A detailed analysis of Rosemary Ainslie's Oscillator Circuit as discussed at overunity.com.

http://www.overunity.com/index.php?topic=10407.msg288440#msg288440

In this analysis, not only is it clearly shown that her measurements have led to an erroneous conclusion of COP=Infinity, but that the INPUT power measurement process can be simplified and reduced to one made with a non-inductive CSR and single DVM.

Regards,
.99

2011-06-18

In order to begin a detailed analysis of the circuit we're discussing, I created a slightly more detailed version of the schematic diagram.

I increased the battery wire inductance to 3.3uH as requested, and I've separated the lumped wire inductance and resistance out to 3 segments as shown. Electrically, this is equivalent, but allows for flexibility in the measurements and analysis.

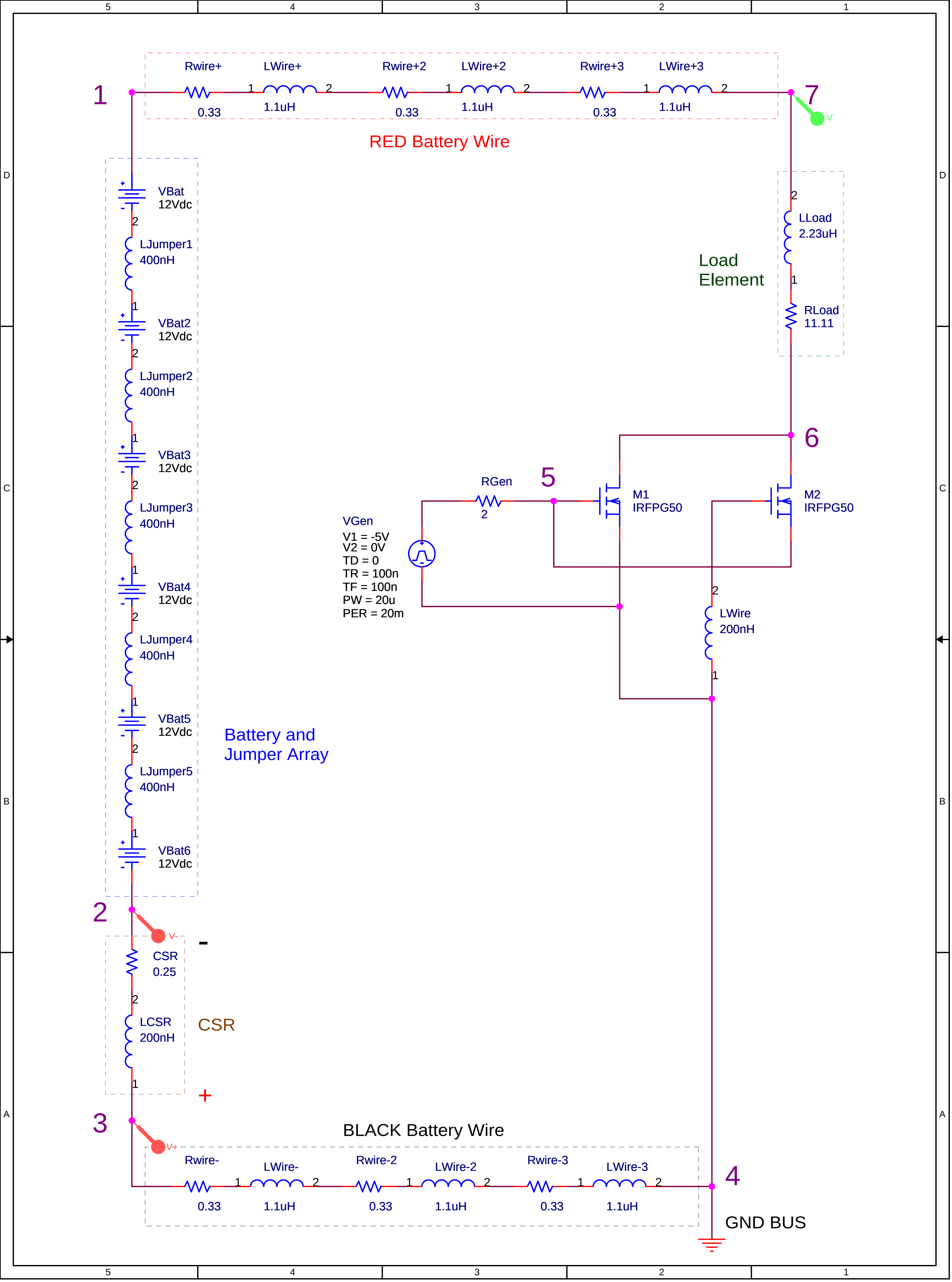
The same was done for the batteries and wire jumpers, as shown. I approximated each wire jumper to be about 20 inches in length, each with an inherent inductance of 20nH per inch, hence the 400nH per jumper.

Remember that the resistors and inductors shown representing the RED and BLACK battery wires are not physical discrete components; they are used to represent hidden but inherent values as a consequence of finite wire resistance and parasitic inductance.

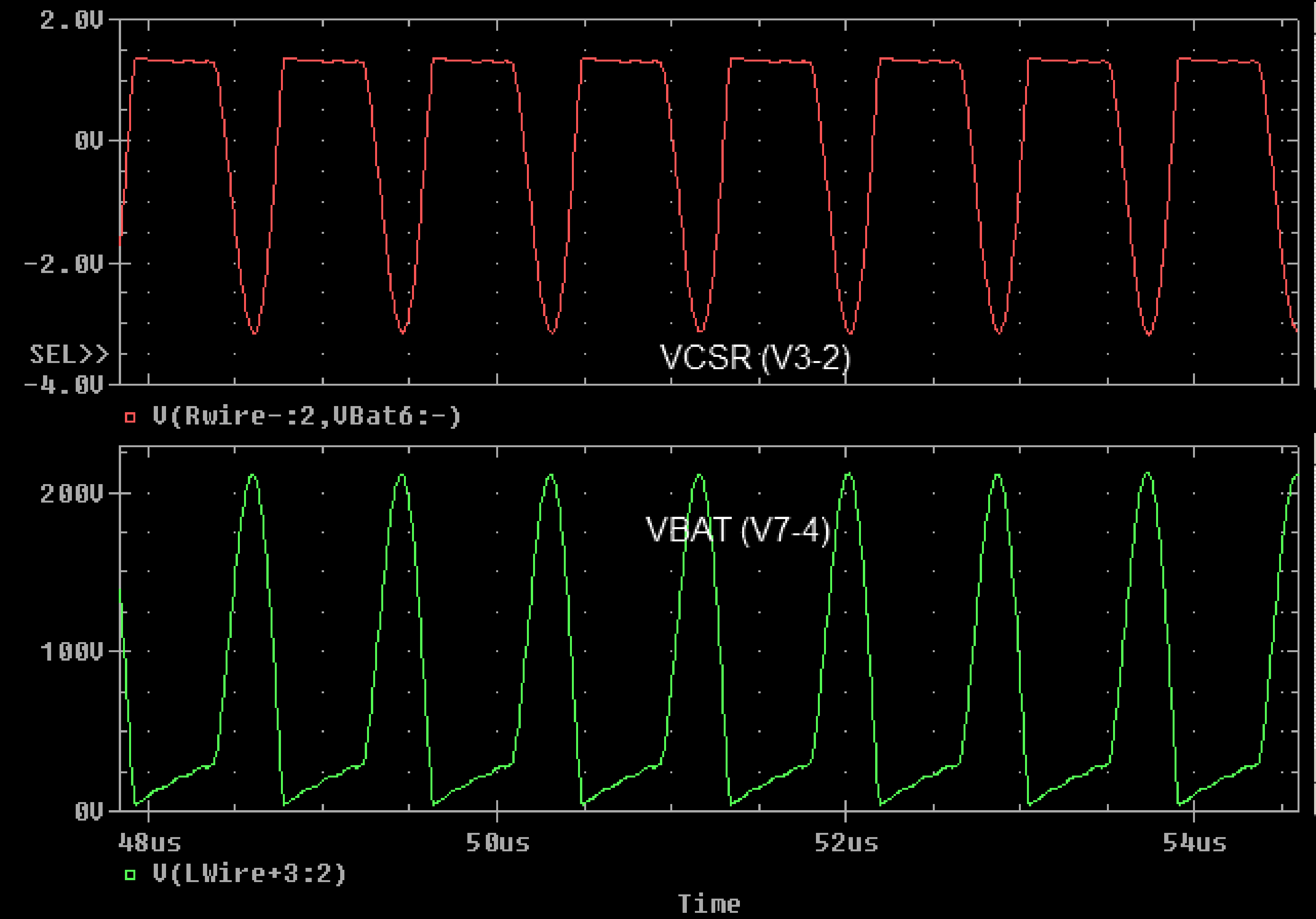
The first scope shots establish a baseline measurement of results similar to previous posts.

With the added inductances, the measurements are slightly different, but still show the apparent negative power to the battery. The net average power for the baseline measurement (scope probes in the positions noted) is about **-106W**.

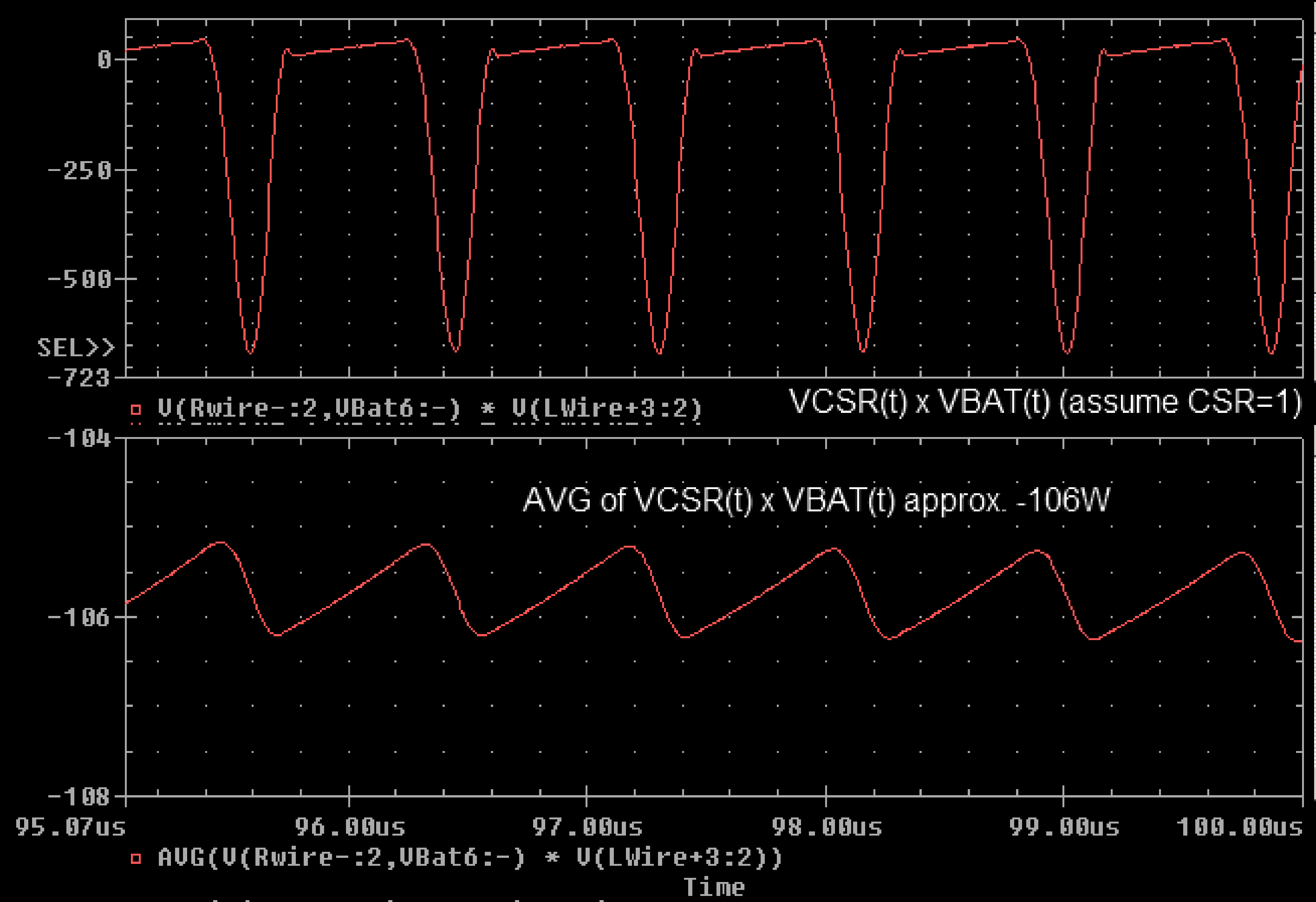
The relevant nodes in the circuit have been numbered 1 through 7. A notation of V3-2 (VCSR) means the voltage across nodes 3 and 2 with the polarity + and - respectively. V7-4 (VBAT) is the baseline battery voltage measurement.



RED Battery Wire
Rwire+ 0.33
LWire+ 1.1uH
Rwire+2 0.33
LWire+2 1.1uH
Rwire+3 0.33
LWire+3 1.1uH
1
7
VBat 12Vdc
LJumper1 400nH
VBat2 12Vdc
LJumper2 400nH
VBat3 12Vdc
LJumper3 400nH
VBat4 12Vdc
LJumper4 400nH
VBat5 12Vdc
LJumper5 400nH
VBat6 12Vdc
Battery and Jumper Array
Load Element
LLoad 2.23uH
RLoad 11.11
6
5
RGen 2
M1 IRFPG50
M2 IRFPG50
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
LWire 200nH
2
CSR 0.25
LCSR 200nH
CSR
3
BLACK Battery Wire
Rwire- 0.33
LWire- 1.1uH
Rwire-2 0.33
LWire-2 1.1uH
Rwire-3 0.33
LWire-3 1.1uH
4
GND BUS



2.0V
0V
-2.0V
SEL>>
-4.0V
VCSR (V3-2)
V(Rwire-:2,VBat6:-)
200V
100V
0V
VBAT (V7-4)
48us
50us
52us
54us
V(LWire+3:2)
Time



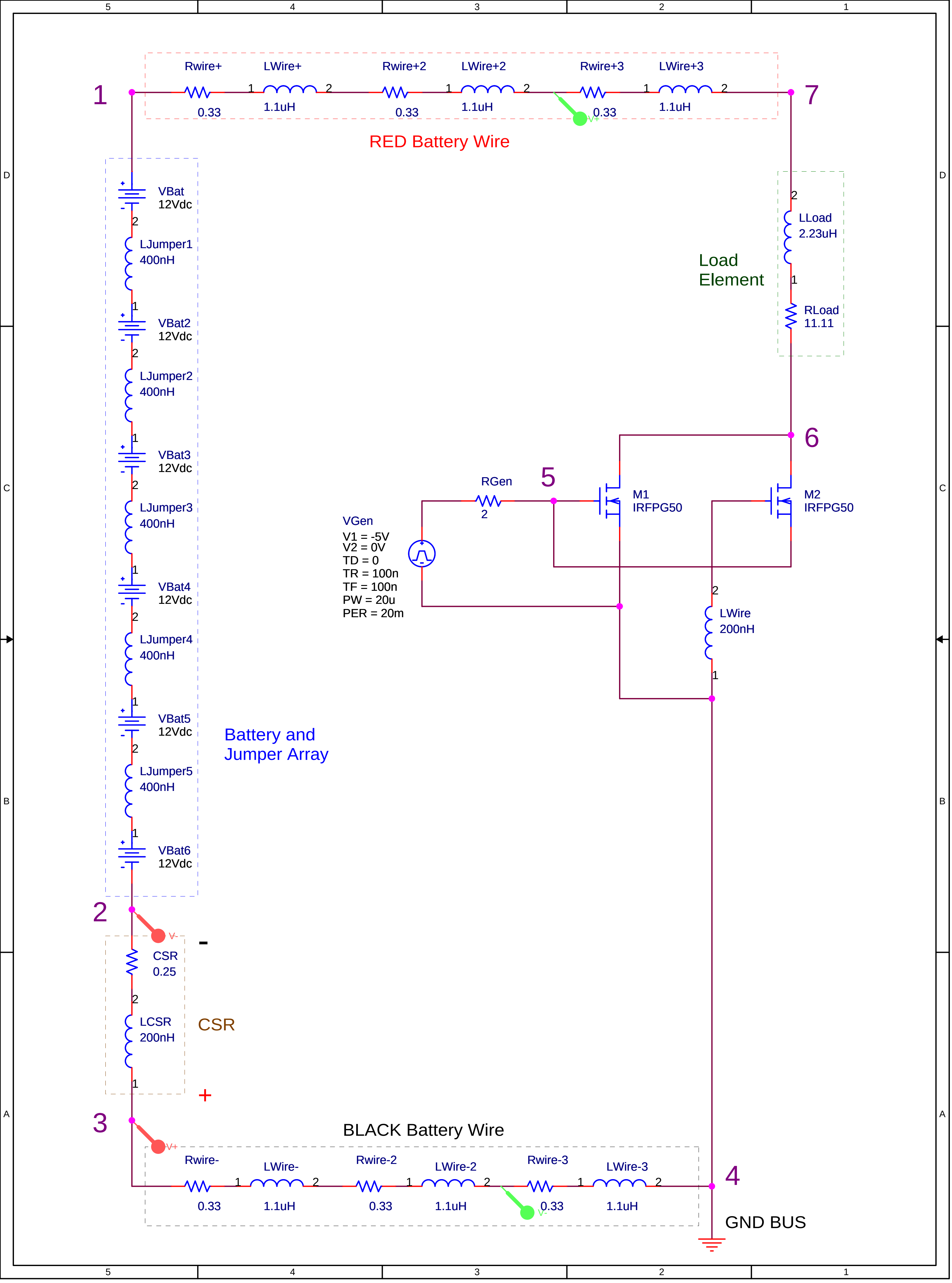
0
-250
-500
SEL>>
-723
V(Rwire-:2,VBat6:-) * V(LWire+3:2)
VCSR(t) x VBAT(t) (assume CSR=1)
-104
AVG of VCSR(t) x VBAT(t) approx. -106W
-106
-108
95.07us
96.00us
97.00us
98.00us
99.00us
100.00us
AVG(V(Rwire-:2,VBat6:-) * V(LWire+3:2))
Time

The schematics and scope shots in this post illustrate the dynamic involved by moving the battery voltage probe from the original nodes V7-4, closer to the battery terminals. In the two additional schematics, the **GREEN** battery voltage probes are moved progressively to the left along the RED and BLACK "wire components".

