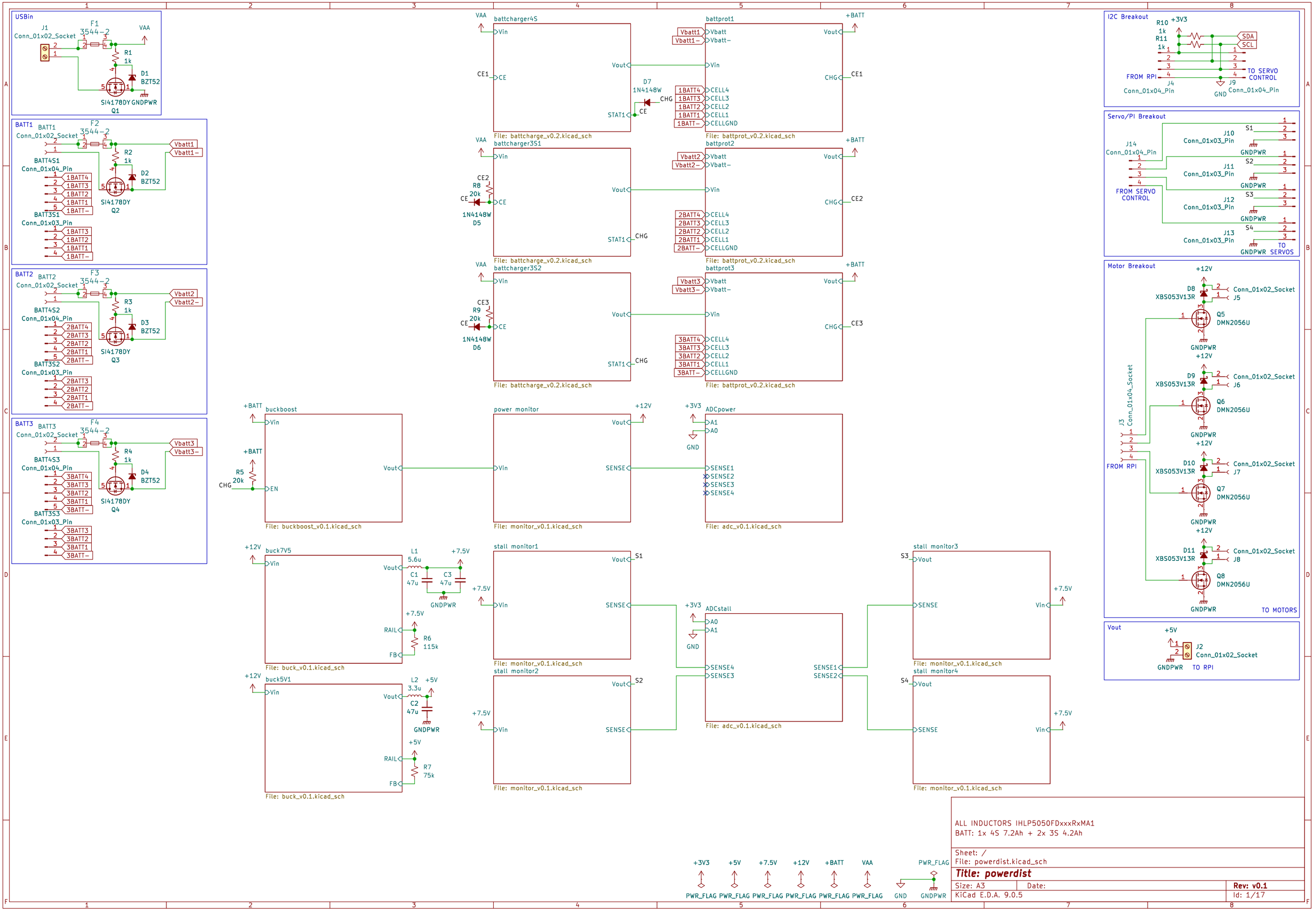

USBin
J1
Conn_01x02_Socket
F1
3544-2
VAA
R1
1k
D1
BZT52
SI4178DY
GNDPWR
Q1
BATT1
BATT1
Conn_01x02_Socket
F2
3544-2
Vbatt1
Vbatt1-
R2
1k
D2
BZT52
SI4178DY
Q2
BATT4S1
Conn_01x04_Pin
1BATT4
1BATT3
1BATT2
1BATT1
1BATT-
BATT3S1
Conn_01x03_Pin
1BATT3
1BATT2
1BATT1
1BATT-
BATT2
BATT2
Conn_01x02_Socket
F3
3544-2
Vbatt2
Vbatt2-
R3
1k
D3
BZT52
SI4178DY
Q3
BATT4S2
Conn_01x04_Pin
2BATT4
2BATT3
2BATT2
2BATT1
2BATT-
BATT3S2
Conn_01x03_Pin
2BATT3
2BATT2
2BATT1
2BATT-
BATT3
BATT3
Conn_01x02_Socket
F4
3544-2
Vbatt3
Vbatt3-
R4
1k
D4
BZT52
SI4178DY
Q4
BATT4S3
Conn_01x04_Pin
3BATT4
3BATT3
3BATT2
3BATT1
3BATT-
BATT3S3
Conn_01x03_Pin
3BATT3
3BATT2
3BATT1
3BATT-
VAA
battcharger4S
Vin
CE1
CE
Vout
STAT1
D7
1N4148W
CHG
CE
File: battcharge_v0.2.kicad_sch
battprot1
Vbatt1
Vbatt1-
Vbatt
Vbatt-
Vout
Vin
CHG
CE1
1BATT4
1BATT3
1BATT2
1BATT1
1BATT-
CELL4
CELL3
CELL2
CELL1
CELLGND
File: battprot_v0.2.kicad_sch
+BATT
VAA
battcharger3S1
Vin
CE2
R8
20k
CE
1N4148W
D5
Vout
STAT1
CHG
File: battcharge_v0.2.kicad_sch
battprot2
Vbatt2
Vbatt2-
Vbatt
Vbatt-
Vout
Vin
CHG
CE2
2BATT4
2BATT3
2BATT2
2BATT1
2BATT-
CELL4
CELL3
CELL2
CELL1
CELLGND
File: battprot_v0.2.kicad_sch
VAA
battcharger3S2
Vin
CE3
R9
20k
CE
1N4148W
D6
Vout
STAT1
CHG
File: battcharge_v0.2.kicad_sch
battprot3
Vbatt3
Vbatt3-
Vbatt
Vbatt-
Vout
Vin
CHG
CE3
3BATT4
3BATT3
3BATT2
3BATT1
3BATT-
CELL4
CELL3
CELL2
CELL1
CELLGND
File: battprot_v0.2.kicad_sch
+BATT
buckboost
Vin
+BATT
R5
20k
CHG
EN
Vout
File: buckboost_v0.1.kicad_sch
power monitor
+12V
Vout
Vin
SENSE
File: monitor_v0.1.kicad_sch
+3V3
ADCpower
A1
A0
GND
SENSE1
SENSE2
SENSE3
SENSE4
File: adc_v0.1.kicad_sch
+12V
buck7V5
Vin
Vout
L1
5.6u
C1
47u
C3
47u
GNDPWR
+7.5V
RAIL
R6
115k
FB
File: buck_v0.1.kicad_sch
+12V
buck5V1
Vin
Vout
L2
3.3u
+5V
C2
47u
GNDPWR
RAIL
R7
75k
FB
File: buck_v0.1.kicad_sch
stall monitor1
Vout
S1
+7.5V
Vin
SENSE
File: monitor_v0.1.kicad_sch
stall monitor2
Vout
S2
+7.5V
Vin
SENSE
File: monitor_v0.1.kicad_sch
+3V3
ADCstall
A0
A1
GND
SENSE4
SENSE3
SENSE1
SENSE2
File: adc_v0.1.kicad_sch
stall monitor3
S3
Vout
SENSE
+7.5V
Vin
File: monitor_v0.1.kicad_sch
stall monitor4
S4
Vout
SENSE
+7.5V
Vin
File: monitor_v0.1.kicad_sch
I2C Breakout
+3V3
R10
1k
R11
1k
SDA
SCL
FROM RPI
