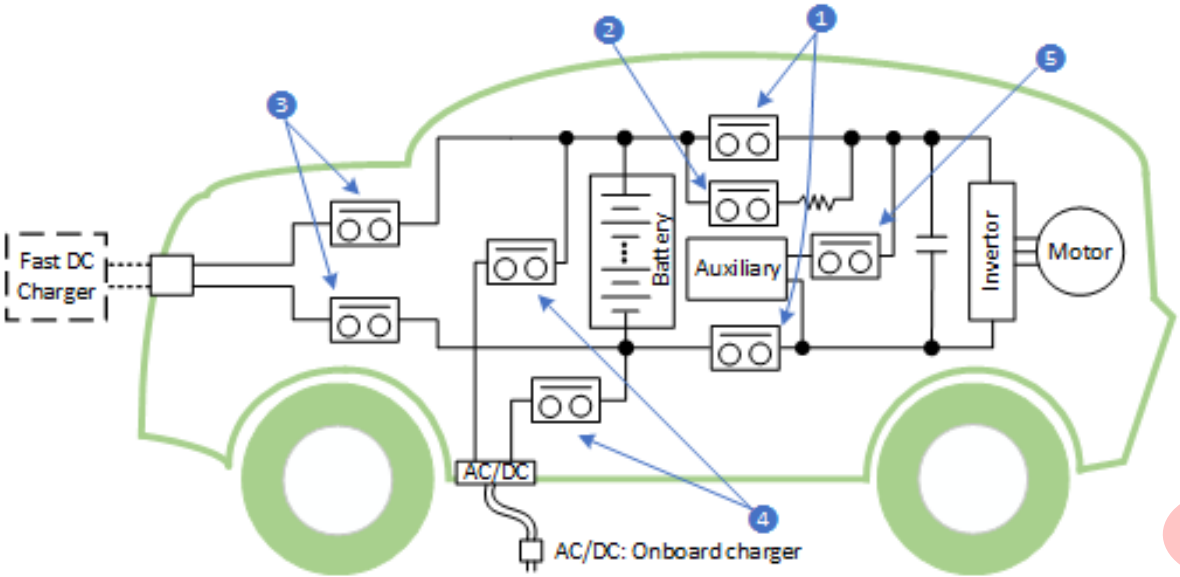
Simplified Power Train Block Diagram of HEV/EV



OBC

- Contactors will exist in HV Battery (BJB/BDU) and PDU.

Contactors in EV/HEV



Typically in PDU (power distribution unit) and controlled by VCU (vehicle control unit)

❷ Pre-charge contactor

❸ DC charge contactors

❹ AC charge contactors

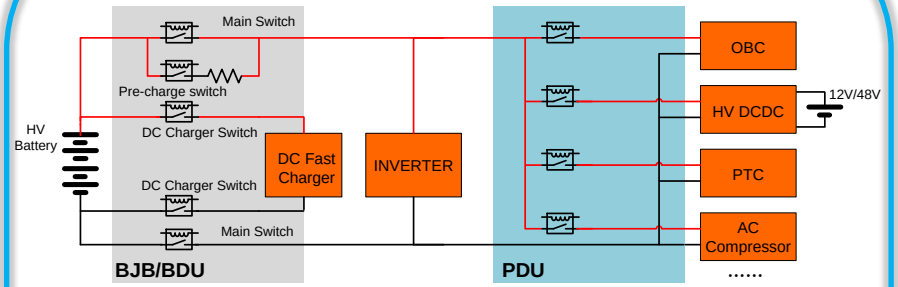
❺ Auxiliary contactor

Typically in BJB/BDU(battery junction box / battery disconnect unit) and controlled by BCU(battery control unit) or dedicated UIR board

- **HEV:** 2 main contactors, 1 pre-charge contactor
- **PHEV:** 2 main contactors, 1 pre-charge contactor, 2 AC charging contactors
- **BEV:** 2 main contactors, 1 pre-charge contactor, 2 AC charging contactors, 2 DC fast charging contactors, and 1 auxiliary contactor