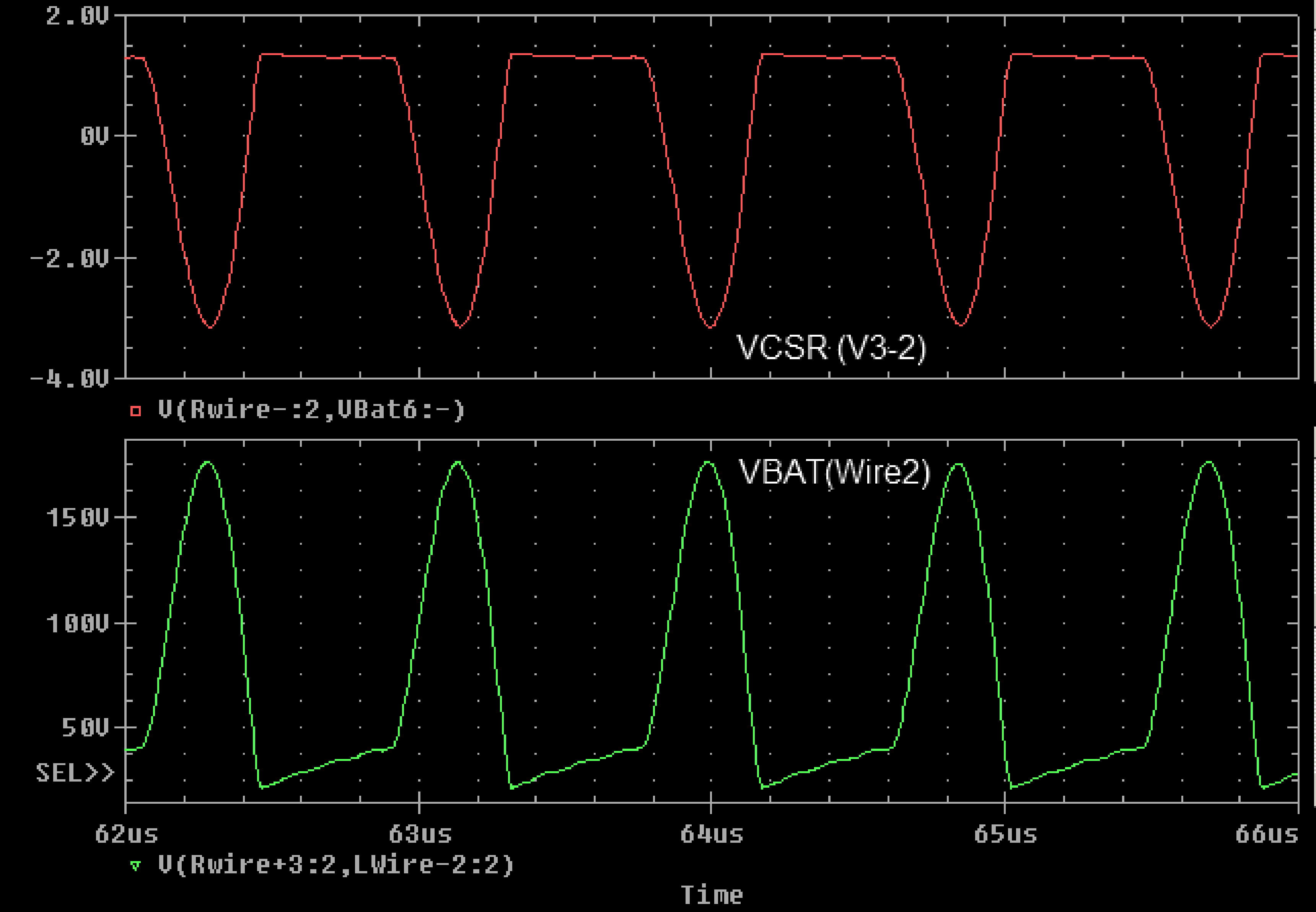
This is the only change for each simulation run. What can be observed is the decreasing peak-to-peak swing in "VBAT" voltage, and the resulting decrease in computed negative average wattage in the battery array.

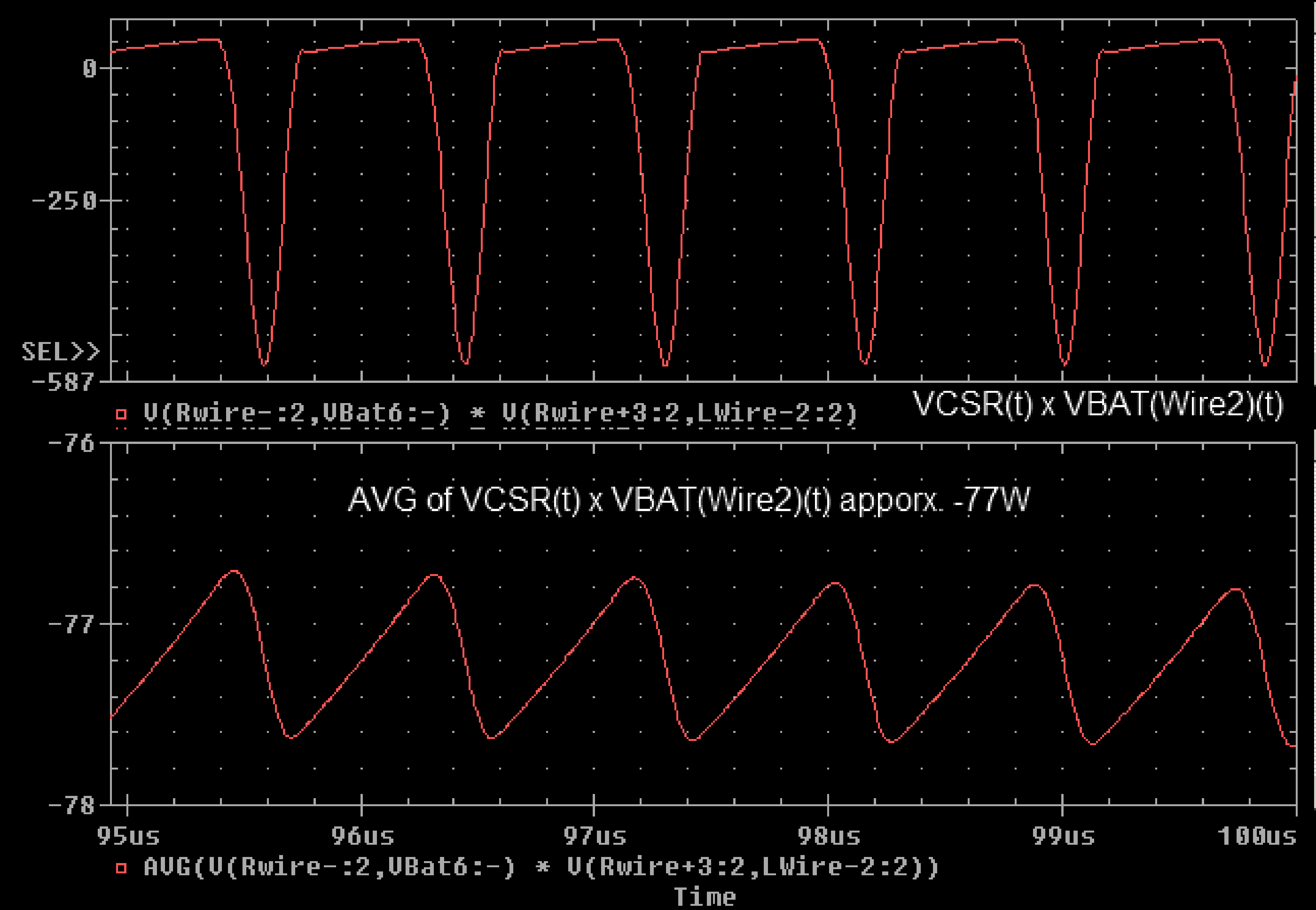
Summary of results thus far:

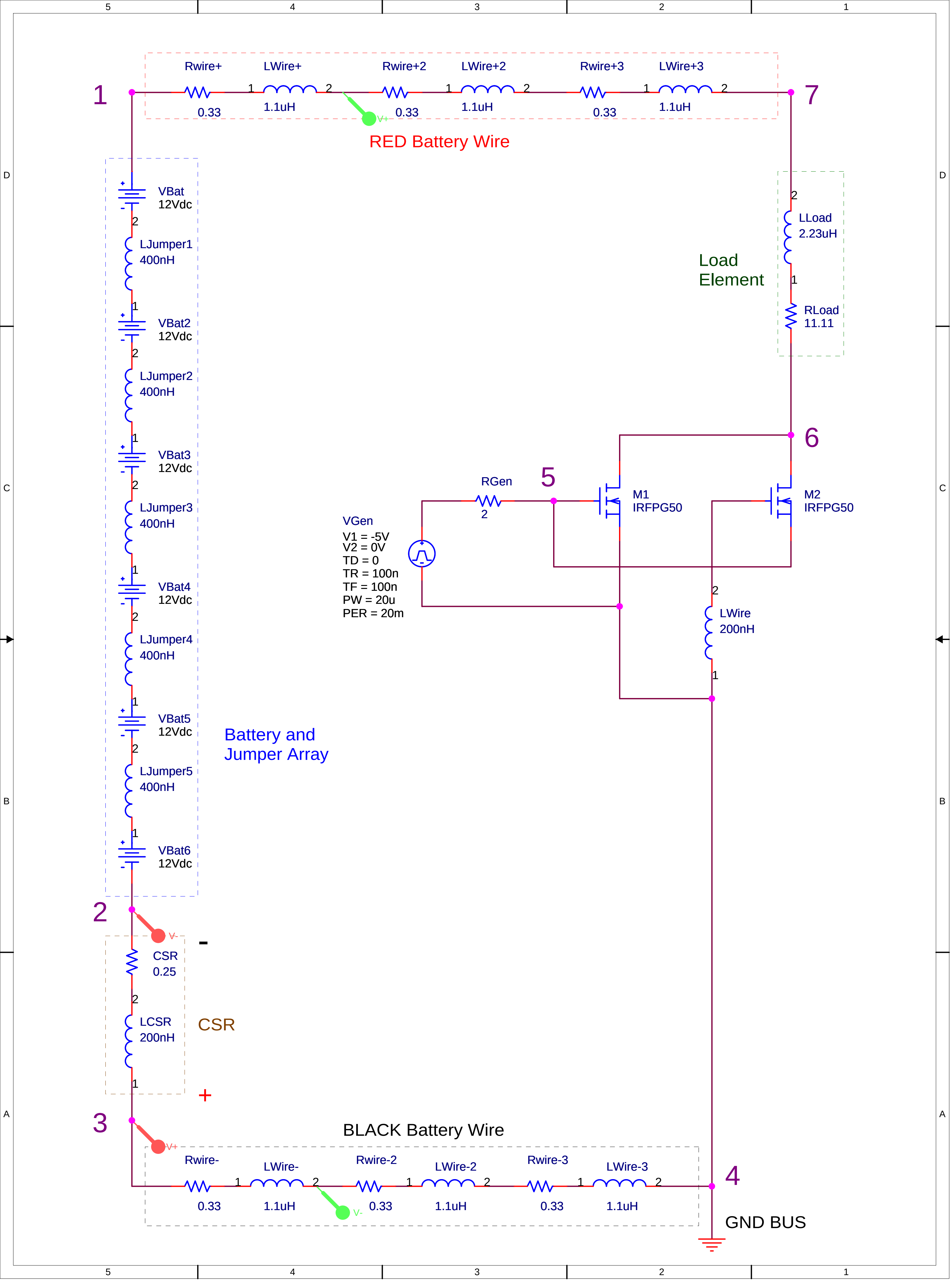
Original full wire length: **-106W**
2/3 battery wire length: **-77W**
1/3 battery wire length: **-48.5W**

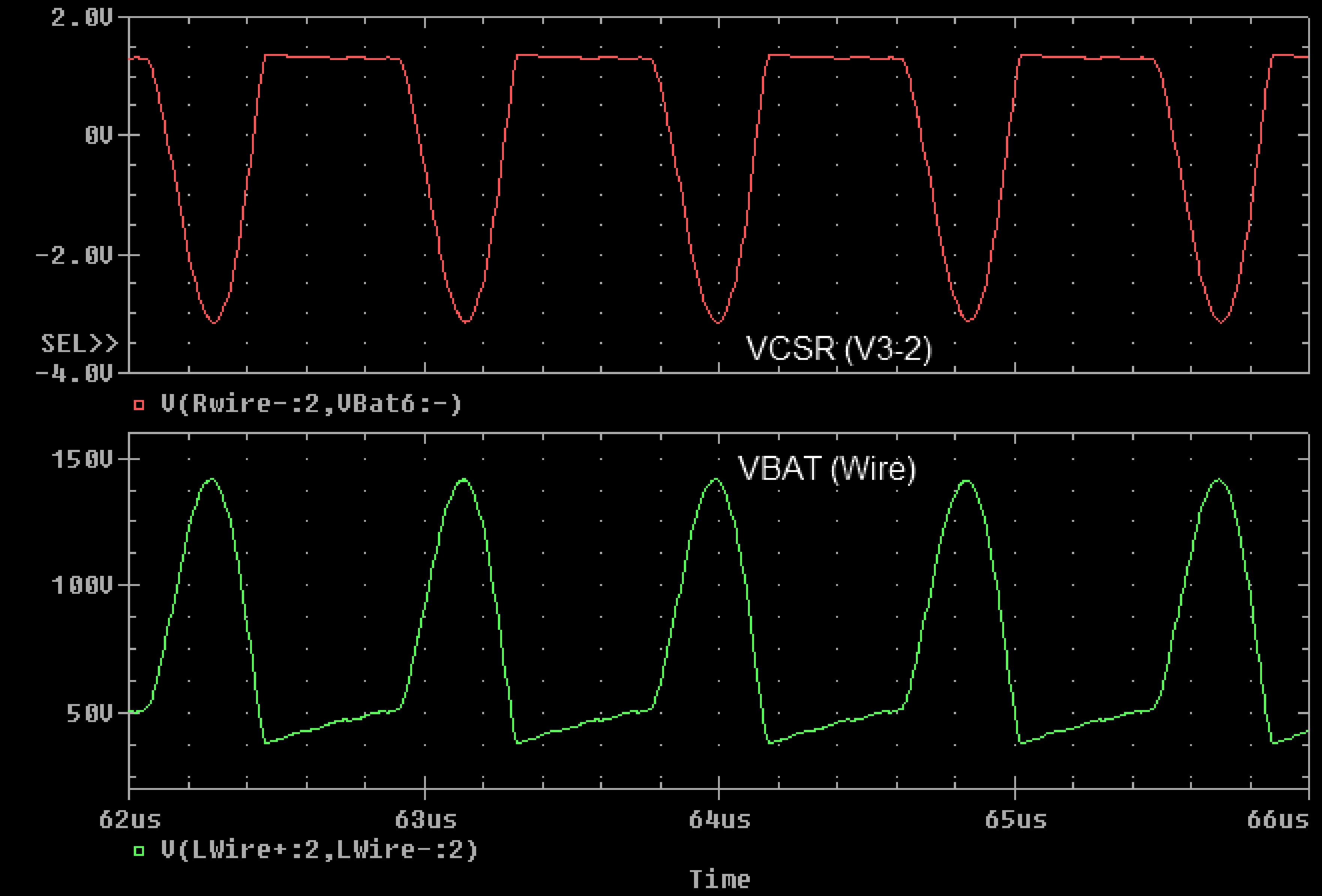


RED Battery Wire
Rwire+ 0.33
LWire+ 1.1uH
Rwire+2 0.33
LWire+2 1.1uH
Rwire+3 0.33
LWire+3 1.1uH
1
7
VBat 12Vdc
LJumper1 400nH
VBat2 12Vdc
LJumper2 400nH
VBat3 12Vdc
LJumper3 400nH
VBat4 12Vdc
LJumper4 400nH
VBat5 12Vdc
LJumper5 400nH
VBat6 12Vdc
Battery and Jumper Array
Load Element
LLoad 2.23uH
RLoad 11.11
6
5
RGen 2
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
M1 IRFPG50
M2 IRFPG50
LWire 200nH
2
CSR 0.25
LCSR 200nH
CSR
-
+
3
BLACK Battery Wire
Rwire- 0.33
LWire- 1.1uH
Rwire-2 0.33
LWire-2 1.1uH
Rwire-3 0.33
LWire-3 1.1uH
4
GND BUS