J4
Conn_01x04_Pin
TO SERVO CONTROL
J9
Conn_01x04_Pin
GND
Servo/PI Breakout
J14
Conn_01x04_Pin
FROM SERVO CONTROL
J10
Conn_01x03_Pin
S1
GNDPWR
J11
Conn_01x03_Pin
S2
GNDPWR
J12
Conn_01x03_Pin
S3
GNDPWR
J13
Conn_01x03_Pin
S4
GNDPWR
TO SERVOS
Motor Breakout
+12V
D8
XBS053V13R
Conn_01x02_Socket
J5
Q5
DMN2056U
GNDPWR
+12V
D9
XBS053V13R
Conn_01x02_Socket
J6
Q6
DMN2056U
GNDPWR
+12V
J3
Conn_01x04_Socket
FROM RPI
D10
XBS053V13R
Conn_01x02_Socket
J7
Q7
DMN2056U
GNDPWR
+12V
D11
XBS053V13R
Conn_01x02_Socket
J8
Q8
DMN2056U
GNDPWR
TO MOTORS
Vout
+5V
J2
Conn_01x02_Socket
GNDPWR
TO RPI
ALL INDUCTORS IHLP5050FDxxxRxMA1
BATT: 1x 4S 7.2Ah + 2x 3S 4.2Ah
Sheet: /
File: powerdist.kicad_sch
Title: powerdist
Size: A3
Date:
Rev: v0.1
KiCad E.D.A. 9.0.5
Id: 1/17
+3V3
+5V
+7.5V
+12V
+BATT
VAA
PWR_FLAG
GND
GNDPWR

USB Input

Vin
Vchg
R12
2
C4
2.2u
>=100V rating
high ESR?
GNDPWR

Status

VAA
D12
LTST-C190KRKT
R13
895
PG
ACTIVE?
D13
LTST-C190KSKT
R14
895
STAT1
CHG?
D14
LTST-C190GKT
R15
895
STAT2
DONE?

U1 BQ24610

Vchg
!DS7!
C5
1u
GND
ACN
ACP
ACDRV
CE
VREF
ISET1
ISET2
ACSET
TTC
VCC
BATDRV
HIDRV
PH
BTST
REGN
LODRV
SRP
SRN
VFB
STAT1
STAT2
PG
TS
GND
!DS12.2!
REGN
C8
1u
!DS7!
GNDPWR
CSRP
C9
100n
!DS12.4!
CSRN
C10
100n
Vfb
STAT1
STAT2
Vref
R17
500k
R18
500k
use battprot's TS->CHG->CE
C6
1u
ISET1
ISET2
Vref
C7
33n

Buck

Vchg
C11
10u
C12
10u
GNDPWR
!DS12.1!
!DS12.6!
REGN
HIDRV
!DS12.2!
Q9
SIS412DN
D15
BAT54CL
BTST
C14
100n
PH
L3
3.3u
CSRP
R26
10m
CSRN
!DS12.4!
Vout
C15
10u
C16
10u
C17
10u
C18
10u
LODRV
!DS12.2!
Q10
SIS412DN
GNDPWR
!DS12.5!
!DS12.6!

Batt Regulator

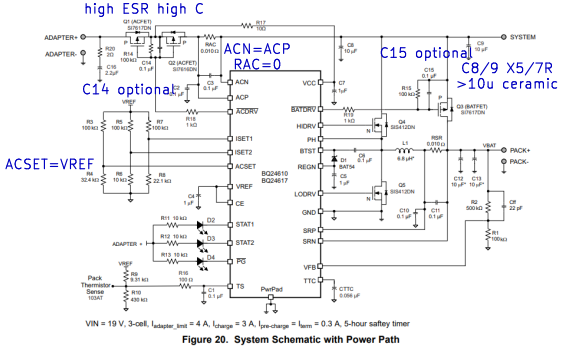
Vout
SW1
OS102011M
C13
22p
R19
700k
R20
500k
R21
100k
Vfb
3S
4S
GND

Cell Selection

Vref
SW2A
JS202011CQN
SW2B
JS202011CQN
ISET1
ISET2
R22
76.8k
R23
26.1k
4.2A
R24
57.6k
R25
44.2k
7.2A
R27
120k
R28
33k
0.72A
R29
90.9k
R30
13k
0.42A
GND

hell to RC: Cin ftw
high ESR high C

ACN=ACP
RAC=0
C15 optional
C8/9 X5/7R
>10u ceramic
C14 optional
ACSET=VREF



VIN = 19 V, 3-cell, $I_{adapter\_limit}$ = 4 A, I_{charge} = 3 A, $I_{pre-charge}$ = I_{term} = 0.3 A, 5-hour safety timer

Figure 20. System Schematic with Power Path

Calculations

Vin=20V
4S 7.2Ah
Vbatt=16.8V=4*4.2V
Pchg=103.68W

D=84%
L=3.3uH
dI=1.4A
Ichg=7.2A
C=40u (datasheet)