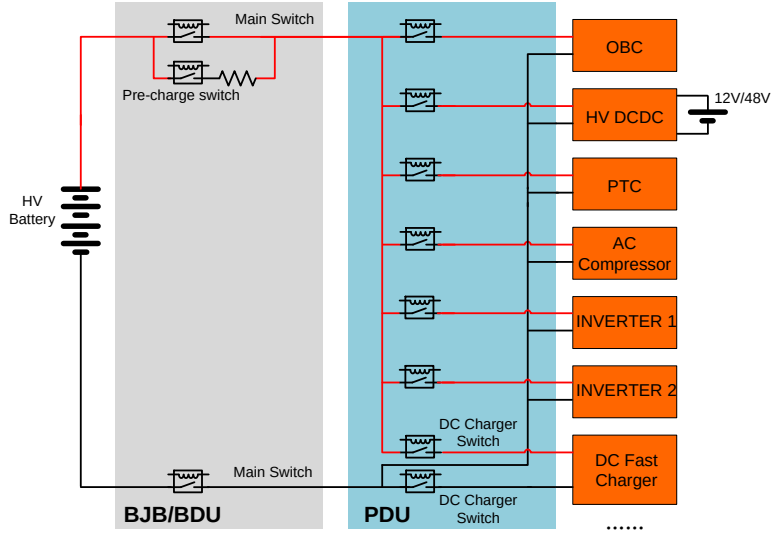
BJB/BDU & PDU topology

Topology 1



- DC Charger Contactors are in **parallel** with Main Contactors
- DC Charger Contactors sit in BJB/BDU and typically controlled by BCU
- Less contactors are used for **cost down**, but can't hand single contactor short circuit