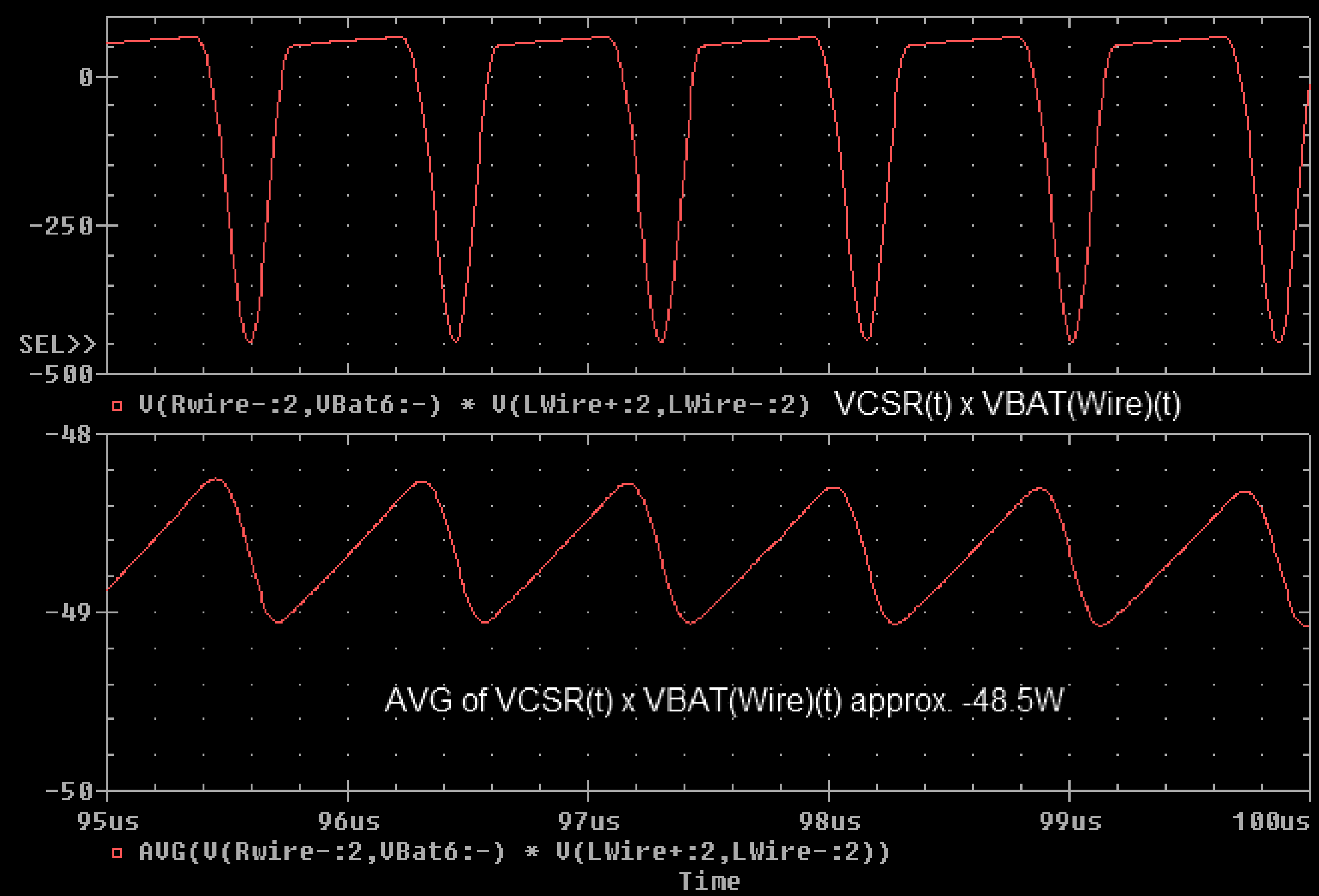

2.0V
0V
-2.0V
-4.0V
VCSR (V3-2)
V(Rwire-:2,VBat6:-)
VBAT(Wire2)
150V
100V
50V
SEL>>
62us
63us
64us
65us
66us
V(Rwire+3:2,LWire-2:2)
Time


0
-250
SEL>>
-587
V(Rwire-:2,VBat6:-) * V(Rwire+3:2,LWire-2:2)
VCSR(t) x VBAT(Wire2)(t)
-76
AVG of VCSR(t) x VBAT(Wire2)(t) apporx. -77W
-77
-78
95us
96us
97us
98us
99us
100us
AVG(V(Rwire-:2,VBat6:-) * V(Rwire+3:2,LWire-2:2))
Time


5
4
3
2
1
D
C
B
A
Rwire+
LWire+
Rwire+2
LWire+2
Rwire+3
LWire+3
0.33
1.1uH
RED Battery Wire
VBat
12Vdc
LJumper1
400nH
VBat2
12Vdc
LJumper2
400nH
VBat3
12Vdc
LJumper3
400nH
VBat4
12Vdc
LJumper4
400nH
VBat5
12Vdc
LJumper5
400nH
VBat6
12Vdc
Battery and
Jumper Array
LLoad
2.23uH
RLoad
11.11
Load
Element
RGen
2
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
M1
IRFPG50
M2
IRFPG50
LWire
200nH
CSR
0.25
LCSR
200nH
CSR
BLACK Battery Wire
Rwire-
LWire-
Rwire-2
LWire-2
Rwire-3
LWire-3
GND BUS
V+
V-



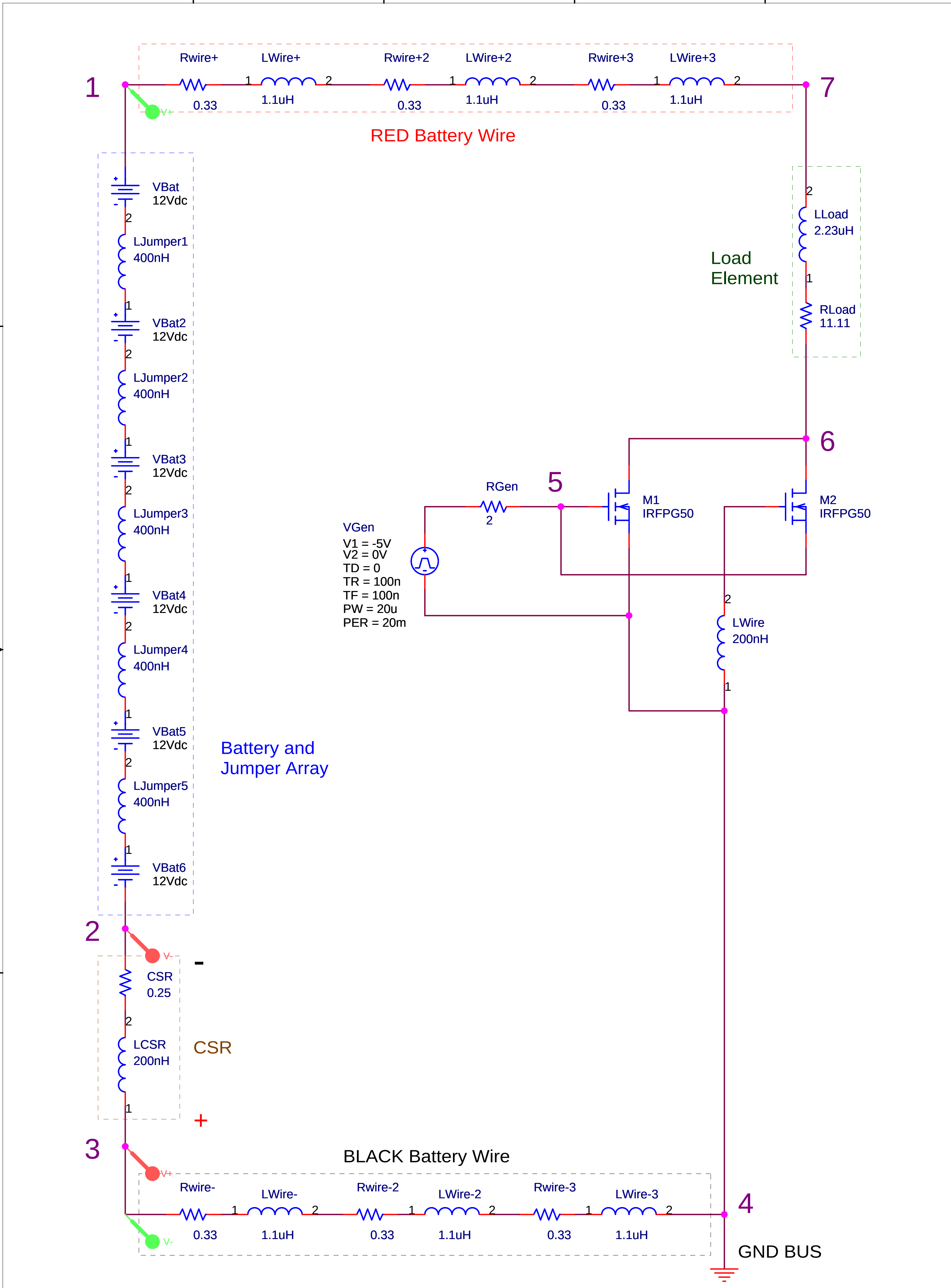
2.00V
0V
-2.00V
SEL>>
-4.00V
VCSR (V3-2)
V(Rwire-:2,VBat6:-)
150V
100V
50V
VBAT (Wire)
62us
63us
64us
65us
66us
V(LWire+:2,LWire-:2)
Time


0
-250
SEL>>
-500
V(Rwire-:2,VBat6:-) * V(LWire+:2,LWire-:2)
VCSR(t) x VBAT(Wire)(t)
-48
-49
-50
AVG of VCSR(t) x VBAT(Wire)(t) approx. -48.5W
95us
96us
97us
98us
99us
100us
AVG(V(Rwire-:2,VBat6:-) * V(LWire+:2,LWire-:2))
Time

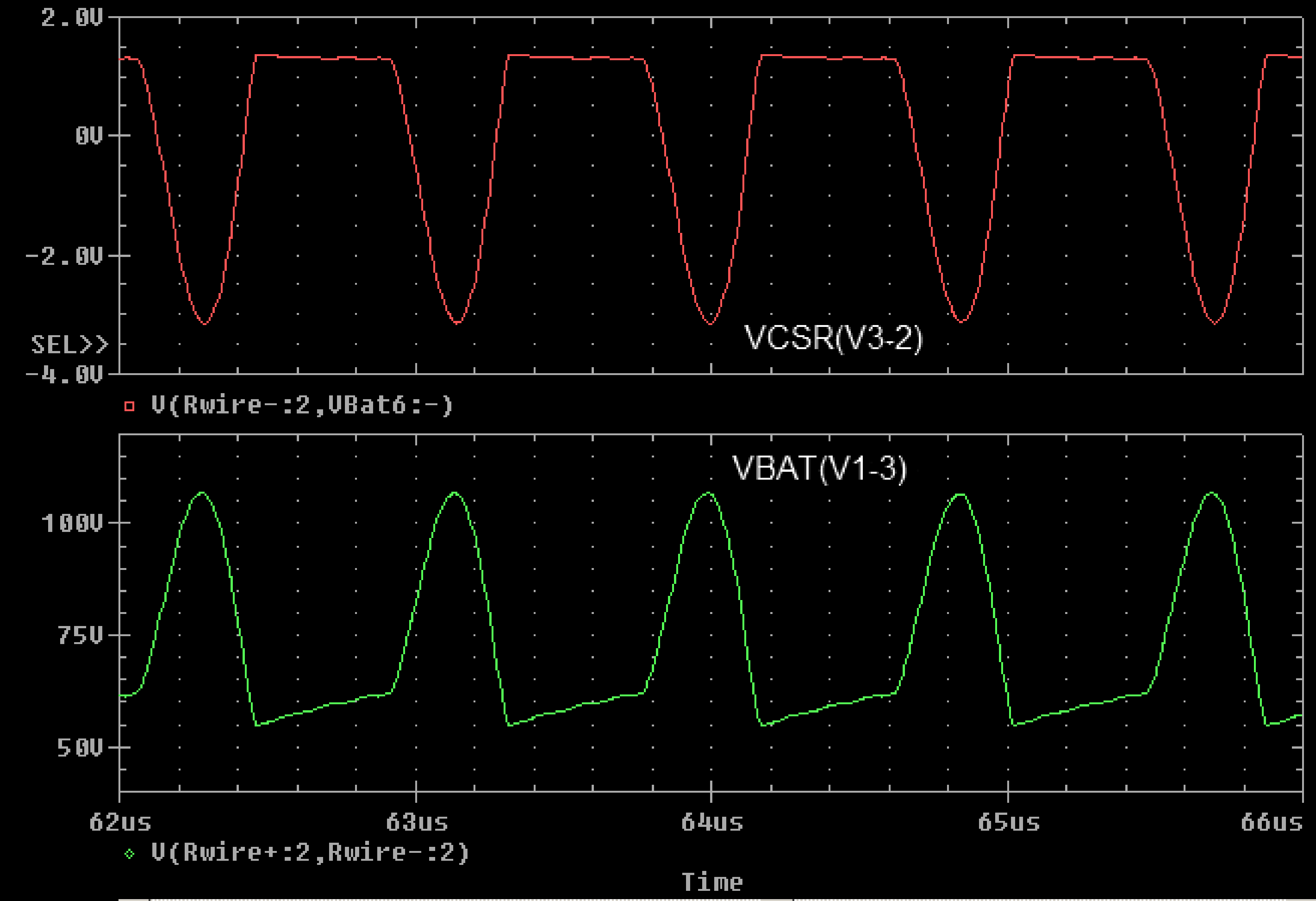
Continuing with the battery voltage probe placement closer and closer to the battery array, the results continue to show a **declining** negative average power in the battery array.

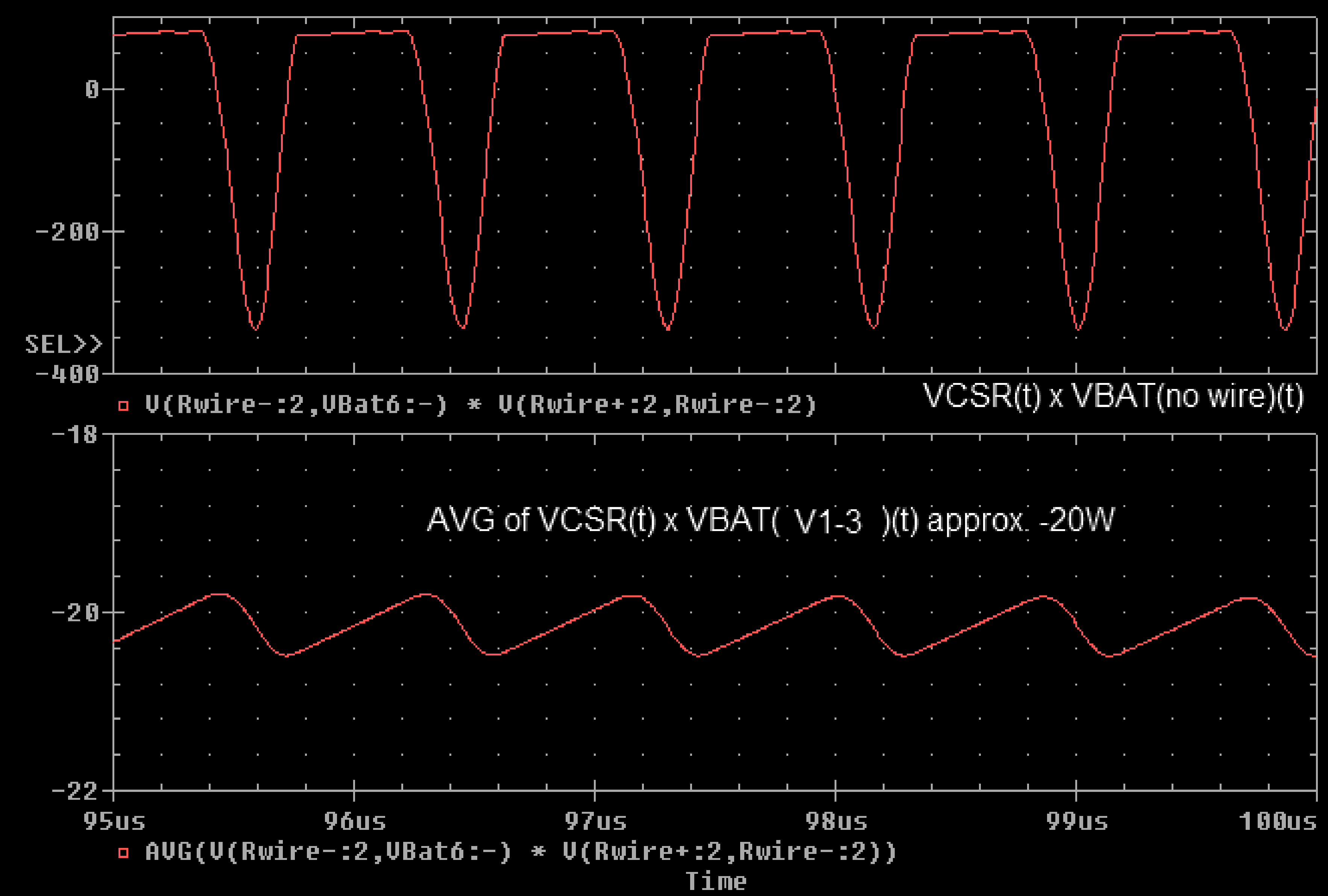
The first test run in this installment is with the voltage probes placed across the battery array and CSR (V1-3), completely eliminating the long battery wire leads. The power computation comes to **-20W**.