Ichg=7.2A
Viset1=1.44V
R8=1.44/3.3=43.6%
R8=44.2k,R7=57.6k

Ipcg=Iterm=0.72A
Viset2=0.72V
R6=0.72/3.3=21.8%
R6=33k,R5=120k

Vin=20V
3S 4.2Ah
Vbatt=12.6V=4*4.2V
Pchg=46.62W

D=63%
L=3.3uH
dI=2.4A
Ichg=4.2A
C=40u (datasheet)

Ichg=4.2A
Viset1=0.84V
R8=0.84/3.3=25.4%
R8=26.1k,R7=76.8k

Ipcg=Iterm=0.42A
Viset2=0.42V
R6=0.42/3.3=12.7%
R6=13k,R5=90.9k

CTTC=33nF
tmax=184.8min

R2/R1=7or5
R1=100k

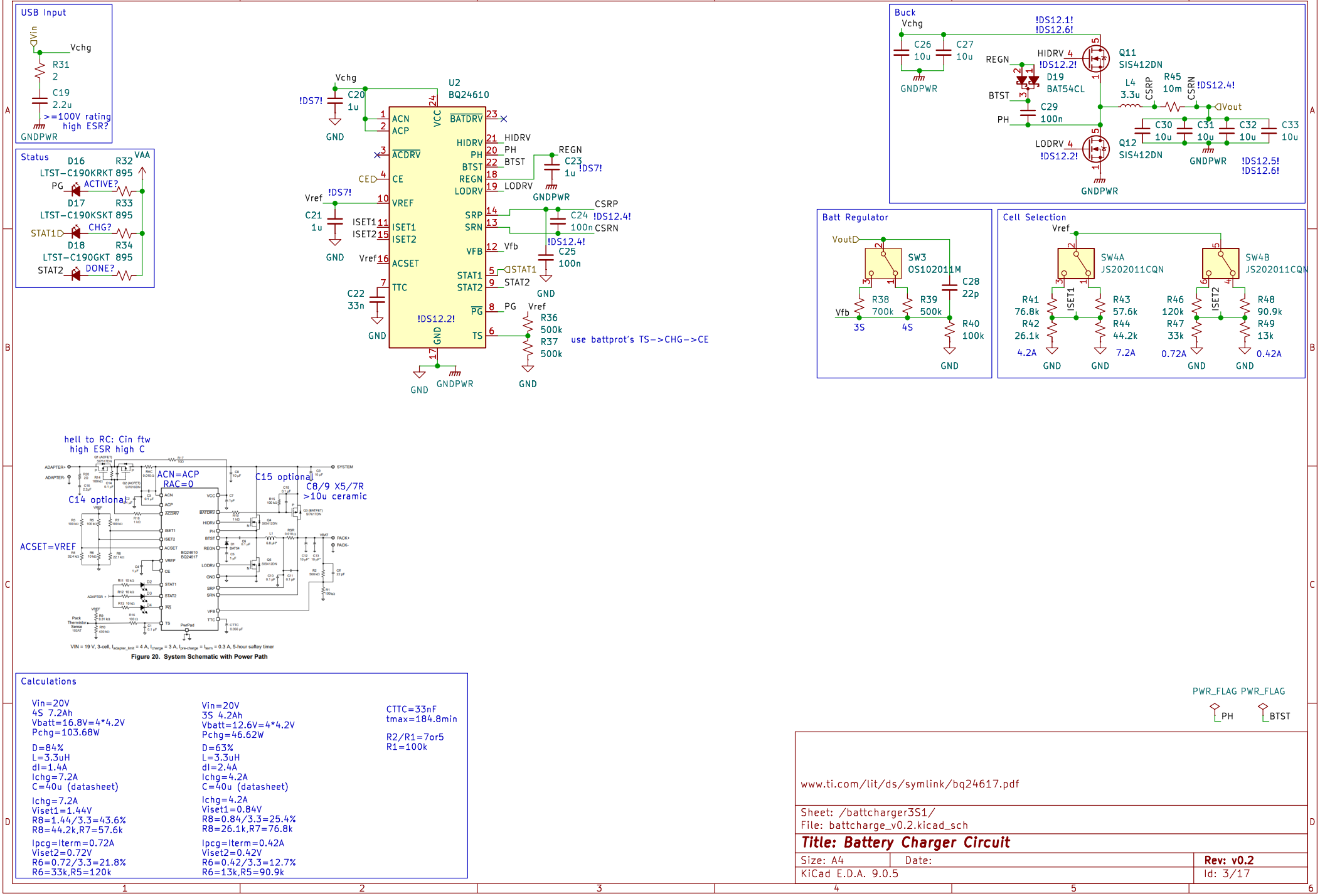
PWR_FLAG PWR_FLAG
PH
BTST

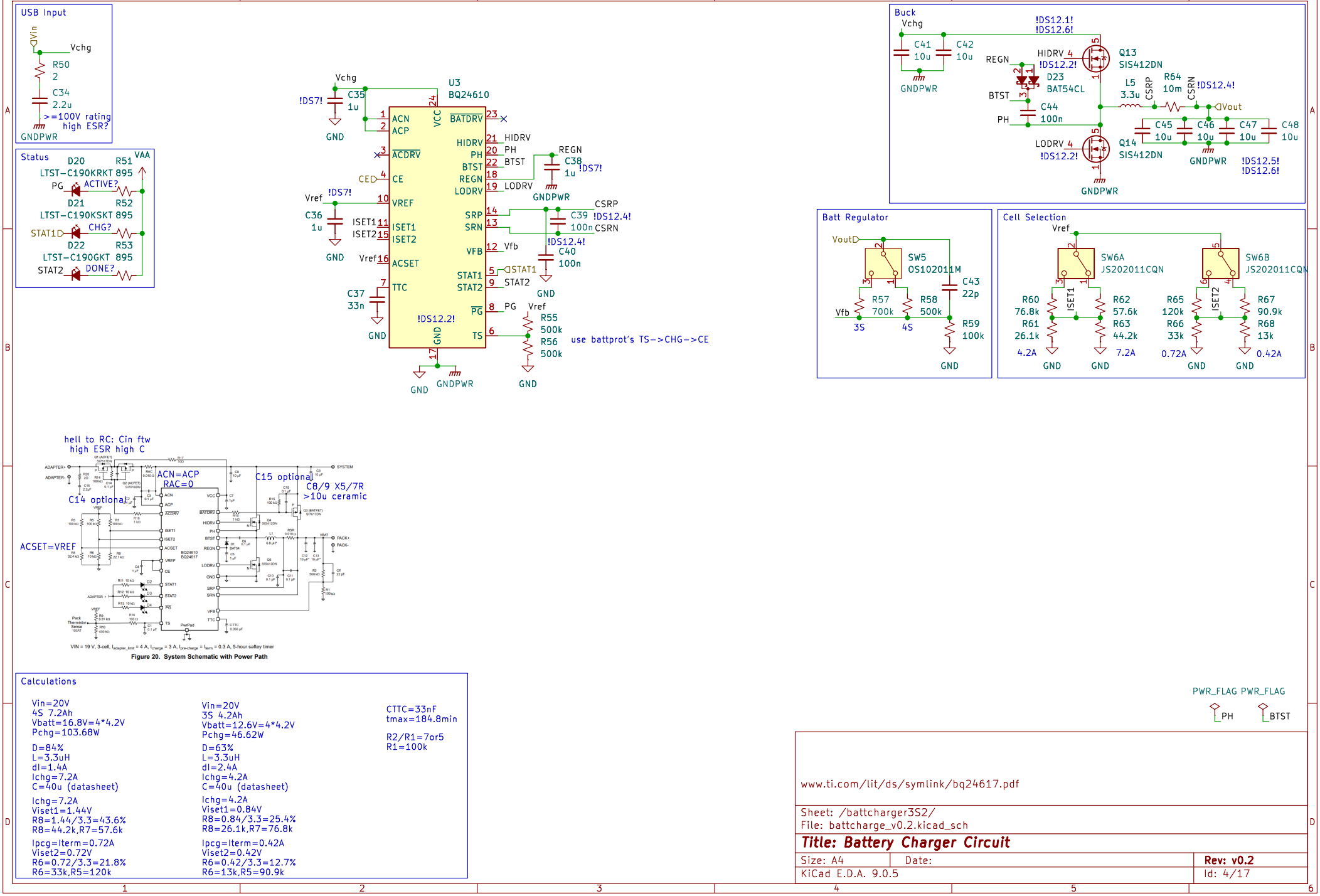
www.ti.com/lit/ds/symlink/bq24617.pdf

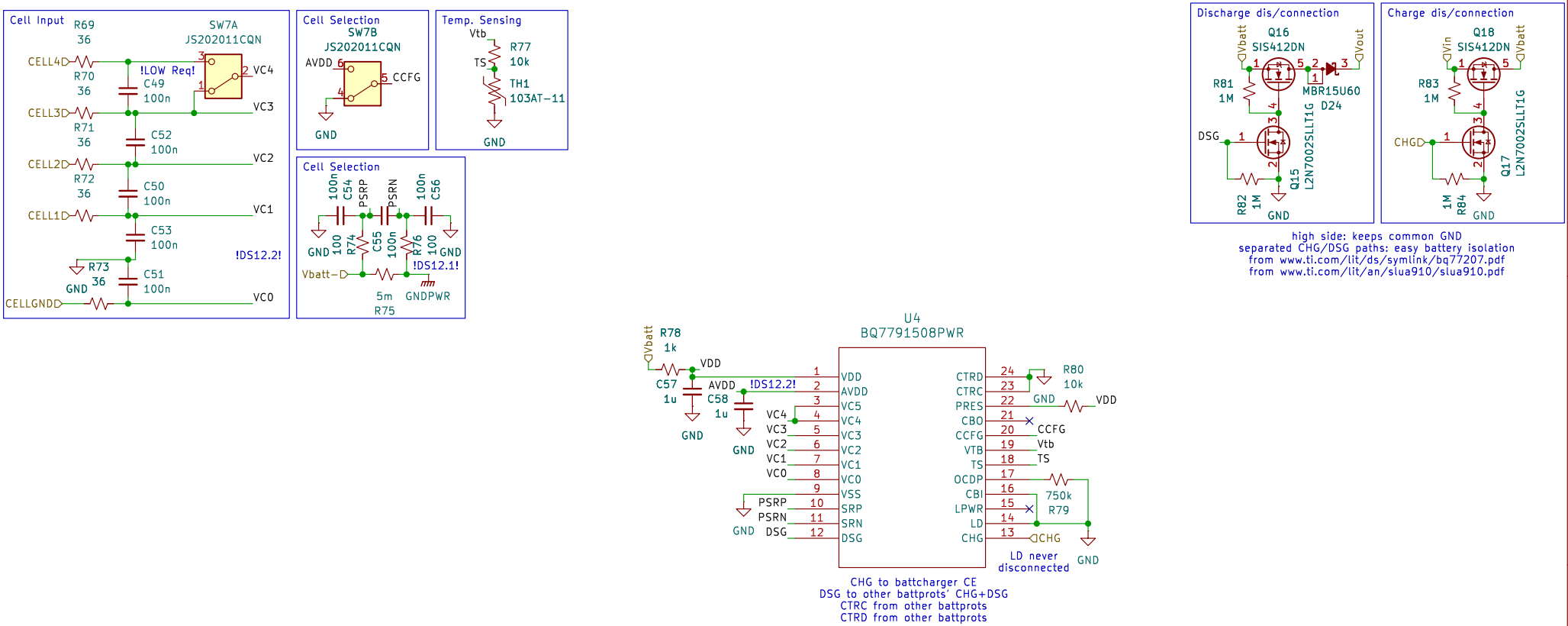
Sheet: /battcharger4S/
File: battcharge_v0.2.kicad_sch