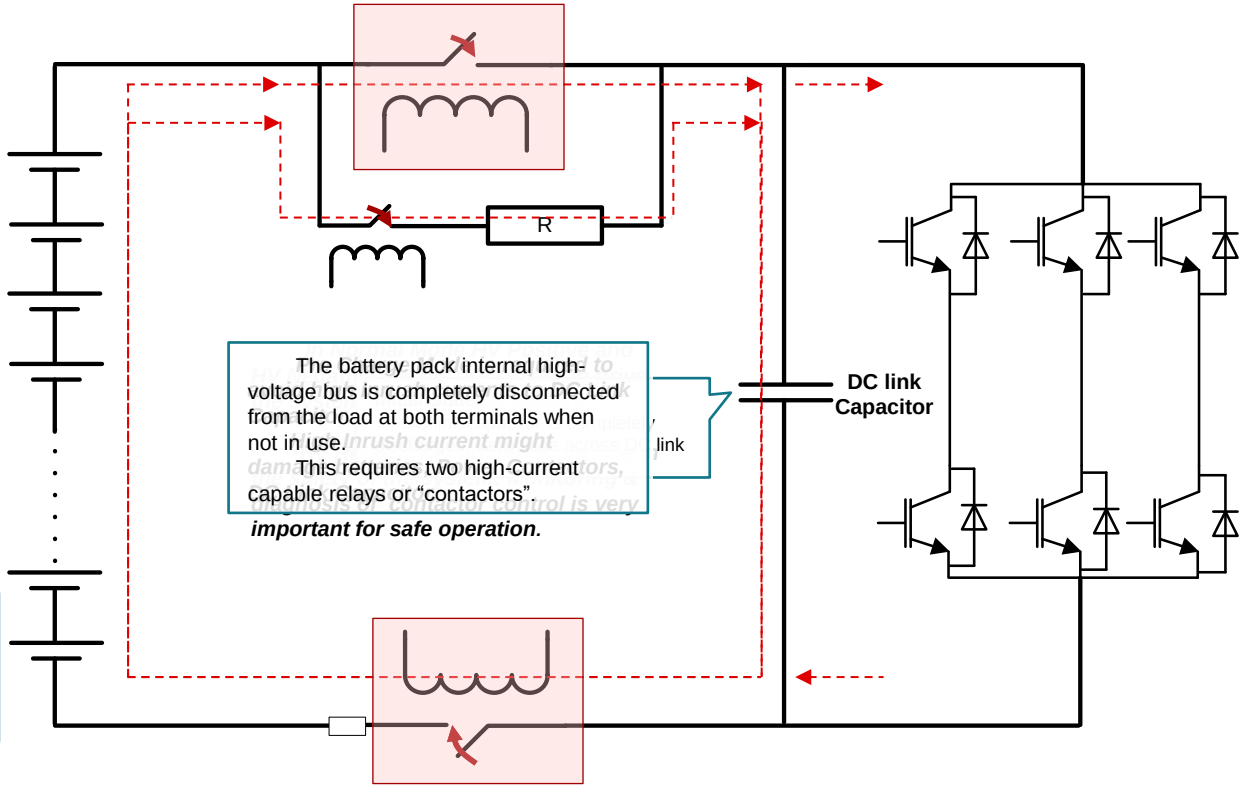
Topology 2



- DC Charger Contactors are in **series** with Main Contactors
- DC Charger Contactors sit in PDU, typically controlled together with other Contactors in PDU by dedicated controller or VCU
- More contactors are used as load switches following main contactors from **robust** perspective of single contactor short circuit

Main contactors & Sequence

Control Sequence



Contactor info

Contactor Information

Three main vendors in the market

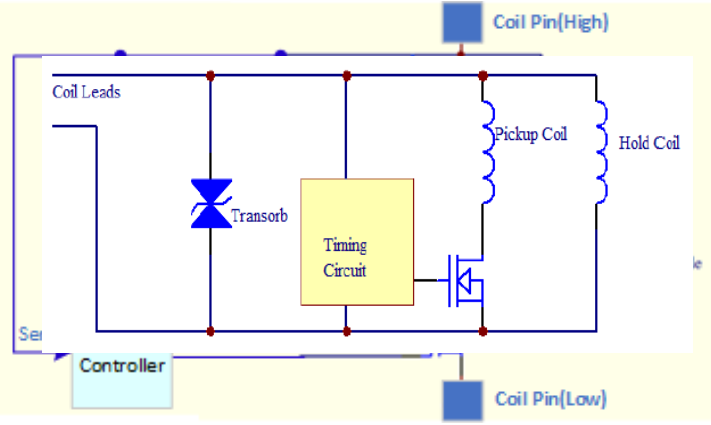
TE 

Panasonic 

GIGAVAC 

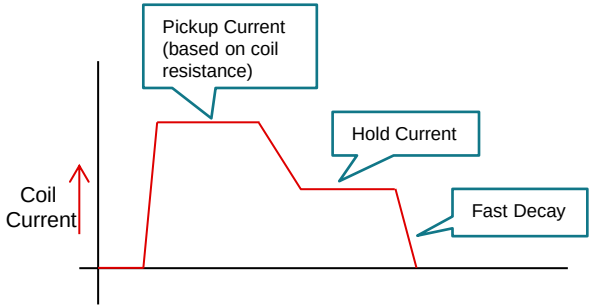
Different coil types

1) Economized coil with internal economizer
   - ❑ ON/OFF control outside contactor(Typically in BCU)
     - ❖ Coil integrates PWM control circuit internally
     - ❖ Dual coil version with internal switch
2) Un-economized coil for external economization
   - ❑ Only coil without PWM control circuit internally
   - ❑ PWM control circuit outside contactor(Typically in BCU)