The second test run is with the battery voltage probes across nodes (V1-2), which eliminates the voltage across the CSR, and is therefore directly across the battery array and the associated battery jumper wires. This power computation comes to **-17.5W**.

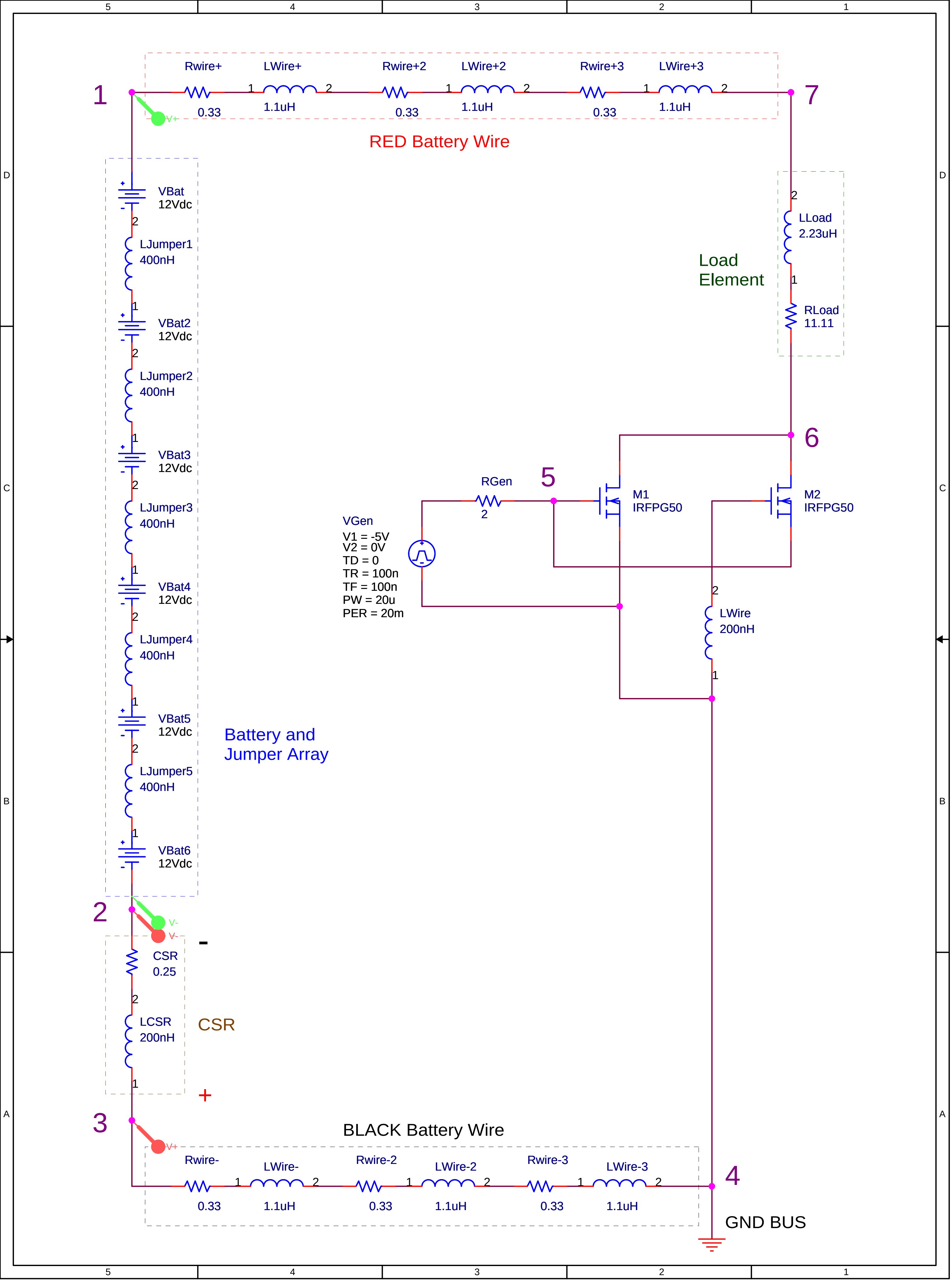


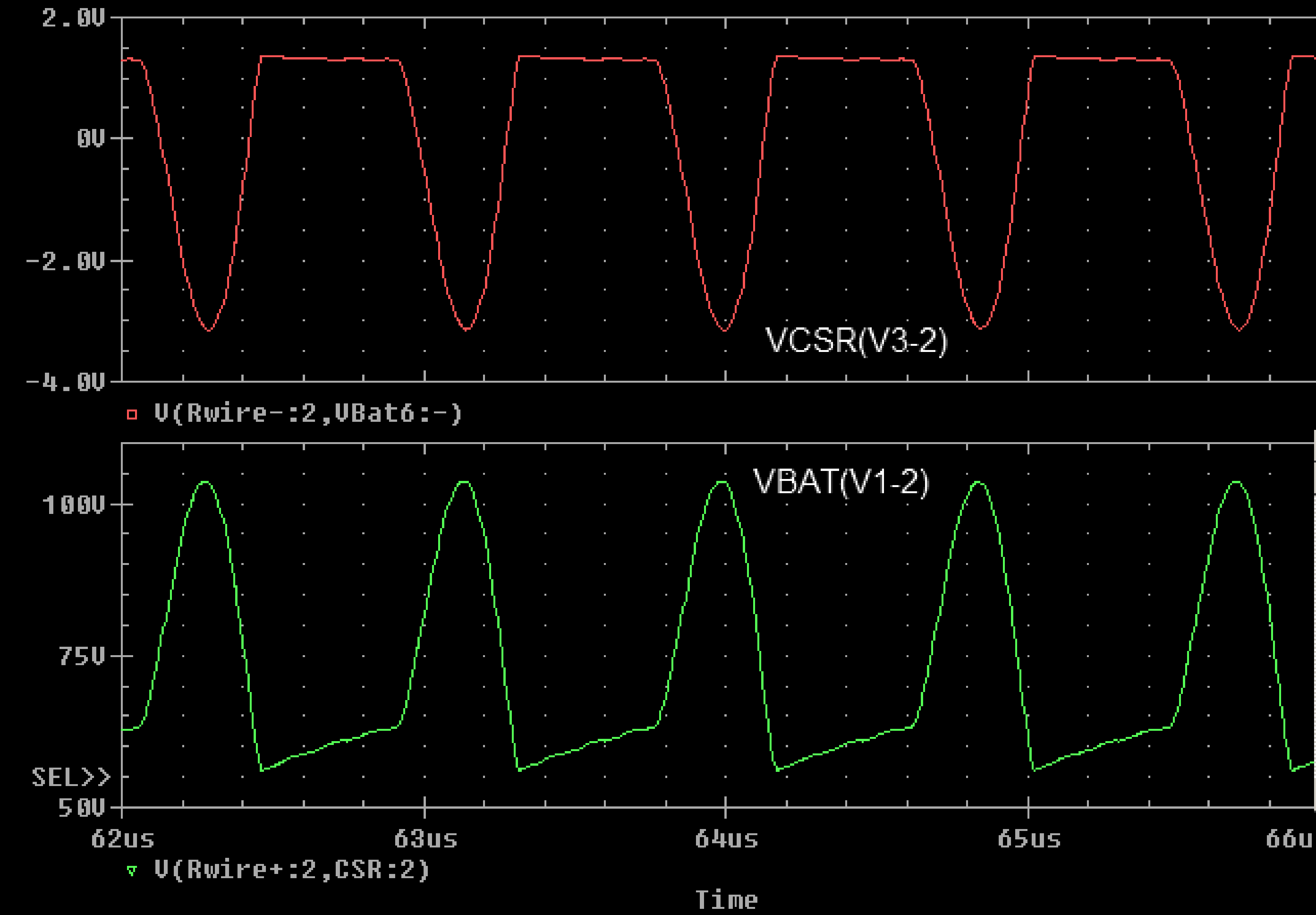
RED Battery Wire
Rwire+
0.33
LWire+
1.1uH
Rwire+2
0.33
LWire+2
1.1uH
Rwire+3
0.33
LWire+3
1.1uH
VBat
12Vdc
LJumper1
400nH
VBat2
12Vdc
LJumper2
400nH
VBat3
12Vdc
LJumper3
400nH
VBat4
12Vdc
LJumper4
400nH
VBat5
12Vdc
LJumper5
400nH
VBat6
12Vdc
Battery and
Jumper Array
Load
Element
LLoad
2.23uH
RLoad
11.11
RGen
2
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
M1
IRFPG50
M2
IRFPG50
LWire
200nH
CSR
0.25
LCSR
200nH
CSR
BLACK Battery Wire
Rwire-
0.33
LWire-
1.1uH
Rwire-2
0.33
LWire-2
1.1uH
Rwire-3
0.33
LWire-3
1.1uH
GND BUS


2.0V
0V
-2.0V
SEL>>
-4.0V
VCSR(V3-2)
V(Rwire-:2,VBat6:-)
VBAT(V1-3)
100V
75V
50V
62us
63us
64us
65us
66us
V(Rwire+:2,Rwire-:2)
Time

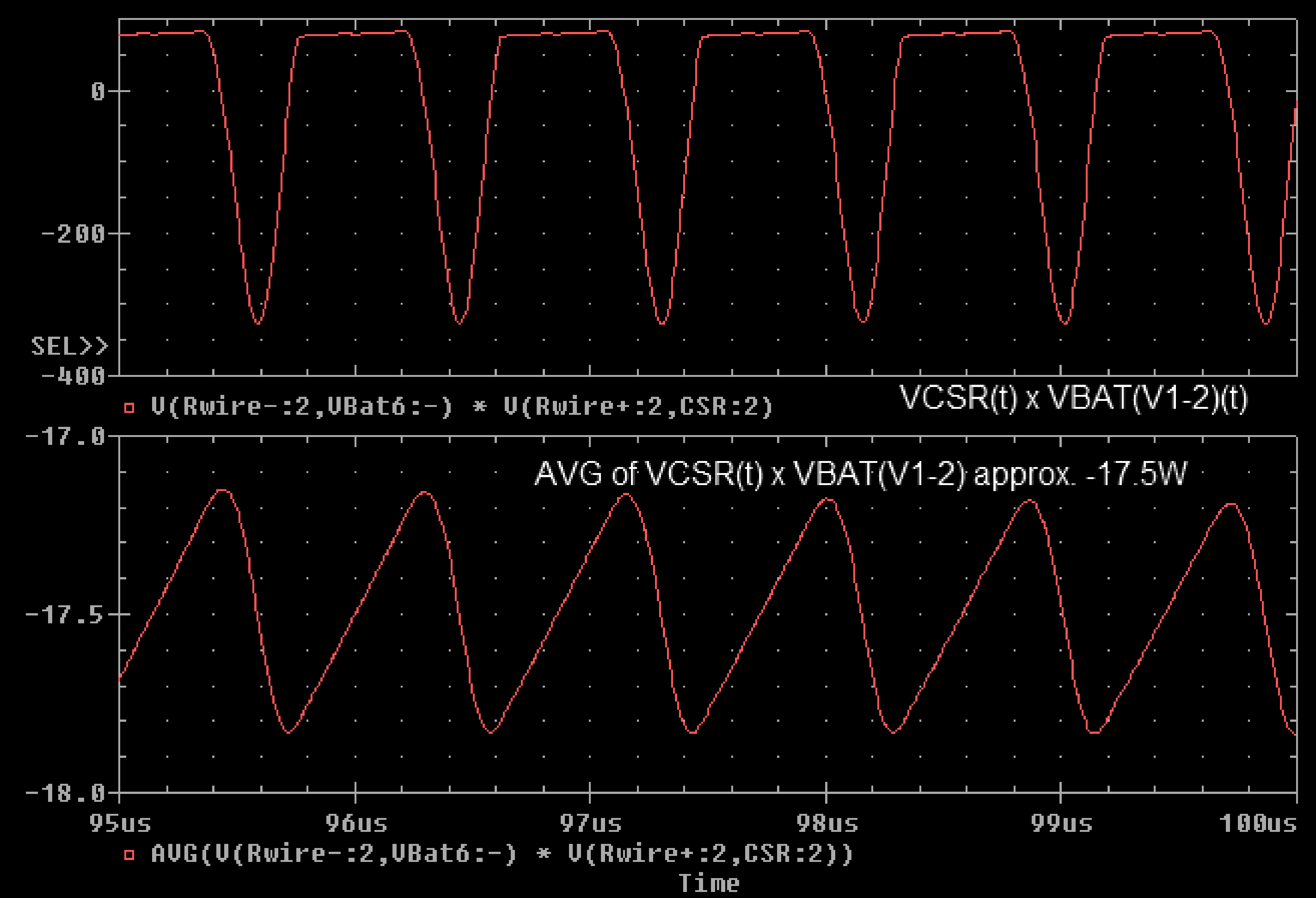


0
-200
SEL>>
-400
V(Rwire-:2,VBat6:-) * V(Rwire+:2,Rwire-:2)
VCSR(t) x VBAT(no wire)(t)
-18
AVG of VCSR(t) x VBAT(V1-3)(t) approx. -20W
-20
-22
95us
96us
97us
98us
99us
100us
AVG(V(Rwire-:2,VBat6:-) * V(Rwire+:2,Rwire-:2))
Time


RED Battery Wire
Rwire+ 0.33
LWire+ 1.1uH
Rwire+2 0.33
LWire+2 1.1uH
Rwire+3 0.33
LWire+3 1.1uH
1
7
V+
VBat 12Vdc
LJumper1 400nH
VBat2 12Vdc
LJumper2 400nH
VBat3 12Vdc
LJumper3 400nH
VBat4 12Vdc
LJumper4 400nH
VBat5 12Vdc
LJumper5 400nH
VBat6 12Vdc
Battery and Jumper Array
Load Element
LLoad 2.23uH
RLoad 11.11
6
5
RGen 2
M1 IRFPG50
M2 IRFPG50
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
LWire 200nH
2
V-
CSR 0.25
LCSR 200nH
CSR
-
+
3
BLACK Battery Wire
Rwire- 0.33
LWire- 1.1uH
Rwire-2 0.33
LWire-2 1.1uH
Rwire-3 0.33
LWire-3 1.1uH
4
GND BUS



2.0V
0V
-2.0V
-4.0V
VCSR(V3-2)
□ V(Rwire-:2,VBat6:-)
VBAT(V1-2)
100V
75V
SEL>>
50V
62us
63us
64us
65us
66u
▽ V(Rwire+:2,CSR:2)
Time



0
-200
SEL>>
-400
V(Rwire-:2,VBat6:-) * V(Rwire+:2,CSR:2)
VCSR(t) x VBAT(V1-2)(t)
-17.0
AVG of VCSR(t) x VBAT(V1-2) approx. -17.5W
-17.5
-18.0
95us
96us
97us
98us
99us
100us
AVG(V(Rwire-:2,VBat6:-) * V(Rwire+:2,CSR:2))
Time

For the next installment of simulation test runs, it's necessary to establish some simple background theory:

If each of the 6 twelve-volt batteries in the battery array have approximately the same state of charge, terminal voltage, and internal resistance, it is reasonable to assume that each of the 6 batteries will receive or supply the same amount of power in the circuit. As such, it is valid to measure and analyze the power in any one of the 6 batteries and apply a factor of 6x to obtain the total power in the circuit.

In this first test, the battery voltage probes are placed across the last jumper wire and last 12V battery. So we are measuring the voltage across a single 12V battery in series with 400nH of wire inductance in a single jumper. The power computes to **-3.8W**.

Next, when the battery voltage probes are placed directly across the single 12V battery and no jumper, **the power changes polarity** and computes to roughly **+1.4W**.

When the wattage probe available in PSpice is used to directly measure the instantaneous power of the single 12V battery, it computes to a net average of approximately **-5.45W**. If you recall the exercise on the polarity of power sources vs. power dissipaters a little while back, you will know that **the proper polarity for a source that is sourcing power, is negative**. The reason the last computation of +1.4W turned out positive, **is because the voltage probes across the CSR are reversed** (as a matter of establishing common ground for both the CSR and battery probes). This has been the case throughout this exercise. It adds a bit of confusion, but that is the direction the "powers" normally go and it's important to keep this straight in one's mind.

Now back to the issue of the correct value for the CSR. As we now know the true power in any one of the six 12V batteries is about -5.45W, and that the previous measurement using a single 12V battery times the CSR voltage (battery current) came to approximately +1.4W (assuming a 1 Ohm value for the CSR), it may become obvious that **assuming the CSR value to be anything other than 0.25 Ohms is incorrect**. If we take the +1.4W measurement and multiply it by 4x (1/0.25), we obtain a power of about +5.6W. I have been approximating the values read off the scope, so in reality the previous measurement would actually be closer to +1.37W. It should be clear from this that **the correct value for the CSR when looking at DC INPUT power, is the actual resistive value of the CSR, in this case 0.25 Ohms** (regardless if the current is pulsed at a high frequency or not).