Title: Battery Charger Circuit

Size: A4	Date:	Rev: v0.2
KiCad E.D.A. 9.0.5		Id: 2/17


USB Input
Vin
Vchg
R31
2
C19
2.2u
>=100V rating
high ESR?
GNDPWR
Status
D16
LTST-C190KRKT
PG
ACTIVE?
R32
895
VAA
D17
LTST-C190KSKT
STAT1
CHG?
R33
895
D18
LTST-C190GKT
STAT2
DONE?
R34
895
U2
BQ24610
ACN
ACP
ACDRV
CE
VREF
ISET1
ISET2
ACSET
TTC
VCC
BATDRV
HIDRV
PH
BTST
REGN
LODRV
SRP
SRN
VFB
STAT1
STAT2
PG
TS
GND
!DS12.2!
C20
1u
!DS7!
C21
1u
C22
33n
C23
1u
C24
100n
CSRP
CSRN
C25
100n
!DS12.4!
R36
500k
R37
500k
use battprot's TS->CHG->CE
Buck
Vchg
C26
10u
C27
10u
GNDPWR
!DS12.1!
!DS12.6!
REGN
HIDRV
!DS12.2!
D19
BAT54CL
BTST
C29
100n
PH
LODRV
!DS12.2!
Q11
SIS412DN
Q12
SIS412DN
L4
3.3u
CSRP
R45
10m
CSRN
!DS12.4!
Vout
C30
10u
C31
10u
C32
10u
C33
10u
!DS12.5!
!DS12.6!
Batt Regulator
Vout
SW3
OS102011M
R38
700k
R39
500k
C28
22p
R40
100k
Vfb
3S
4S
Cell Selection
Vref
SW4A
JS202011CQN
SW4B
JS202011CQN
ISET1
ISET2
R41
76.8k
R42
26.1k
R43
57.6k
R44
44.2k
R46
120k
R47
33k
R48
90.9k
R49
13k
4.2A
7.2A
0.72A
0.42A
hell to RC: Cin ftw
high ESR high C
ACN=ACP
RAC=0
C15 optional
C8/9 X5/7R
>10u ceramic
C14 optional
ACSET=VREF
VIN = 19 V, 3-cell, Iadapter_limit = 4 A, Icharge = 3 A, Ipre-charge = Iterm = 0.3 A, 5-hour saftey timer
Figure 20. System Schematic with Power Path
Calculations
Vin=20V
4S 7.2Ah
Vbatt=16.8V=4*4.2V
Pchg=103.68W
D=84%
L=3.3uH
dI=1.4A
Ichg=7.2A
C=40u (datasheet)
Ichg=7.2A
Viset1=1.44V
R8=1.44/3.3=43.6%
R8=44.2k,R7=57.6k
Ipcg=Iterm=0.72A
Viset2=0.72V
R6=0.72/3.3=21.8%
R6=33k,R5=120k
Vin=20V
3S 4.2Ah
Vbatt=12.6V=4*4.2V
Pchg=46.62W
D=63%
L=3.3uH
dI=2.4A
Ichg=4.2A
C=40u (datasheet)
Ichg=4.2A
Viset1=0.84V
R8=0.84/3.3=25.4%
R8=26.1k,R7=76.8k
Ipcg=Iterm=0.42A
Viset2=0.42V
R6=0.42/3.3=12.7%
R6=13k,R5=90.9k
CTTC=33nF
tmax=184.8min
R2/R1=7or5
R1=100k
PWR_FLAG PWR_FLAG
PH
BTST
www.ti.com/lit/ds/symlink/bq24617.pdf
Sheet: /battcharger3S1/
File: battcharge_v0.2.kicad_sch
Title: Battery Charger Circuit
Size: A4
Date:
Rev: v0.2
KiCad E.D.A. 9.0.5
Id: 3/17


USB Input
Vin
Vchg
R50
2
C34
2.2u
>=100V rating
high ESR?
GNDPWR
Status
D20
LTST-C190KRKT
PG
ACTIVE?
R51
895
VAA
D21
LTST-C190KSKT
STAT1
CHG?
R52
895
D22
LTST-C190GKT
STAT2
DONE?
R53
895
U3
BQ24610
!DS7!
C35
1u
GND
ACN
ACP
ACDRV
CE
VREF
ISET1
ISET2
ACSET
TTC
VCC
BATDRV
HIDRV
PH
BTST
REGN
LODRV
SRP
SRN
VFB
STAT1
STAT2
PG
TS
GNDPWR
REGN
C38
1u
!DS7!
CSRP
C39
100n
!DS12.4!
CSRN
C40
100n
Vref
C36
1u
ISET1
ISET2
ACSET
C37
33n
!DS12.2!
Vfb
R55
500k
R56
500k
use battprot's TS->CHG->CE
Buck
Vchg
C41
10u
C42
10u
GNDPWR
!DS12.1!
!DS12.6!
REGN
HIDRV
!DS12.2!
Q13
SIS412DN
D23
BAT54CL
BTST
C44
100n
PH
L5
3.3u
CSRP
R64
10m
CSRN
!DS12.4!
Vout
C45
10u
C46
10u
C47
10u
C48
10u
LODRV
!DS12.2!
Q14
SIS412DN
!DS12.5!
!DS12.6!
Batt Regulator
Vout
SW5
OS102011M
R57
700k
R58
500k
C43
22p
Vfb
3S
4S
R59
100k
Cell Selection
Vref
SW6A
JS202011CQN
SW6B
JS202011CQN
R60
76.8k
R61
26.1k
4.2A
ISET1
R62
57.6k
R63
44.2k
7.2A
R65
120k
R66
33k
0.72A
ISET2
R67
90.9k
R68
13k
0.42A
hell to RC: Cin ftw
high ESR high C
ACN=ACP
RAC=0
C15 optional
C8/9 X5/7R
>10u ceramic
C14 optional
ACSET=VREF
Figure 20. System Schematic with Power Path
Calculations
Vin=20V
4S 7.2Ah
Vbatt=16.8V=4*4.2V
Pchg=103.68W
D=84%
L=3.3uH
dI=1.4A
Ichg=7.2A
C=40u (datasheet)
Ichg=7.2A
Viset1=1.44V
R8=1.44/3.3=43.6%
R8=44.2k,R7=57.6k
Ipcg=Iterm=0.72A
Viset2=0.72V
R6=0.72/3.3=21.8%
R6=33k,R5=120k
Vin=20V
3S 4.2Ah
Vbatt=12.6V=4*4.2V
Pchg=46.62W
D=63%
L=3.3uH
dI=2.4A
Ichg=4.2A
C=40u (datasheet)
Ichg=4.2A
Viset1=0.84V
R8=0.84/3.3=25.4%
R8=26.1k,R7=76.8k
Ipcg=Iterm=0.42A
Viset2=0.42V
R6=0.42/3.3=12.7%
R6=13k,R5=90.9k
CTTC=33nF
tmax=184.8min
R2/R1=7or5
R1=100k
PWR_FLAG PWR_FLAG
PH
BTST
www.ti.com/lit/ds/symlink/bq24617.pdf
Sheet: /battcharger3S2/
File: battcharge_v0.2.kicad_sch
Title: Battery Charger Circuit
Size: A4
Date:
Rev: v0.2
KiCad E.D.A. 9.0.5
Id: 4/17



Ibal=50mA<<Iterm=0.72A or 0.42A
Vcell=4.2V
Rbal=12
Vcell/Ibal=2*Rin+Rbal
Rin=.5(Vcell/Ibal-Rbal)
Rin=36

Vocd1=70mV
let Iocd1=14A (138W@9.9V, 229W@16.4V)
Rsns=5m
Vocd2=140mV
Iocd2=28A
Vscd=300mV
Iscd=60A
Vocc=60mV
Iocc=12A