Control requirement

Driver requirements



✓ **Pickup phase**

Current reaches maximum and contactor closed during the phase

✓ **Hold phase**

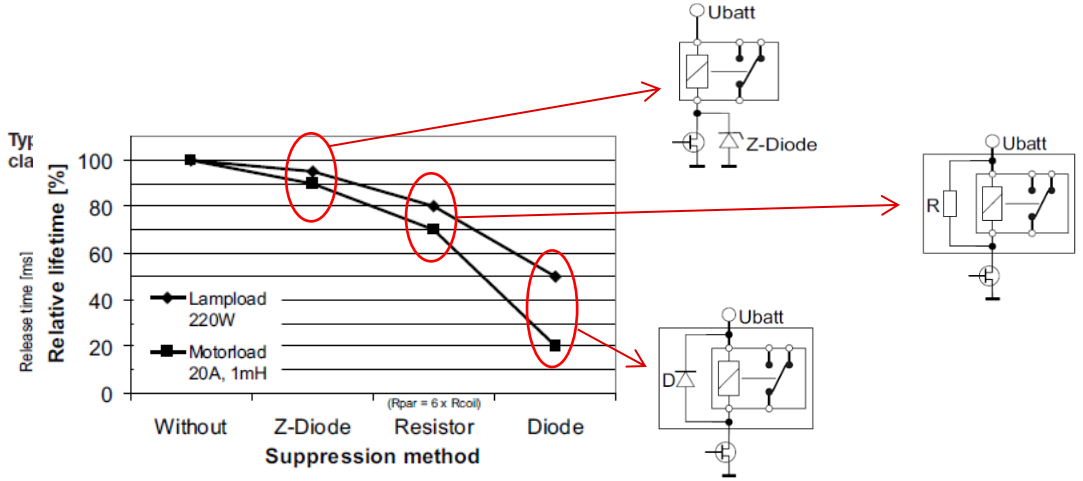
Keep smaller current to maintain contactor closed efficiently

✓ **Fast decay phase**

Current fast decay with voltage suppression to open contactor quickly

Fast decay benefits

- ✓ Faster release time
- ✓ Longer life time



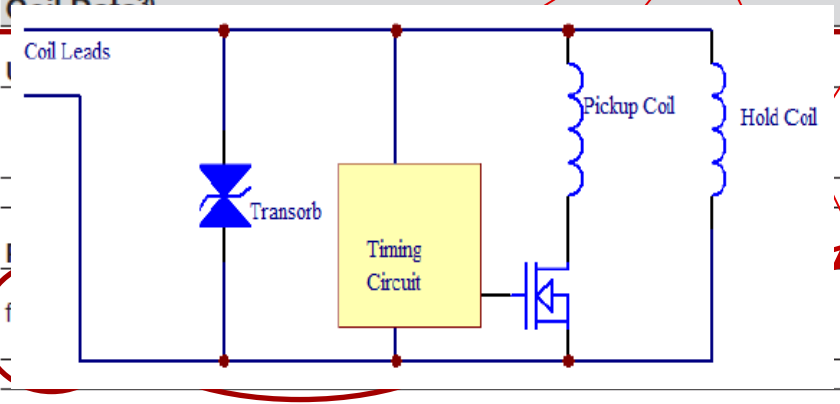
Coil info Example

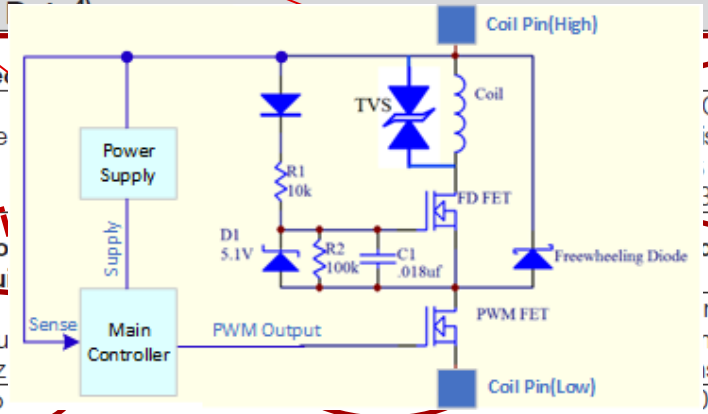
Determine maximum pickup current as UBAT/Rcoil

Hold current requirement with PWM control

EVC250 Spec

EVC500 Spec





Economized: dual coil version with internal switch

Coil code	Rated voltage VDC	Operate voltage VDC	Nominal inrush current ADC	Non-release voltage VDC	Max. voltage VDC	Coil resistance Ω±10%
0002	12	7.0	4.0	4.0	16.0	3.6/36[6]

Economized coil with internal economizer (valid from -40°C to 85°C)