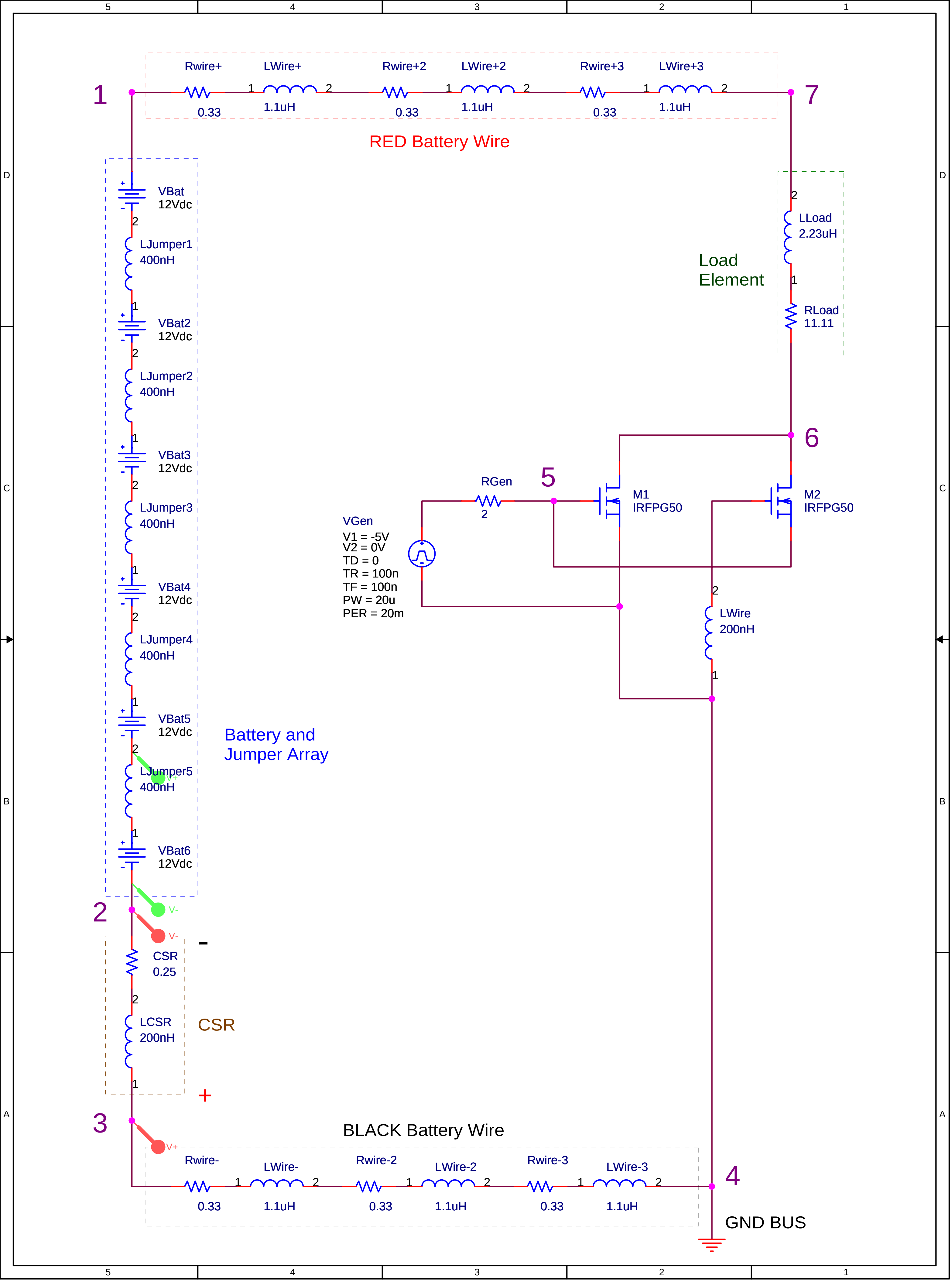
Computing the total power (using the Wattage probe) from all 6 batteries in the array we have:

-5.45W x 6 = **-32.7W**

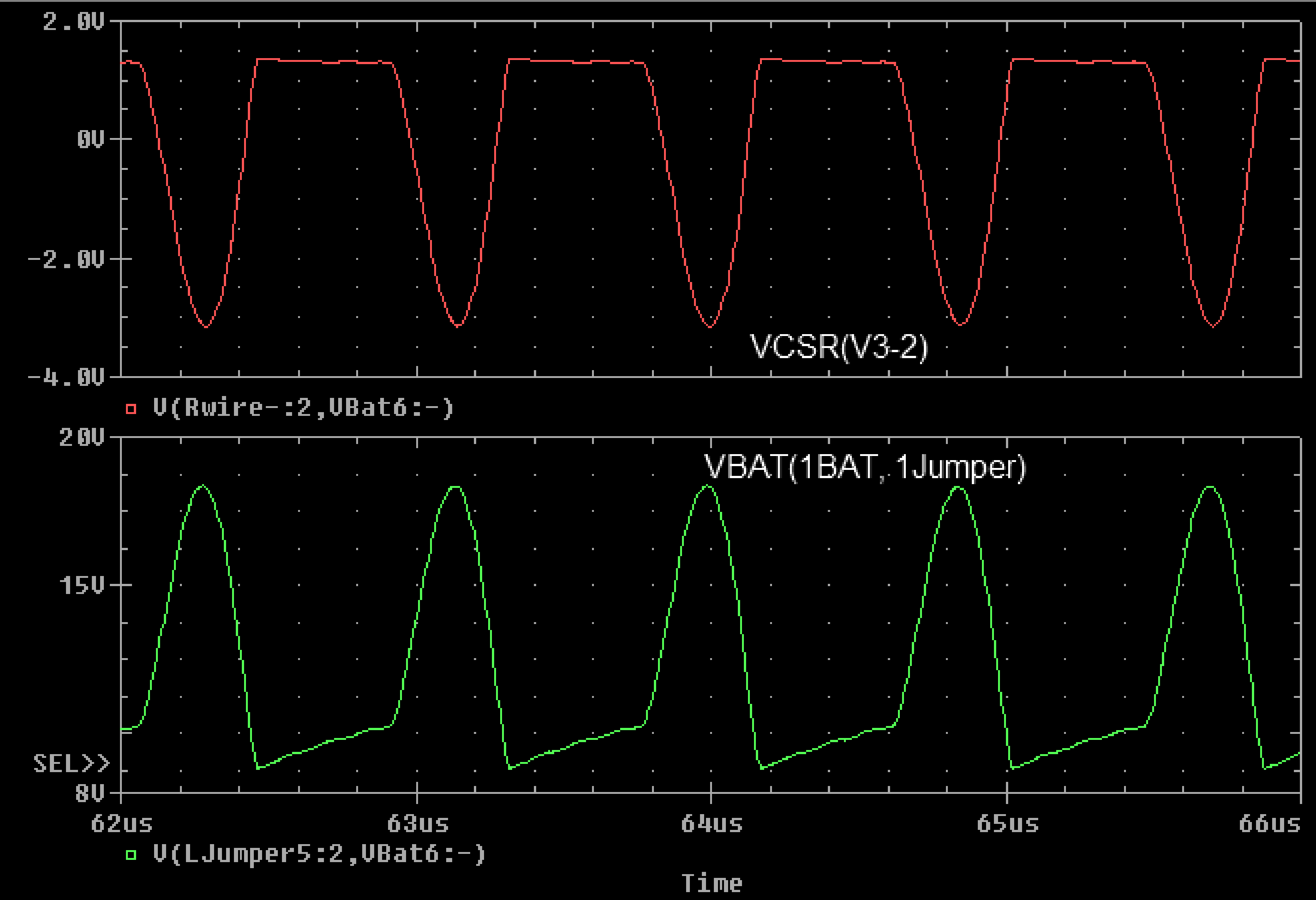
This is the actual correct value and polarity for the total INPUT power of the battery array in this particular simulation.

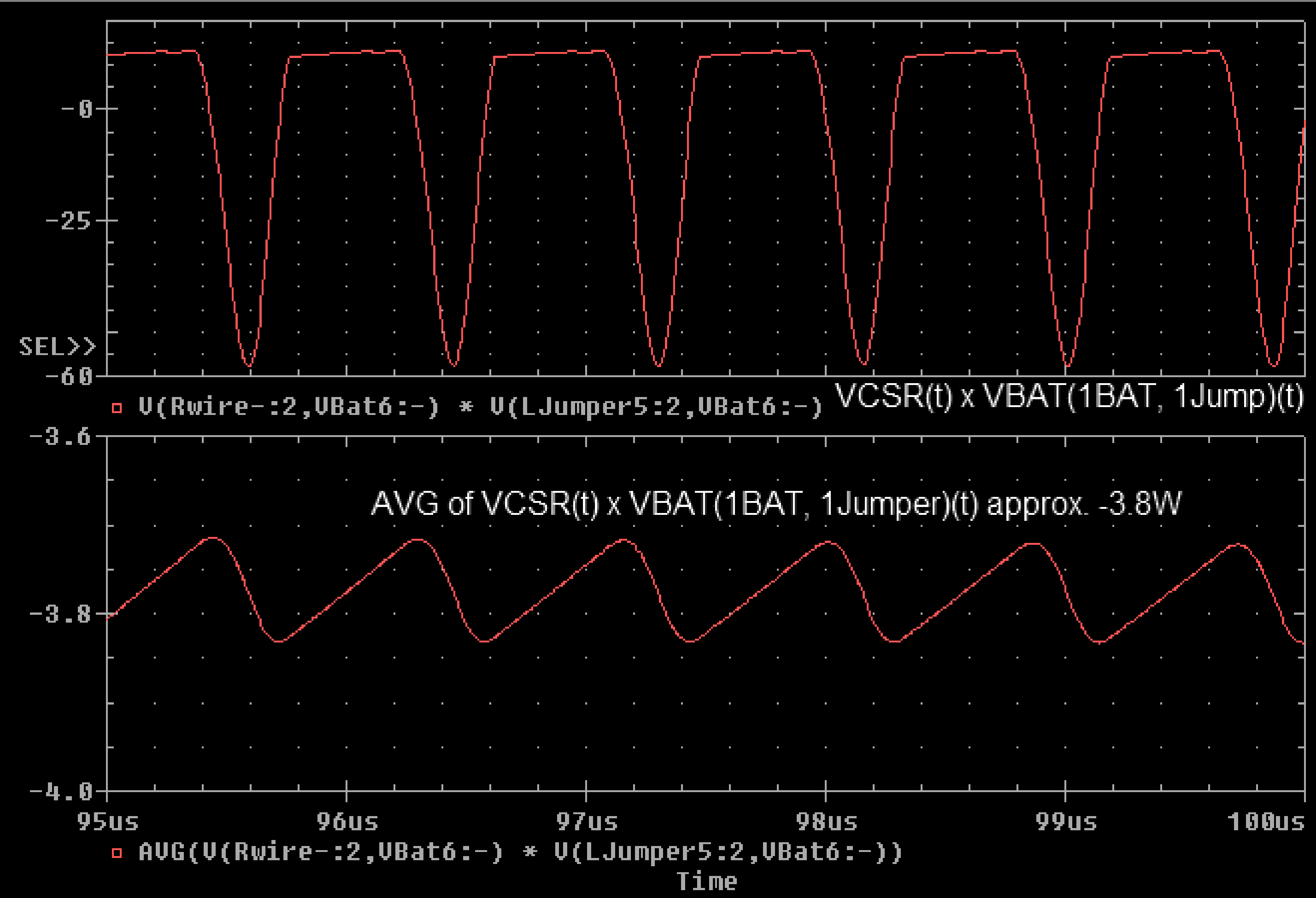
Now, if we take the previous +1.37W measurement (which used the VCSR(t) x VBAT(t)) using just a single battery and no jumper wire, and multiply it by 4 (because of the 0.25 Ohm CSR), then by 6 (for 6 batteries in the array), we obtain a power of about **+32.88W**.

Other than the polarity difference (because the CSR probes are reversed), the two powers are almost identical in magnitude, and it is safe to say that now with the inductance eliminated in the battery voltage measurement, the VCSR(t) x VBAT(t) computation by the scope is very accurate.

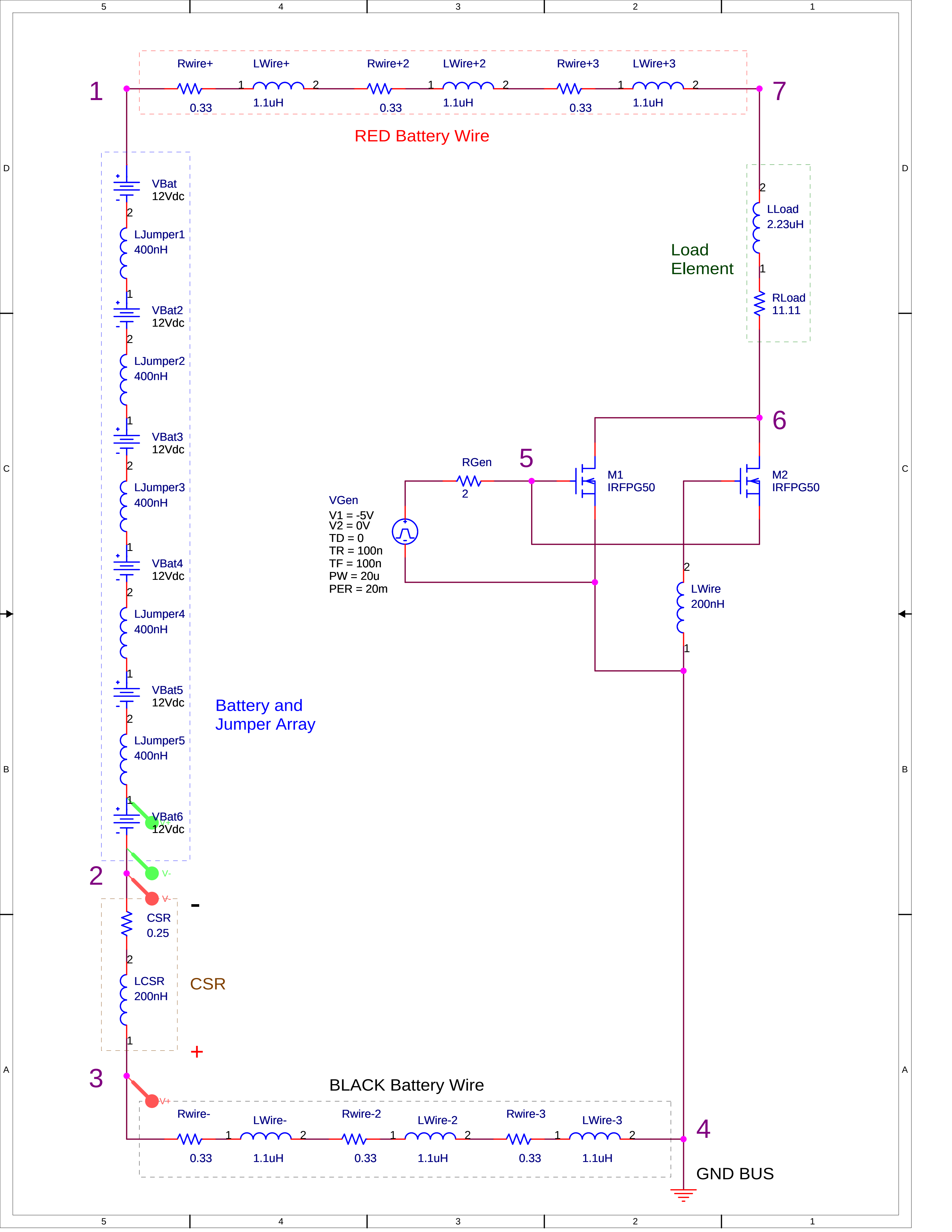


RED Battery Wire
Rwire+ 0.33
LWire+ 1.1uH
Rwire+2 0.33
LWire+2 1.1uH
Rwire+3 0.33
LWire+3 1.1uH
1
7
VBat 12Vdc
LJumper1 400nH
VBat2 12Vdc
LJumper2 400nH
VBat3 12Vdc
LJumper3 400nH
VBat4 12Vdc
LJumper4 400nH
VBat5 12Vdc
LJumper5 400nH
VBat6 12Vdc
Battery and Jumper Array
Load Element
LLoad 2.23uH
RLoad 11.11
6
5
RGen 2
M1 IRFPG50
M2 IRFPG50
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
LWire 200nH
2
CSR 0.25
LCSR 200nH
CSR
-
+
3
BLACK Battery Wire
Rwire- 0.33
LWire- 1.1uH
Rwire-2 0.33
LWire-2 1.1uH
Rwire-3 0.33
LWire-3 1.1uH
4
GND BUS