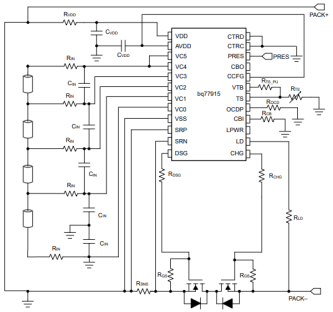


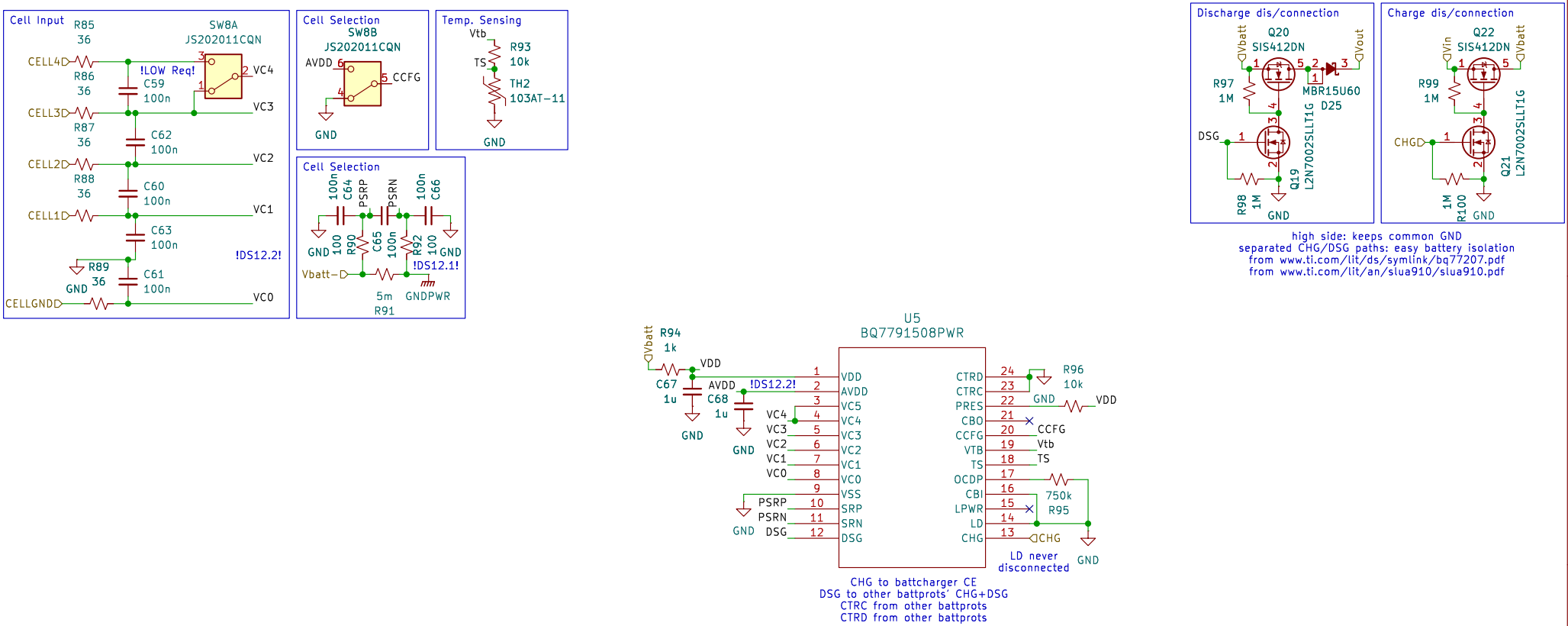
Figure 9-12. 4-Series Configuration with Internal Cell Balancing and HIBERNATE Mode Enabled

www.ti.com/lit/ds/symlink/bq77915.pdf

Sheet: /battprot1/
File: battprot_v0.2.kicad_sch

Title: Battery Protection Circuit

Size: A4	Date:	**Rev: v0.2**
KiCad E.D.A. 9.0.5		Id: 5/17



Ibal=50mA<<Iterm=0.72A or 0.42A
Vcell=4.2V
Rbal=12
Vcell/Ibal=2*Rin+Rbal
Rin=.5(Vcell/Ibal-Rbal)
Rin=36

Vocd1=70mV
let Iocd1=14A (138W@9.9V, 229W@16.4V)
Rsns=5m
Vocd2=140mV
Iocd2=28A
Vscd=300mV
Iscd=60A
Vocc=60mV
Iocc=12A

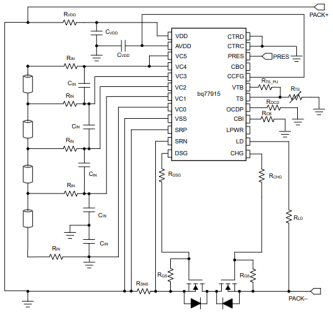


Figure 9-12. 4-Series Configuration with Internal Cell Balancing and HIBERNATE Mode Enabled

www.ti.com/lit/ds/symlink/bq77915.pdf

Sheet: /battprot2/
File: battprot_v0.2.kicad_sch

Title: Battery Protection Circuit

Size: A4	Date:	**Rev: v0.2**
KiCad E.D.A. 9.0.5		Id: 6/17

Cell Input

R101 36
SW9A JS202011CQN
CELL4 R102 36 !LOW Req! C69 100n VC4
CELL3 R103 36 C72 100n VC3
CELL2 R104 36 C70 100n VC2
CELL1 C73 100n VC1
R105 36 C71 100n !DS12.2!
GND CELLGND VC0

Cell Selection

SW9B JS202011CQN
AVDD CCFG GND

Temp. Sensing

Vtb R109 10k TS TH3 103AT-11 GND

Cell Selection

100n C74 PSRP R106 100 GND
PSRN C75 100n R108 100 100n C76 GND
!DS12.1!
Vbatt− 5m R107 GNDPWR

Discharge dis/connection

Vbatt Q24 SIS412DN Vout
R113 1M MBR15U60 D26
DSG Q23 L2N7002SLLT1G
R114 1M GND

Charge dis/connection

Vin Q26 SIS412DN Vbatt
R115 1M
CHG Q25 L2N7002SLLT1G
1M R116 GND

high side: keeps common GND
separated CHG/DSG paths: easy battery isolation
from www.ti.com/lit/ds/symlink/bq77207.pdf
from www.ti.com/lit/an/slua910/slua910.pdf

U6
BQ7791508PWR

Vbatt R110 1k VDD
C77 1u AVDD !DS12.2! C78 1u GND
VC4 VC3 VC2 VC1 VC0
PSRP PSRN DSG

1 VDD
2 AVDD
3 VC5
4 VC4
5 VC3
6 VC2
7 VC1
8 VC0
9 VSS
10 SRP
11 SRN
12 DSG

24 CTRD
23 CTRC
22 PRES
21 CBO
20 CCFG
19 VTB
18 TS
17 OCDP
16 CBI
15 LPWR
14 LD
13 CHG

R112 10k GND VDD
CCFG Vtb TS
750k R111 CHG
LD never disconnected GND

CHG to battcharger CE
DSG to other battprots' CHG+DSG
CTRC from other battprots
CTRD from other battprots