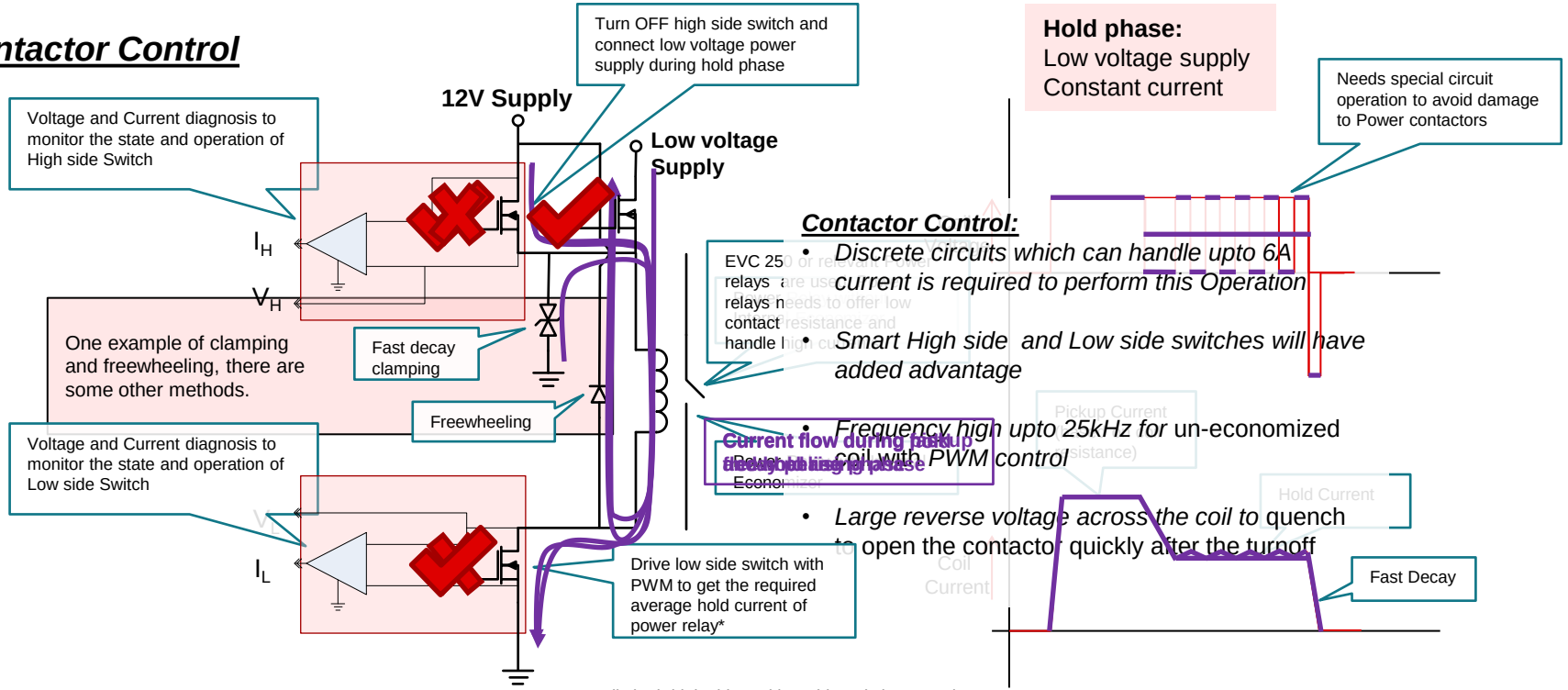
Coil code	Operating voltage range VDC	Inrush current at 23°C A	Max. inrush time ms	Nominal frequency kHz	Nominal duty cycle %
A	9 to 36	3.8	130	19.9	20

Economized coil parameters

Dual coil economizer ⟷ PWM control economizer

Contactor control principle

Contactor Control



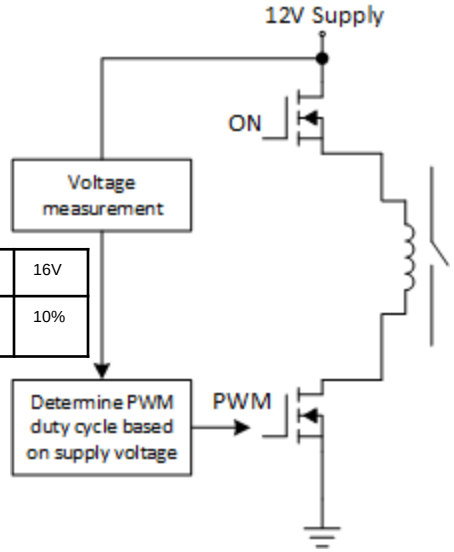
*Actually both high side and low side switches can do PWM control, but it's more suitable to use low side switch do high frequency PWM control up to 25kHz.