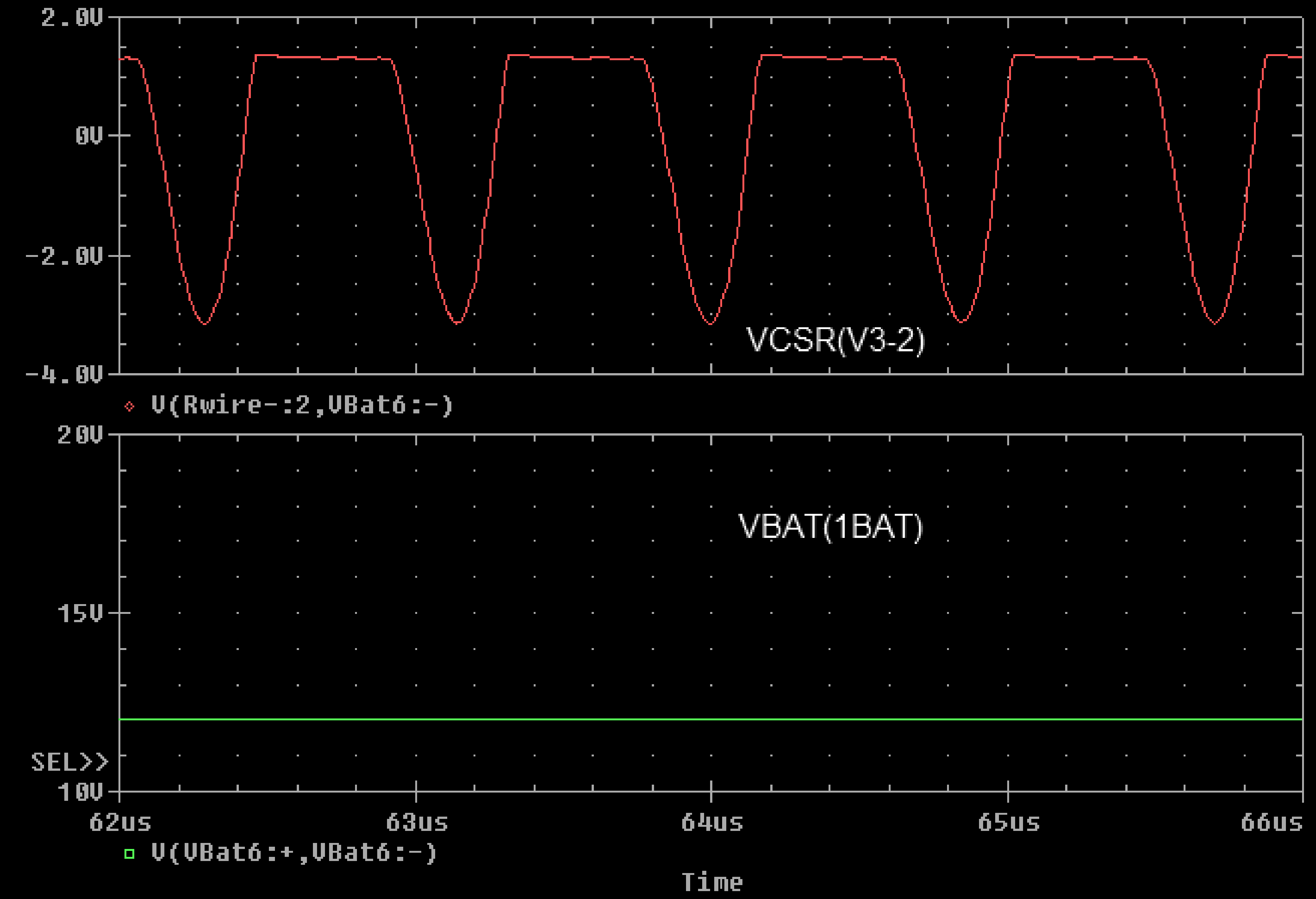

2.0V
0V
-2.0V
-4.0V
VCSR(V3-2)
V(Rwire-:2,VBat6:-)
20V
VBAT(1BAT, 1Jumper)
15V
SEL>>
8V
62us
63us
64us
65us
66us
V(LJumper5:2,VBat6:-)
Time

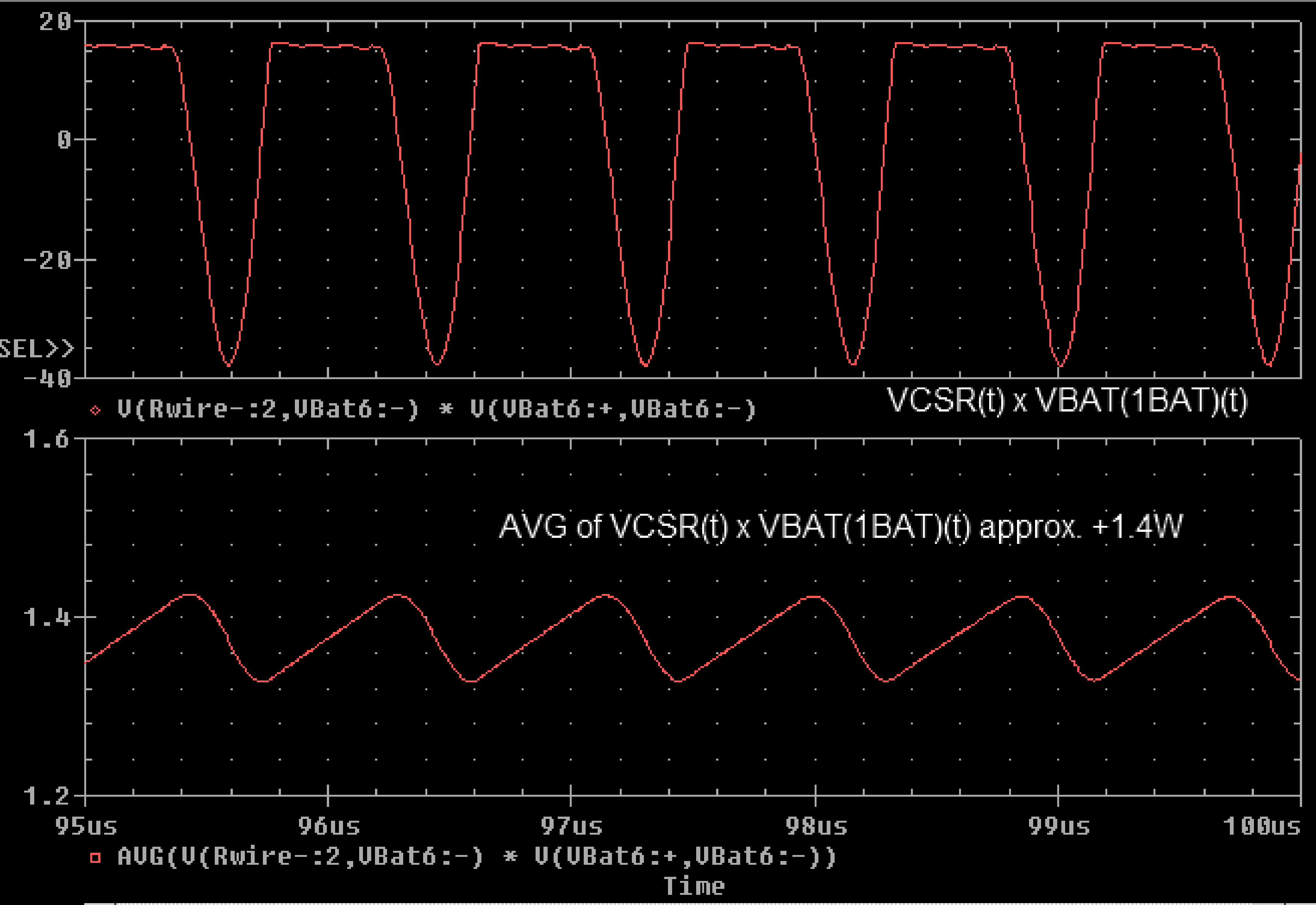


-0
-25
SEL>>
-60
V(Rwire-:2,VBat6:-) * V(LJumper5:2,VBat6:-)
VCSR(t) x VBAT(1BAT, 1Jump)(t)
-3.6
AVG of VCSR(t) x VBAT(1BAT, 1Jumper)(t) approx. -3.8W
-3.8
-4.0
95us
96us
97us
98us
99us
100us
AVG(V(Rwire-:2,VBat6:-) * V(LJumper5:2,VBat6:-))
Time

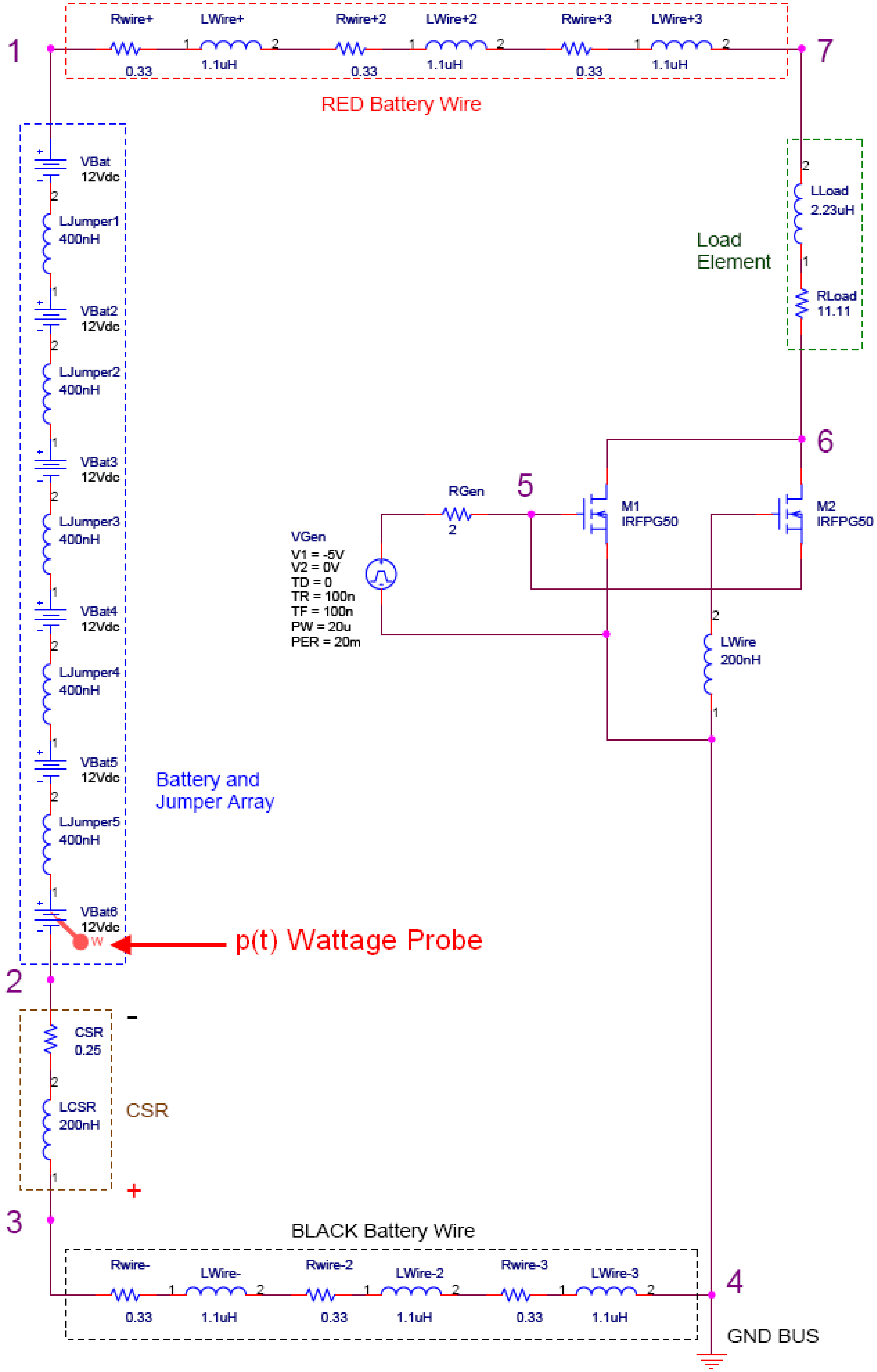


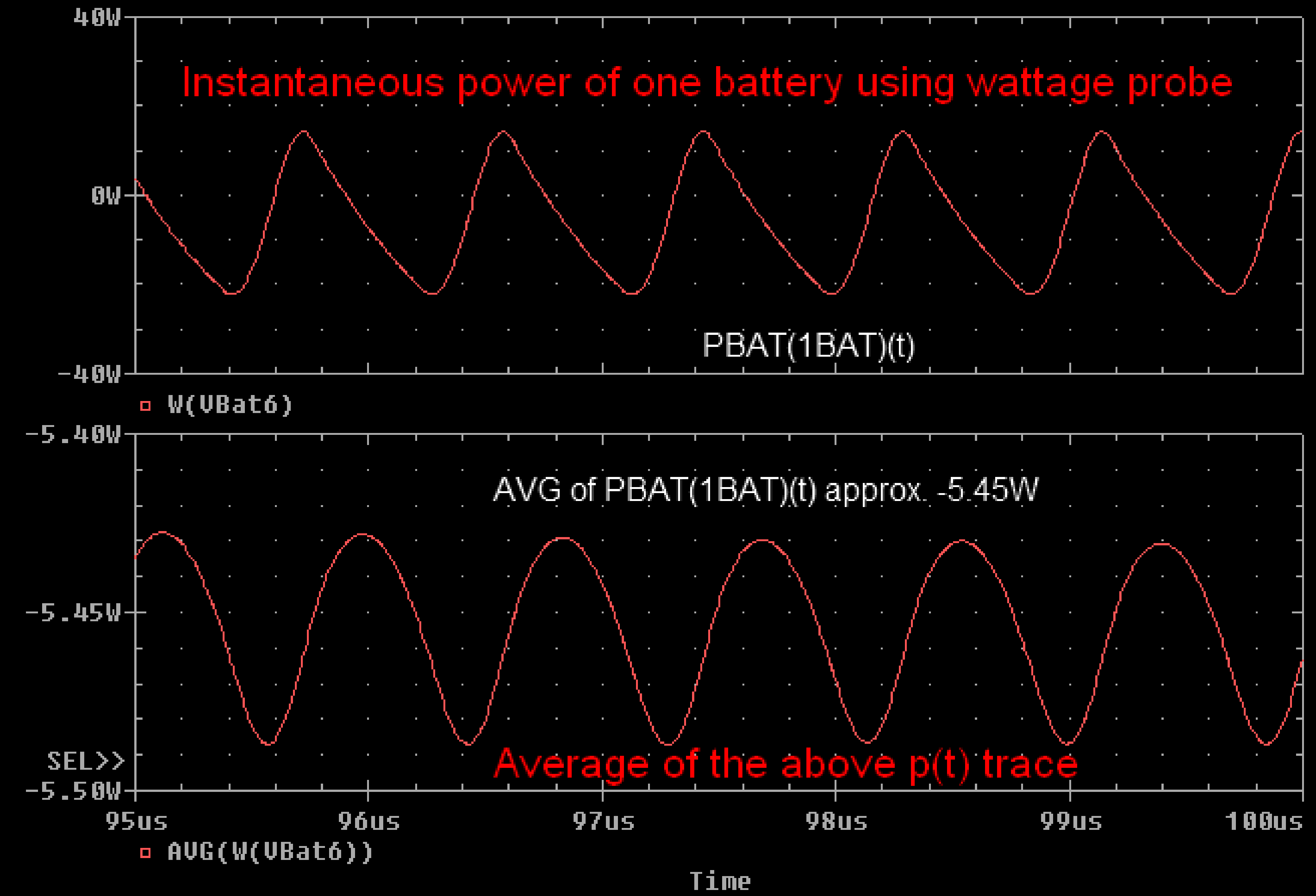
1
Rwire+
0.33
LWire+
1.1uH
Rwire+2
0.33
LWire+2
1.1uH
Rwire+3
0.33
LWire+3
1.1uH
7
RED Battery Wire
VBat
12Vdc
LJumper1
400nH
VBat2
12Vdc
LJumper2
400nH
VBat3
12Vdc
LJumper3
400nH
VBat4
12Vdc
LJumper4
400nH
VBat5
12Vdc
LJumper5
400nH
VBat6
12Vdc
Battery and
Jumper Array
LLoad
2.23uH
RLoad
11.11
Load
Element
6
5
RGen
M1
IRFPG50
M2
IRFPG50
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
LWire
200nH
2
V-
V-
-
CSR
0.25
LCSR
200nH
CSR
+
3
V+
BLACK Battery Wire
Rwire-
0.33
LWire-
1.1uH
Rwire-2
0.33
LWire-2
1.1uH
Rwire-3
0.33
LWire-3
1.1uH
4
GND BUS


2.0V
0V
-2.0V
-4.0V
VCSR(V3-2)
V(Rwire-:2,VBat6:-)
20V
VBAT(1BAT)
15V
SEL>>
10V
62us
63us
64us
65us
66us
V(VBat6:+,VBat6:-)
Time



20
0
-20
SEL>>
-40
◇ V(Rwire-:2,VBat6:-) * V(VBat6:+,VBat6:-)
VCSR(t) x VBAT(1BAT)(t)
1.6
AVG of VCSR(t) x VBAT(1BAT)(t) approx. +1.4W
1.4
1.2
95us
96us
97us
98us
99us
100us
□ AVG(V(Rwire-:2,VBat6:-) * V(VBat6:+,VBat6:-))
Time


Rwire+
LWire+
Rwire+2
LWire+2
Rwire+3
LWire+3
1
0.33
1.1uH
0.33
1.1uH
0.33
1.1uH
7
RED Battery Wire
VBat
12Vdc
LJumper1
400nH
VBat2
12Vdc
LJumper2
400nH
VBat3
12Vdc
LJumper3
400nH
VBat4
12Vdc
LJumper4
400nH
VBat5
12Vdc
LJumper5
400nH
VBat6
12Vdc
Battery and
Jumper Array
p(t) Wattage Probe
LLoad
2.23uH
RLoad
11.11
Load
Element
6
RGen
5
M1
IRFPG50
M2
IRFPG50
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
LWire
200nH
2
CSR
0.25
LCSR
200nH
CSR
3
BLACK Battery Wire
Rwire-
LWire-
Rwire-2
LWire-2
Rwire-3
LWire-3
0.33
1.1uH
0.33
1.1uH
0.33
1.1uH
4
GND BUS



40W
0W
-40W
Instantaneous power of one battery using wattage probe
PBAT(1BAT)(t)
W(VBat6)
-5.40W
-5.45W
-5.50W
SEL>>
AVG of PBAT(1BAT)(t) approx. -5.45W
Average of the above p(t) trace
95us
96us
97us
98us
99us
100us
AVG(W(VBat6))
Time

A summary of the detailed analysis performed thus far:

In order to more fully explore the subtleties of this circuit, the battery array and battery jumper wiring was included in the diagram, and hence in the simulation. The jumper wiring adds a total of 2uH inductance (5 jumpers x 400nH ea.) to the battery circuit. In addition, the DC feed wires from the battery array (RED and BLACK) to the MOSFETs and Load Element mounted on the perf board, were broken down into 3 wire segments, each with an inherent inductance of 1.1uH and resistance of 0.33 Ohms.