Ibal=50mA<<Iterm=0.72A or 0.42A
Vcell=4.2V
Rbal=12
Vcell/Ibal=2*Rin+Rbal
Rin=.5(Vcell/Ibal−Rbal)
Rin=36

Vocd1=70mV
let Iocd1=14A (138W@9.9V, 229W@16.4V)
Rsns=5m
Vocd2=140mV
Iocd2=28A
Vscd=300mV
Iscd=60A
Vocc=60mV
Iocc=12A

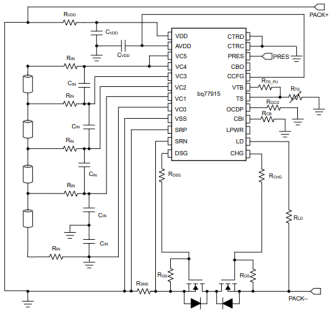


Figure 9-12. 4-Series Configuration with Internal Cell Balancing and HIBERNATE Mode Enabled

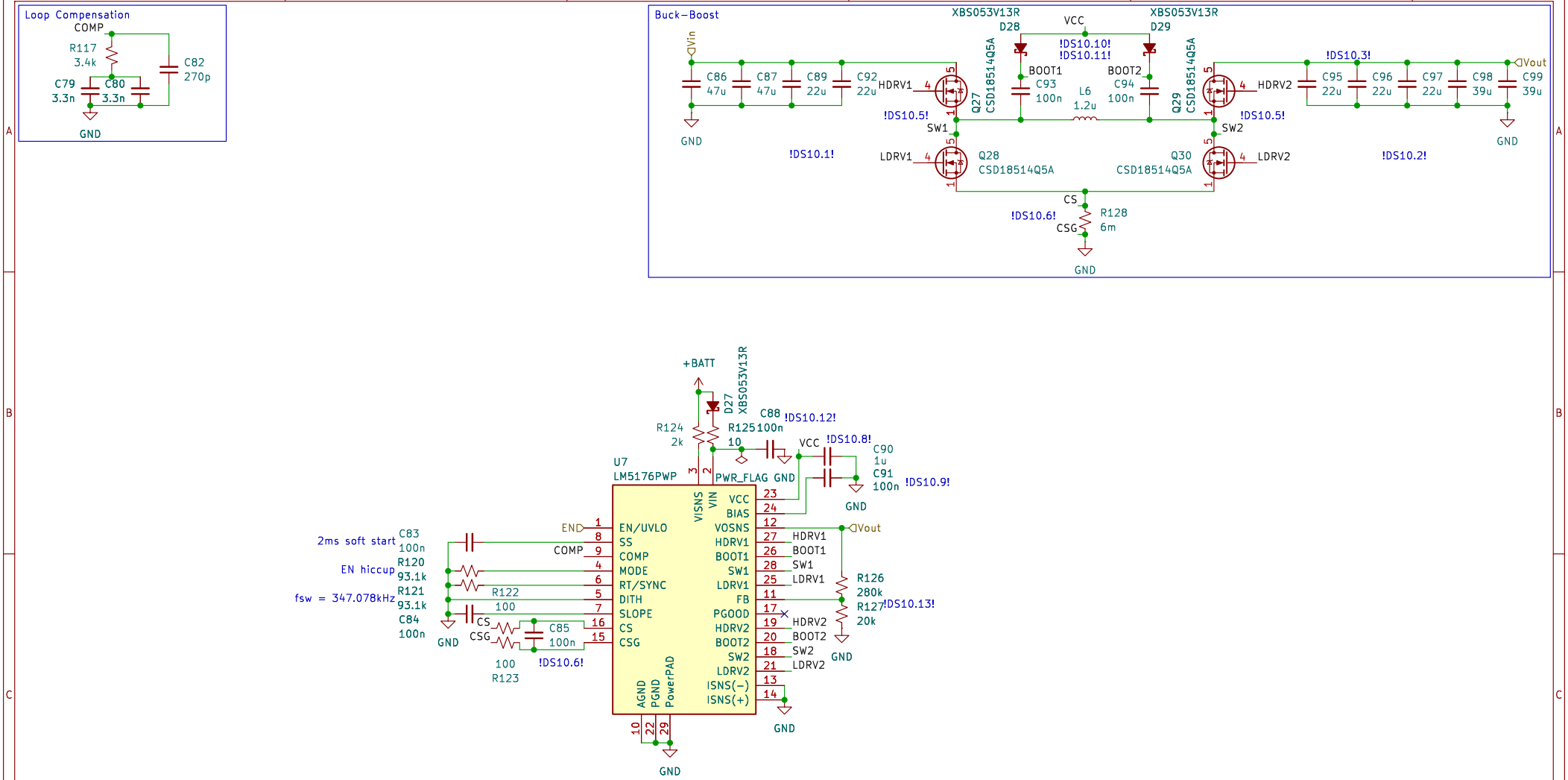
VDD PWR_FLAG

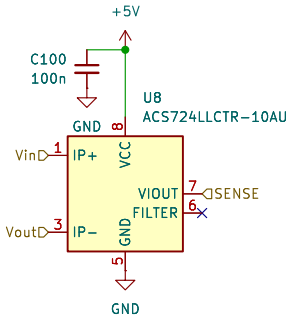
www.ti.com/lit/ds/symlink/bq77915.pdf

Sheet: /battprot3/
File: battprot_v0.2.kicad_sch

Title: Battery Protection Circuit

Size: A4	Date:	**Rev: v0.2**
KiCad E.D.A. 9.0.5		Id: 7/17


Loop Compensation
COMP
R117
3.4k
C82
270p
C79
3.3n
C80
3.3n
GND
Buck-Boost
XBS053V13R
D28
VCC
XBS053V13R
D29
!DS10.10!
!DS10.11!
Vin
C86
47u
C87
47u
C89
22u
C92
22u
HDRV1
Q27
CSD18514Q5A
BOOT1
C93
100n
L6
1.2u
BOOT2
C94
100n
Q29
CSD18514Q5A
HDRV2
!DS10.3!
C95
22u
C96
22u
C97
22u
C98
39u
C99
39u
Vout
GND
!DS10.5!
SW1
SW2
!DS10.5!
!DS10.1!
LDRV1
Q28
CSD18514Q5A
Q30
CSD18514Q5A
LDRV2
!DS10.2!
CS
!DS10.6!
R128
6m
CSG
GND
+BATT
D27
XBS053V13R
C88
100n
!DS10.12!
R124
2k
R125
10
VCC
!DS10.8!
C90
1u
C91
100n
!DS10.9!
GND
U7
LM5176PWP
PWR_FLAG
GND
VISNS
VIN
VCC
BIAS
VOSNS
HDRV1
BOOT1
SW1
LDRV1
FB
PGOOD
HDRV2
BOOT2
SW2
LDRV2
ISNS(-)
ISNS(+)
EN/UVLO
SS
COMP
MODE
RT/SYNC
DITH
SLOPE
CS
CSG
AGND
PGND
PowerPAD
END
2ms soft start
C83
100n
EN hiccup
R120
93.1k
fsw = 347.078kHz
R121
93.1k
C84
100n
R122
100
R123
100
C85
100n
!DS10.6!
Vout
R126
280k
R127
20k
!DS10.13!
GND
VCC
PWR_FLAG
www.ti.com/lit/ds/symlink/lm5176.pdf
Sheet: /buckboost/
File: buckboost_v0.1.kicad_sch
Title: Buck-Boost Converter
Size: A4
Date:
Rev: v0.1
KiCad E.D.A. 9.0.5
Id: 8/17