PWM hold control loop

Pulse width modulation – voltage feedback

Calibration map example

Voltage	8V	10V	12V	14V	16V
Duty cycle	30%	22%	15%	12%	10%

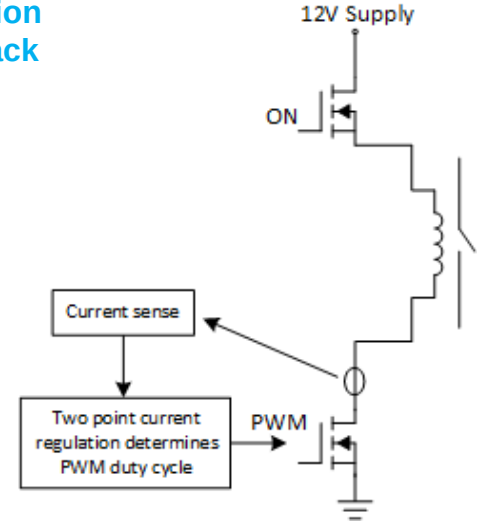


- **Simple realization hardware circuits for low cost**
- Open current loop control with poor current accuracy
- Need each pre-calibration work to get voltage-duty cycle map for different contactors

Pulse width modulation – current feedback

Current setting example

Current	High	Low
Value	1A	0.8A

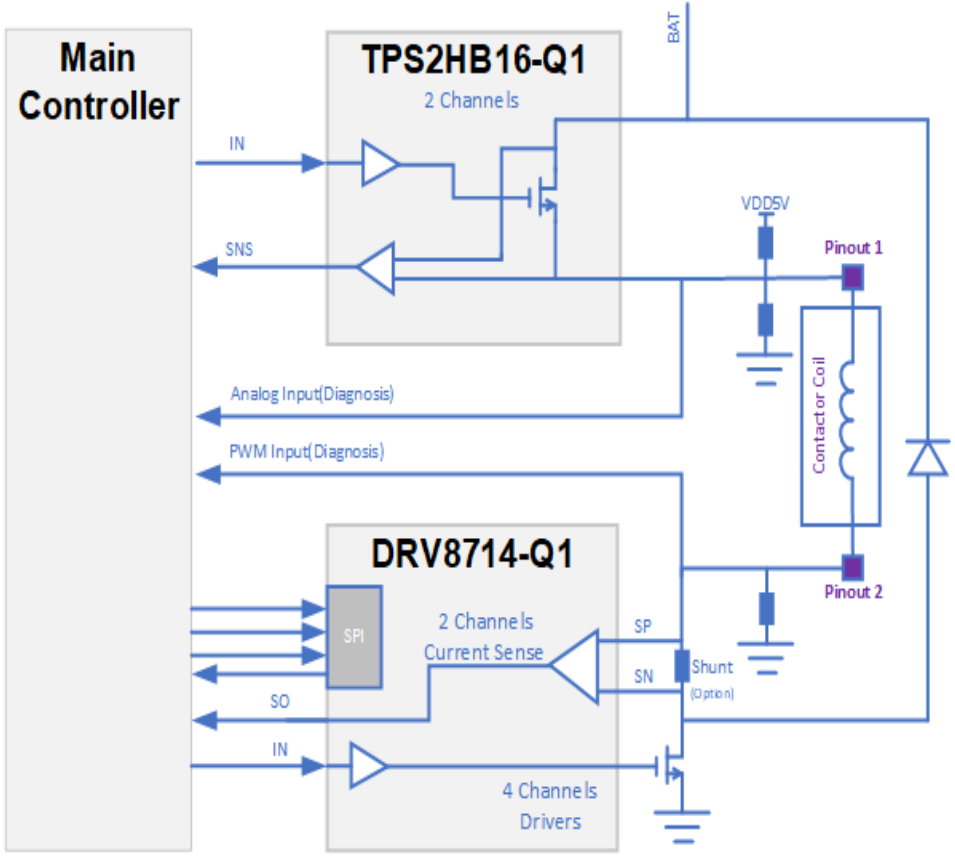


- **Closed current loop control with precise current accuracy**
- No need of voltage-duty cycle map without pre-calibration work
- Dedicated current sense approach with cost increase