So the expanded DC feed wiring still exhibits a significant magnitude of total inductance (3.3uH) and resistance (1 Ohm) in keeping with previous diagrams and simulations, with the exception that about 1/3 more inductance was added at Rose's request. The previous total inductance was 2uH in each leg, now there is 3.3uH. The battery jumper wiring has a total of 2uH as previously mentioned.

From here, battery voltage measurements were taken across several points in the battery wiring part of the circuit. When multiplied with the CSR probe voltage, first the instantaneous, then average INPUT power was reiteratively computed for each battery voltage measurement point, and displayed in the many scope shots. The battery voltage measurement points start at node 7 shown on the diagram. This is the voltage measured at node 7 in reference to the GND BUS node 4. From here the battery voltage probes were moved progressively to the left (on both the RED and BLACK wire simultaneously) in the schematic such that **the wiring inductance effects on the battery voltage measurement become evident**. After 4 measurements, the battery probes end up located at nodes 1 and 3. At this point, the battery voltage is being measured across the battery/jumper array and the CSR inclusive (see "schema04.png"). This measurement point eliminates **the effects** of the inductance and resistance contributed by the RED and BLACK battery feed wires. Because the interest is strictly in the battery voltage alone, the bottom battery voltage probe was moved to node 2 in the schematic (see "schema05.png"). This now eliminates **the effects** of the CSR resistance and inductance on the battery voltage measurement. Throughout this progression of battery voltage measurement points closer and closer to the battery array, it was shown that the net battery power, although negative in polarity, was decreasing in magnitude with each progressive move closer to the battery array. Note, for each and every measurement throughout the exercise, the CSR probes remain across the CSR unchanged.

Next, it was explained that a valid INPUT power analysis can be performed by measuring only one of the six batteries in the array, assuming that each of the six are in a similar operating condition. Combining the voltage measurement across the last battery in the array with the adjacent CSR voltage (current) reading, INPUT power can be computed. Total circuit power is computed simply by multiplying by 6.

The next battery voltage measurement was taken across the last 12V battery (VBat6) and its associated wire jumper (LJumper5). See "schema06.png". Here it is shown that the INPUT power still computes to a negative value (-3.8W) (assuming CSR=1Ohm).

Once again, because the interest is strictly in the voltage across the battery itself, the top battery voltage probe was moved down, eliminating **the effects** of the jumper inductance on the measurement and providing a direct measurement of the battery voltage alone. See "schema07.png". As a reminder, it is critical to keep in mind how the INPUT power is computed; PBAT(t) = VBAT(t) x IBAT(t). VBAT is the battery voltage (either a single 12V, or all six), and this **can not** include the voltage contributed by any stray inductance. It is imperative therefore to measure the battery voltage directly across the battery terminals; no jumper or feed wiring can be included in this battery voltage measurement.

With the battery voltage probes placed directly across the last battery (Vbat6), the battery power computes to about +1.37W. As a result of measuring the battery voltage directly, thus eliminating the effects of the jumper inductance, the battery net average power figure has actually reversed polarity. Previously, when "LJumper5" **was included** in the battery voltage measurement, the net average battery (Vbat6) power computed to about -3.8W. This is the most important point all ought to pay close attention to, because it clearly shows how the inductance associated with only ~20 inches of wire can completely skew the net average power computation.

Next, it was shown that the total net average power from all six batteries computed to -32.7W (-5.45W ea.) using the Wattage probe available in PSpice. Note that the polarity of this net average power is negative, and **this is the correct polarity for a source that is sourcing a net power**. If the battery source was **receiving** a net power, the polarity would have been positive. This -32.7W is the TRUE power being sourced by the six batteries, and the key word is **sourced**. The evidence produced from the simulation clearly shows that the batteries are not receiving a net power and are not being charged, despite what **appears to be the contrary** when the battery voltage measurements are NOT made with the probes directly across the battery terminals (i.e. with inductance affecting the measurement as is the case shown in "schema06.png").

The probes as placed across the CSR are reversed, relative to the orientation of the probes as placed across the battery Vbat6. See "schema07.png". From top to bottom starting at the top of Vbat6, the probes are placed as follows: **+, -, -, +**. This is the reason a power computation using the probes configured as such, will yield a positive power (when made with no inductance in the battery voltage measurement) when multiplied together and averaged to produce a net power figure. The figure of +1.37W previously obtained clearly illustrates this fact (for a refresher, please refer to the previous discussion on the correct power polarity for power sources (NEG) and power sinks (POS)). The only reason the probes were placed in reverse across the CSR in the simulation, is because this is the best method available when using standard passive scope probes; it allows for a common ground point for both scope channels at node 2. This is how the Ainslie team was advised to orient the probes, therefore it was done this way in the simulation as well in order to keep the results the same.

The issue regarding the actual value that should be used for the CSR, is an issue that will be addressed in the next installments.

A re-post of the brief discussion on the polarity of power for sources and sinks.

Regarding the probes across the CSR; note the voltage across the battery and CSR are in reverse polarity, hence the power computation for sources sourcing power is NEGATIVE. **Since the probes on the CSR are in reverse, the polarity of the power computation results in a POSITIVE figure**.

The original post:

Power **coming from** (as opposed to **going to**) a source such as a battery, **will always compute to a negative number**.

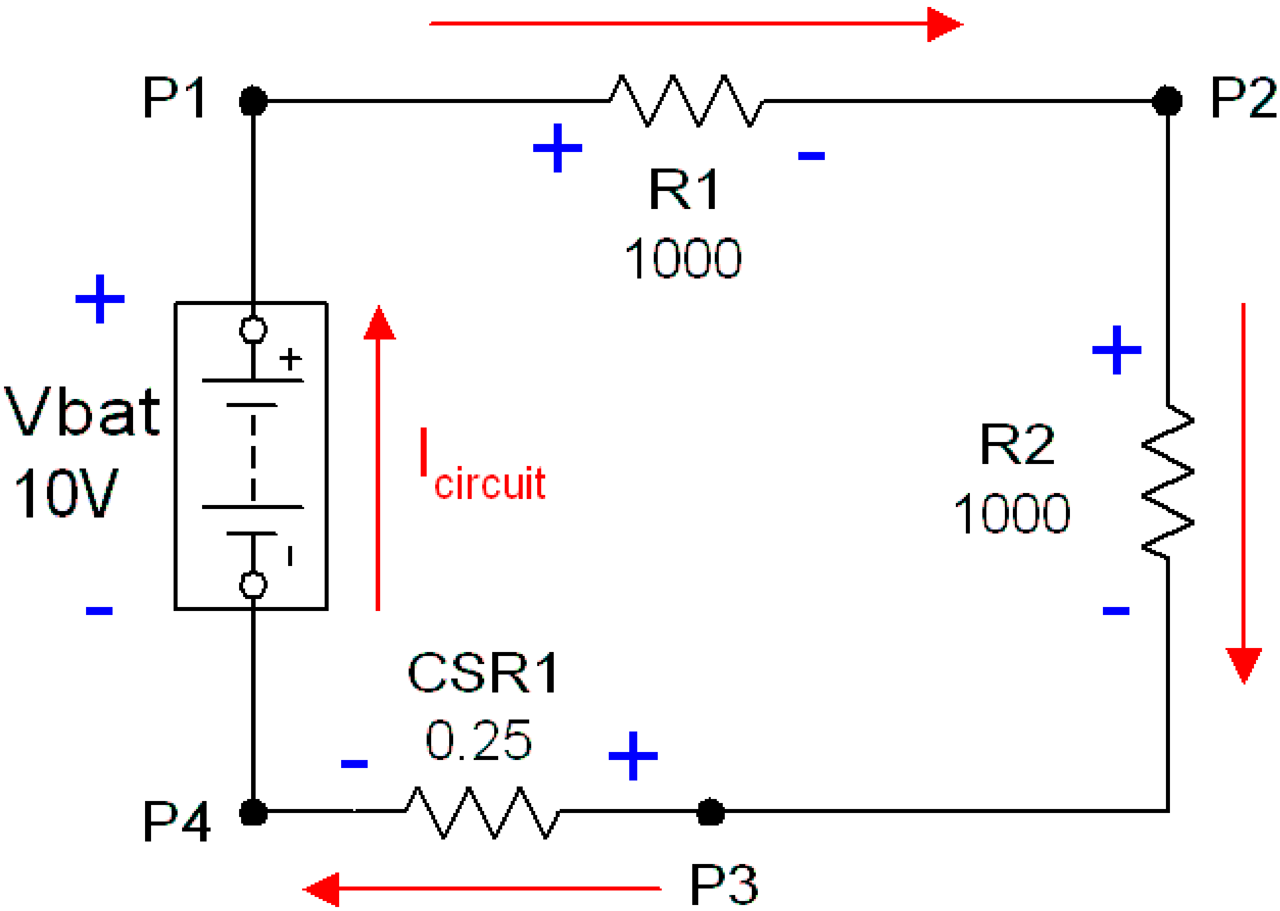
In the attached diagram, there is a simple example with one source (Vbat) and some resistive loads, R1, R2, and CSR1.

The electric field across any source is always in opposition to the direction of current through that source.

I have marked the direction of current in RED and the polarity of the potential difference across each component in BLUE. Note that the battery Vbat has a potential difference **opposite** to that of all three loads? Since power in a component is the voltage across it times the current through it, it's now obvious why a **source** will have a **negative sign** associated with its power. At the loads, the potential difference across them and the current through them are in the same direction, and hence the power associated with **any load** is **positive**.

Under normal circumstances, any power source loses or gives up energy, and any load gains or receives energy, so this is an easy way to remember what polarity the power should be in each.

SPICE does not do anything unusual by applying a negative polarity to any source power that it plots on its scope, because you can see that this is precisely how the math works out.



Battery Power = Battery (V) x (I)

The electric field of any source always opposes the direction of conventional current through it.

The blue markers indicate the polarity of the potential difference across each component.

P_{R1} = V(P1 - P2) x V(P3 - P4)/0.25 =>
P_{R1} = 4.999V x 1.2498mV/0.25 = **+24.99mW**

however,

P_{Vbat}= V(P4 - P1) x V(P3 - P4)/0.25 =>
P_{Vbat}= -10V x 1.2498mV/0.25 = **-49.99mW**

For this next installment, let's begin by reviewing one of the last simulation test runs. Referring to **schema07.png** and the associated scope shot **scope13.png**, we see that when the oscilloscope probes are placed directly across the terminals of one of the six batteries, the scope trace is essentially a flat line at the 12V level, indicating the battery's DC voltage reading. Providing that the battery's internal resistance is reasonably low (typically less than 0.01 Ohms when fully charged), the scope trace will be reasonably, if not perfectly flat, with no ripple caused by the circulating currents. In practice however, there will always be a finite internal resistance, and at times when the battery is not fully charged, we may in fact see some small amount of ripple riding on the flat 12V trace. Depending on the currents being drawn from the battery and the battery's state of charge (SOC), the amount of ripple might vary from a few millivolts, to several hundred millivolts. In most cases, the ripple won't exceed 1Vp or so.

Generally speaking however, when measuring the battery voltage on a loaded but charged battery, the resulting trace will essentially be **a flat line at the voltage level present directly on the battery terminals**. For all intents and purposes, this voltage is "pure DC", and will be referred to as "DC" from this point forward.

Reviewing the methodology involved in obtaining the measurement of average input power (Pin), we have:

Pin(avg) = AVG[VBAT(t) x VCSR/CSR(t)], or in words;

Average input power is equal to the average of the product of the instantaneous battery voltage, and the scaled (by the CSR value) instantaneous voltage across the CSR.

For the moment, we will acknowledge that the CSR value will vary (due to the presence of 200nH of parasitic inductance in series with the CSR, as shown) under the conditions of a high frequency current through it.

Knowing that a properly measured battery voltage will result in essentially a flat DC trace, we can slightly alter the above power equation to the following:

Pin(avg) = AVG[VBAT(DC) x VCSR/CSR(t)], or in words;

Average input power is equal to the average of the product of the battery voltage (in DC), and the scaled (by the CSR value) instantaneous voltage across the CSR.

From this we can see that the DC battery voltage is simply **a constant multiplying factor** that is applied to the VCSR/CSR(t) factor in the power equation. There are no phase considerations involved here because the phase angle between a DC voltage and any current (varying or not) is 0^{o}. The COS of 0^{o} is 1, and this means that the power factor associated with a DC source is 1. So although still valid, it should now be obvious that an oscilloscope channel is NOT required to properly obtain the required battery voltage for a DC INPUT power measurement! **A digital voltage meter (DVM, DMM) placed directly across the battery terminals is all that is needed**.

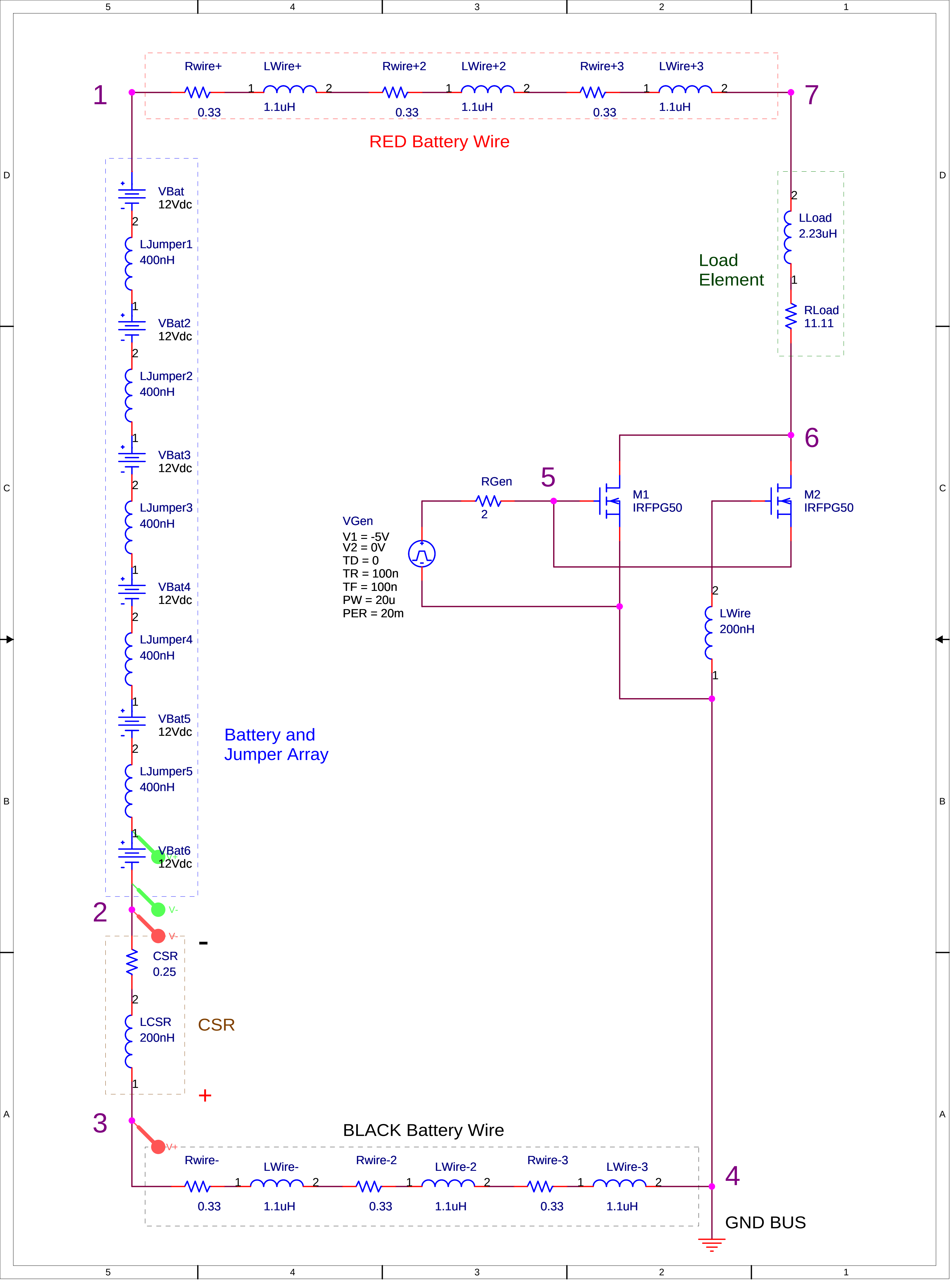
What if we don't measure the battery voltage with the probes placed directly across the battery terminals? Well, it turns out that **if dealt with properly**, this is not a huge problem at all. We know that the battery voltage should be essentially a flat line representing the battery terminal voltage. We also know that if we take a battery voltage measurement with the probes placed across two points that include any amount of parasitic inductance (i.e. battery wiring), the measurement points will show a considerable amount of ripple riding on the true DC voltage if observed with an oscilloscope. No problem.

Because we know that the battery voltage should be "flat", we are permitted to apply a significant amount of filtering (or averaging) to the signal being measured across these two "displaced" battery measurement points. The result is a reading of DC voltage minus a small DC voltage drop across the battery wiring resistance. In other words, this voltage measurement will be extremely close to the same measurement made with the probes directly across the battery terminals.