www.allegromicro.com/~/media/Files/Datasheets/ACS724-Datasheet.ashx

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Title: Power Monitor

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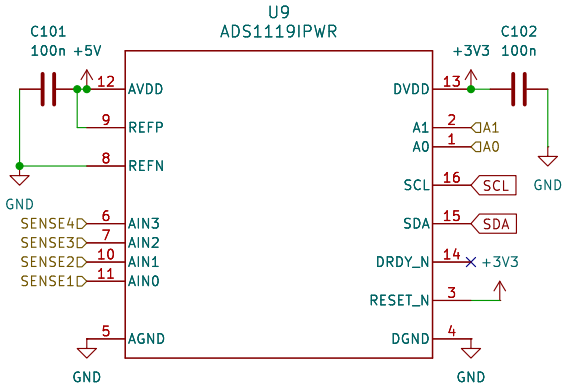
KiCad E.D.A. 9.0.5		Id: 9/17



www.ti.com/lit/ds/symlink/ads1119.pdf

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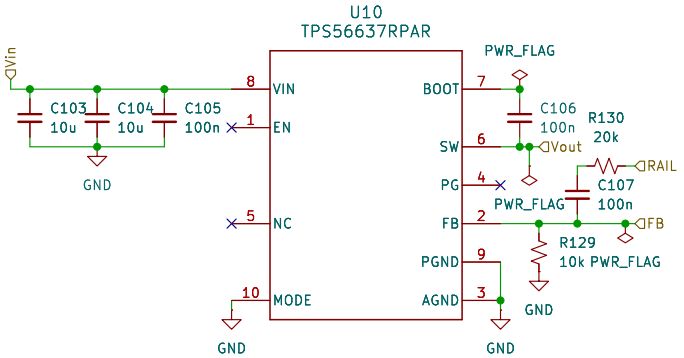
Size: A4	Date:	**Rev: v0.1**
KiCad E.D.A. 9.0.5		Id: 10/17



www.ti.com/lit/ds/symlink/tps56637.pdf

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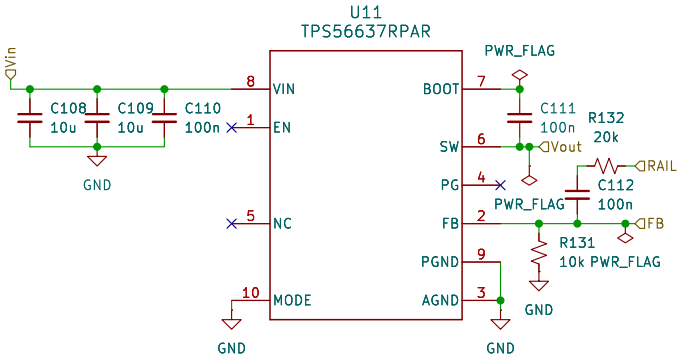
Title: Buck Converter

Size: A4	Date:	**Rev: v0.1**
KiCad E.D.A. 9.0.5		Id: 11/17



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Title: Buck Converter

Size: A4	Date:	**Rev: v0.1**
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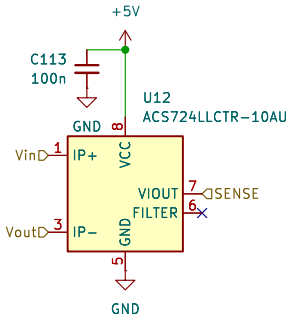

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Size: A4	Date:	**Rev: v0.1**
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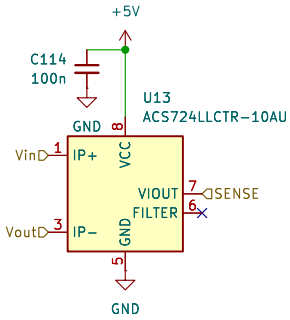

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Title: Power Monitor

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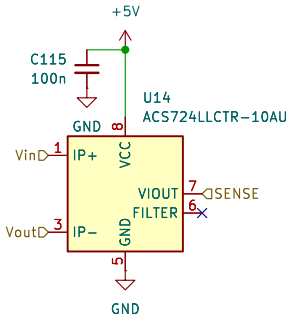

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Title: Power Monitor

Size: A4	Date:	**Rev: v0.1**
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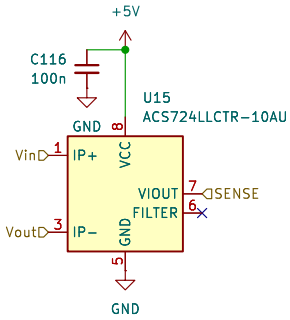

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Title: Power Monitor

Size: A4	Date:	**Rev: v0.1**
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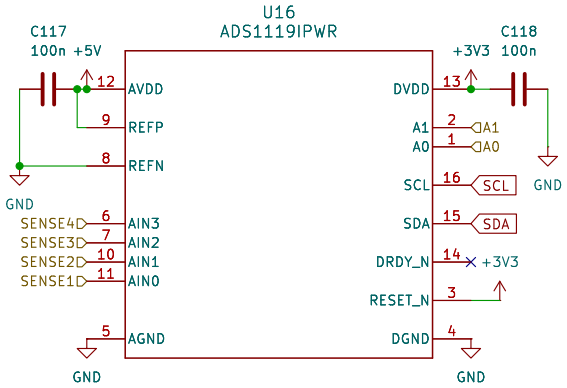

www.ti.com/lit/ds/symlink/ads1119.pdf

Sheet: /ADCpower/
File: adc_v0.1.kicad_sch

Title: Power Monitor

Size: A4	Date:	**Rev: v0.1**
KiCad E.D.A. 9.0.5		Id: 17/17