Proposal for un-economized coil with PWM control

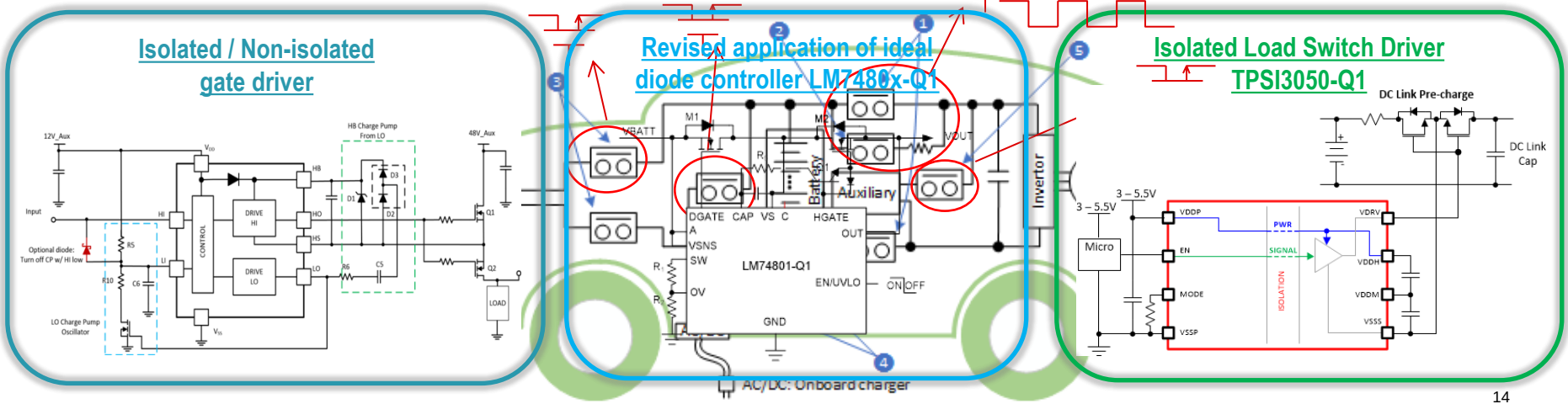
Modular Design w/ Existing Chipsets

- **Solution description**
  - ✓ Fulfill diagnosis function together with pullup, pulldown bias circuits and chip internal diagnosis
  - ✓ Coil current is measured to microcontroller for current close loop control (Current close loop control is not mandatory)
  - ✓ 2-ch current closed loop control(1pcs TPS2HB16 + 1pcs DRV8714)
  - ✓ 4-ch non-current loop control(2pcs TPS2HB16 + 1pcs DRV8714)
- **TPS2HB16-Q1 for ON/OFF high-side control**
  - ✓ Current limit adjustable of 4.1A
  - ✓ Integrated thermal protection
  - ✓ Integrated clamp to demagnetize inductive loads up to 50mJ
  - ✓ Provides fault indication through SNS pin
- **DRV8714-Q1 for PWM low-side control**
  - ✓ 4-ch pre-drivers with up to 62mA output source & sink drive current
  - ✓ 2 channel current shunt amplifiers
  - ✓ I/O PWM input control
  - ✓ SPI: Detailed configuration and diagnostics
  - ✓ Offline open load and short circuit diagnostics



Solid state switch trend

- ✓ Solid state switches have the advantage of low failure rate, long life time and robust integration which trend to replace mechanical contactors.
- ✓ Main positive contactor and pre-charge contactor & resistor can be combined together replaced by a channel solid state switch whilst using PWM control for pre-charging the DC link capacitor.
- ✓ According to LV123-1745 of VW80303, at least one contactor should be retained at one pole while solid state switch is used.
- ✓ **48V system will be the first and ready to adopt Solid State Switches to replace HV Contactors**



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