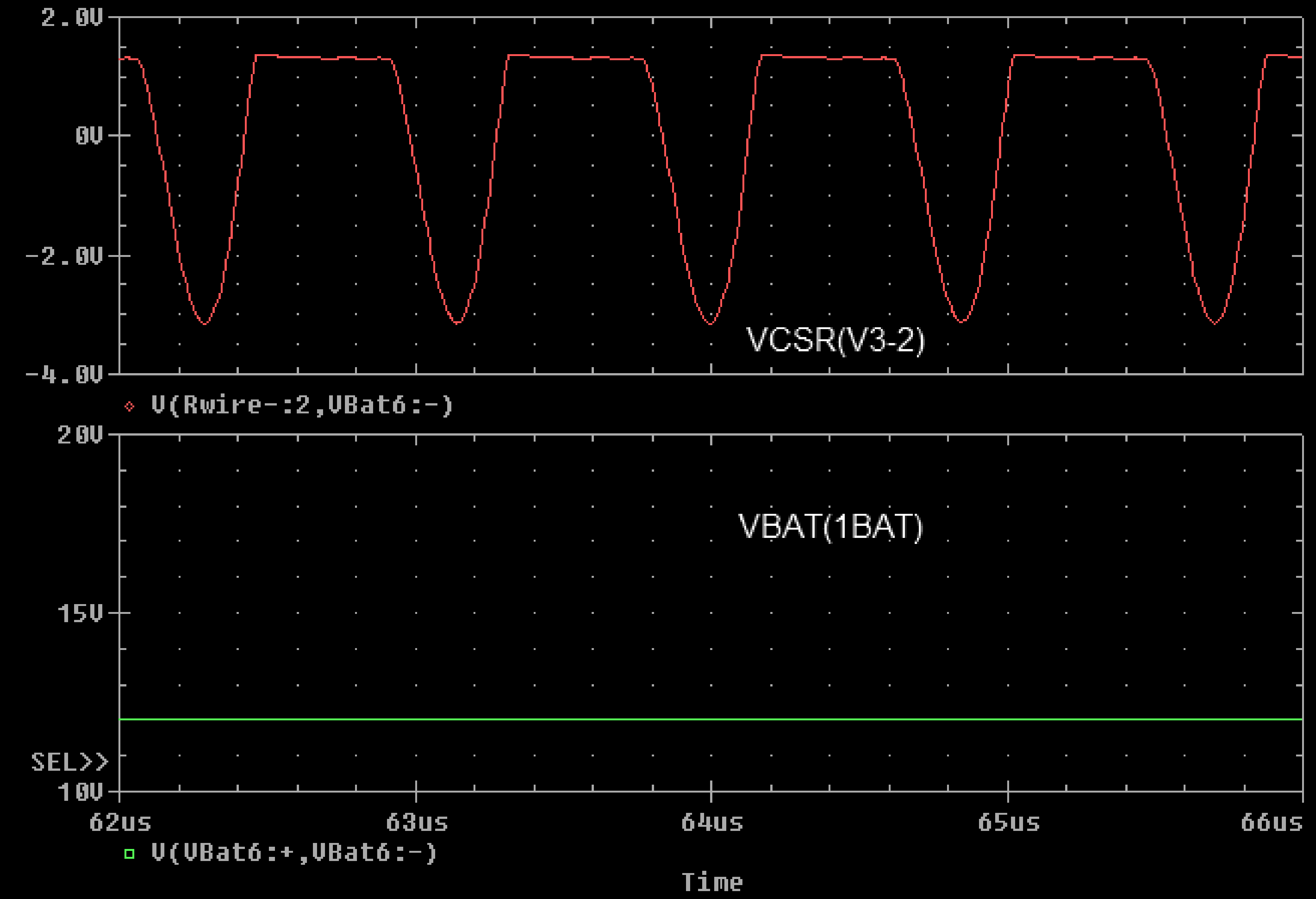
Let’s look at this scenario with the simulation, and see how close the two measurements are:

Referring to **schema01.png**, note the green probe at measurement point 7 (ignore the CSR probes for now). **scope16.png** shows the battery voltage as measured from nodes 7 to 4 (GND). The peak to peak voltage is over 200Vpp, but after averaging, the value is a little under 71VDC. The averaging is done with the built-in function in PSpice, however the same result is achieved by measuring the same points with a DMM, with or without the utilization of a non-intrusive RC filter in front of it. The six 12V batteries add to 72VDC, but some voltage drop is expected due to the wiring resistance of 2 Ohms total.

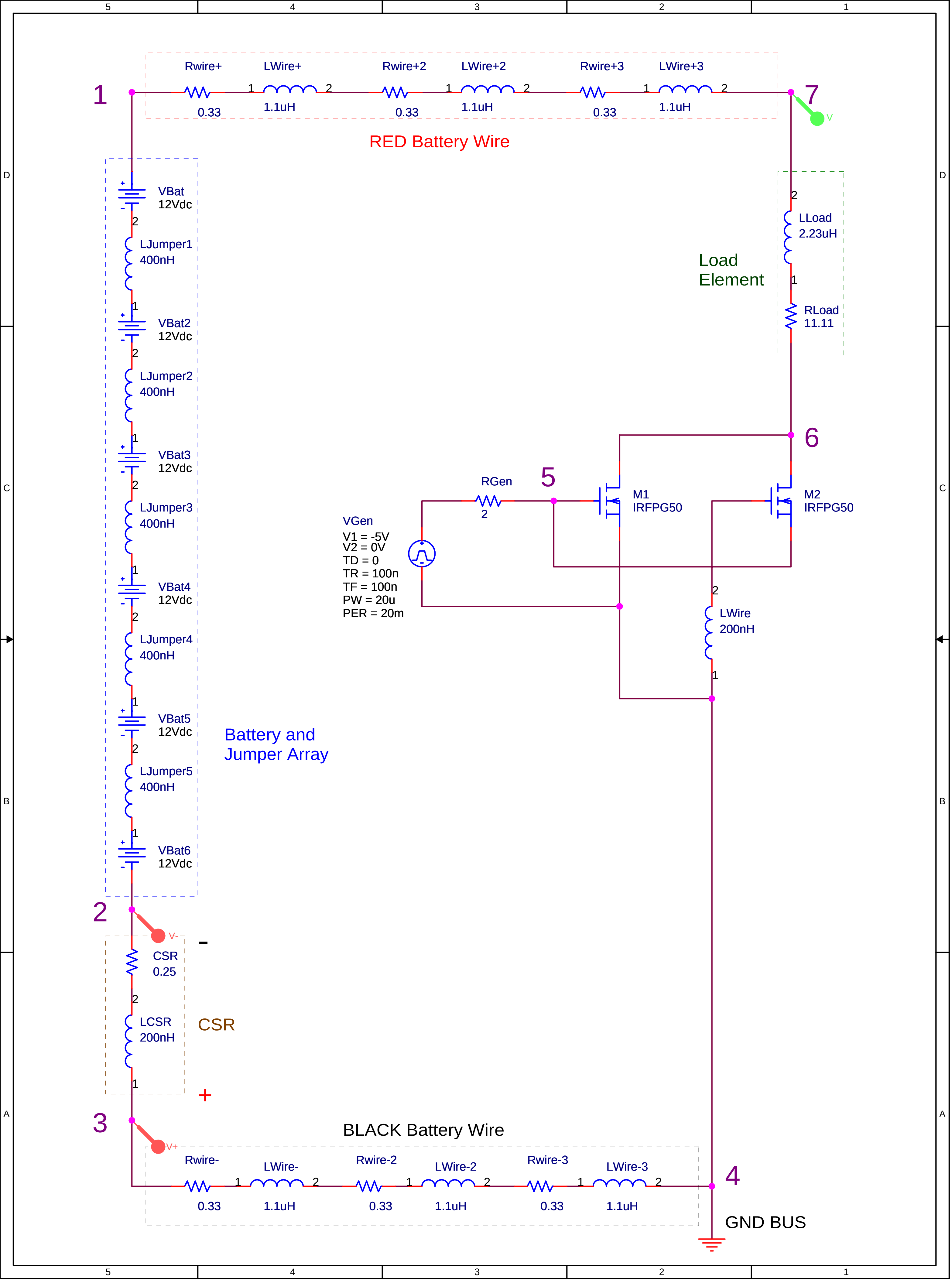
So it has now been established that you can obtain a clean accurate battery voltage measurement as part of the INPUT power measurement, by using a DVM and non-loading RC filter (optional). Moreover, the battery voltage measurement can also be obtained using an oscilloscope channel by applying a running MEAN function to the resulting trace, and as long as averaging is performed on this measurement, the measurement probes do not have to be placed directly on the battery terminals. This applies to both a scope and DMM measurement.

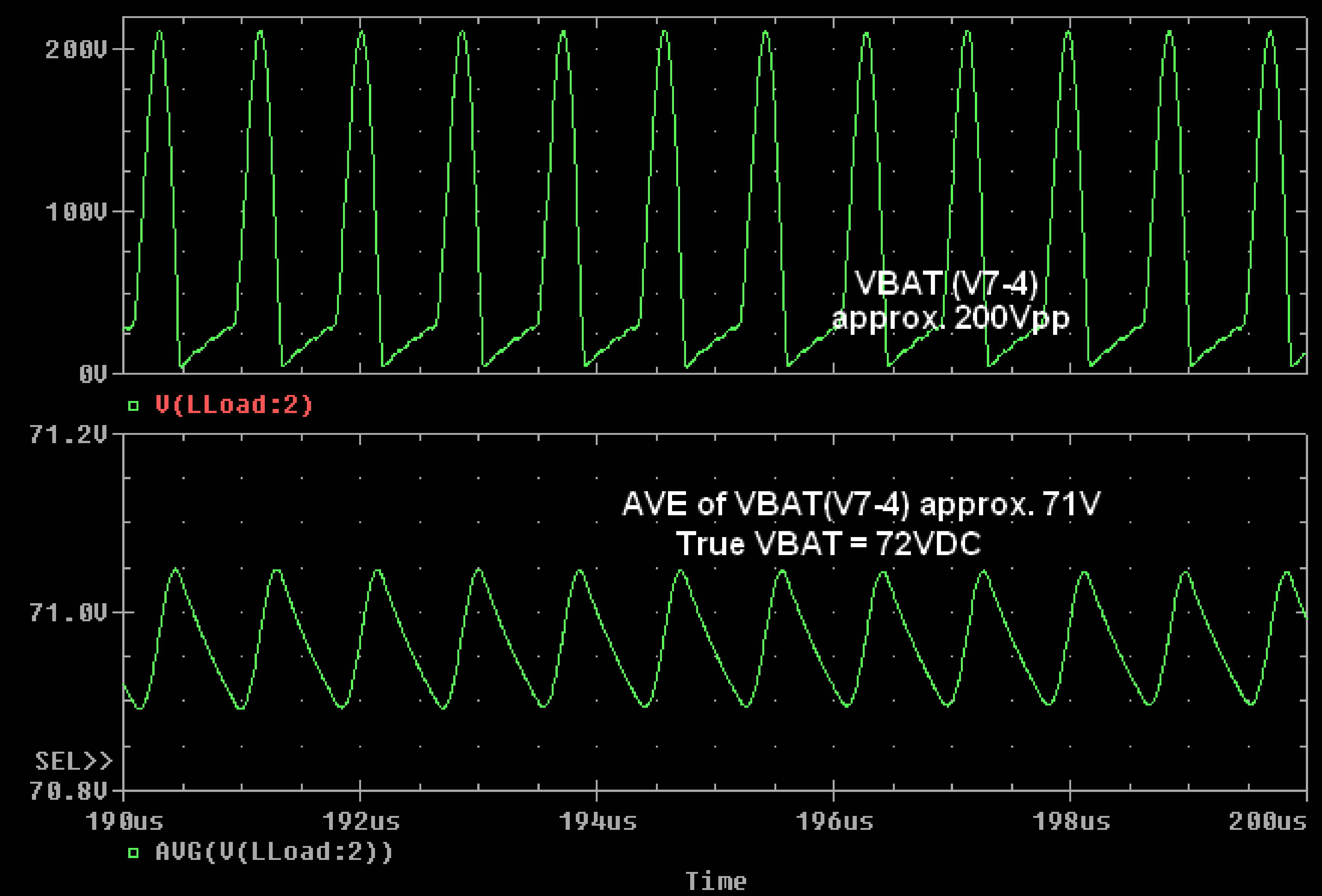


RED Battery Wire
Rwire+
0.33
LWire+
1.1uH
Rwire+2
0.33
LWire+2
1.1uH
Rwire+3
0.33
LWire+3
1.1uH
1
7
VBat
12Vdc
LJumper1
400nH
VBat2
12Vdc
LJumper2
400nH
VBat3
12Vdc
LJumper3
400nH
VBat4
12Vdc
LJumper4
400nH
VBat5
12Vdc
LJumper5
400nH
VBat6
12Vdc
Battery and
Jumper Array
Load
Element
LLoad
2.23uH
RLoad
11.11
6
5
RGen
M1
IRFPG50
M2
IRFPG50
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
LWire
200nH
2
V-
V-
-
CSR
0.25
LCSR
200nH
CSR
+
3
V+
BLACK Battery Wire
Rwire-
0.33
LWire-
1.1uH
Rwire-2
0.33
LWire-2
1.1uH
Rwire-3
0.33
LWire-3
1.1uH
4
GND BUS



2.0V
0V
-2.0V
-4.0V
VCSR(V3-2)
V(Rwire-:2,VBat6:-)
20V
VBAT(1BAT)
15V
SEL>>
10V
62us
63us
64us
65us
66us
V(VBat6:+,VBat6:-)
Time


RED Battery Wire
Rwire+ 0.33
LWire+ 1.1uH
Rwire+2 0.33
LWire+2 1.1uH
Rwire+3 0.33
LWire+3 1.1uH
1
7
VBat 12Vdc
LJumper1 400nH
VBat2 12Vdc
LJumper2 400nH
VBat3 12Vdc
LJumper3 400nH
VBat4 12Vdc
LJumper4 400nH
VBat5 12Vdc
LJumper5 400nH
VBat6 12Vdc
Battery and Jumper Array
Load Element
LLoad 2.23uH
RLoad 11.11
6
5
RGen 2
M1 IRFPG50
M2 IRFPG50
VGen
V1 = -5V
V2 = 0V
TD = 0
TR = 100n
TF = 100n
PW = 20u
PER = 20m
LWire 200nH
2
CSR 0.25
LCSR 200nH
CSR
-
+
3
BLACK Battery Wire
Rwire- 0.33
LWire- 1.1uH
Rwire-2 0.33
LWire-2 1.1uH
Rwire-3 0.33
LWire-3 1.1uH
4
GND BUS



200V
100V
0V
VBAT (V7-4)
approx. 200Vpp
V(LLoad:2)
71.2V
71.0V
70.8V
AVE of VBAT(V7-4) approx. 71V
True VBAT = 72VDC
SEL>>
190us
192us
194us
196us
198us
200us
AVG(V(LLoad:2))
Time

From the last installment in this detailed analysis, it was established that for INPUT power measurements involving DC sources, the source voltage can be measured with either an oscilloscope (using the MEAN computation) or DMM. It was shown that the DC source voltage measurement could be taken directly across the battery terminals, or at the far end of a considerable length of battery feed wiring, with essentially the same resulting average voltage reading.

This DC source voltage measurement is a DC value with essentially no ripple associated with it. With heavy enough averaging in the DMM (with the aid of an RC low-pass filter if necessary), the resulting measurement will be a smooth DC value. This DC value becomes a "constant" multiplicand that is multiplied with the instantaneous current to produce instantaneous power. As there is zero phase angle between a DC voltage and any current, phase considerations need not be taken into account for this INPUT power measurement.

At this point, the equation for average INPUT power (Pin) is as follows:

Pin(avg) = AVG[VBAT(DC) x VCSR/CSR(t)], and in words;

The average input power is equal to the average of the product of the DC battery voltage (in DC) and the scaled (by the CSR value) instantaneous CSR voltage (which is battery current).

As the AVG and DC values of a DC quantity are equal, the DC battery voltage in the above equation can be moved outside the square brackets as follows:

Pin(avg) = VBAT(AVG) x AVG[VCSR/CSR(t)], where VBAT(AVG) is readily obtained (as previously described) by using a DMM or scope, and is a constant, eg. "71V".

In summary, we have established that the voltage of a voltage source is essentially a constant, and that in order to obtain the average INPUT power figure, this constant is multiplied with **the average of the source's instantaneous current**.

What is "the average of the source's instantaneous current"?

Before we answer that question, let's briefly look at an important aspect of the DC source INPUT power measurement. What this measurement strictly entails, is **the net average power from or to the source**. Although pulsed alternating currents may be involved, there will always be a net average power either being supplied by the DC source to the circuit, or vice-versa.

So the average of the DC source's current is obtained simply by applying an averaging function to the instantaneous voltage wave form across the CSR. As you may have already surmised, this averaging function can readily be accomplished with the use of a DMM, with or without the implementation of an optional non-loading RC low-pass filter.

What this measurement results in, is a constant and stable net DC voltage across the CSR. Once this DC voltage is divided by the value of the CSR, we are left with the net average current from or to the DC source (battery) (and this value of current is DC).

Important Note: The DMM or oscilloscope probe positioning across the CSR is far more critical than is the case for the battery voltage measurement. This is due to the fact that the true battery voltage is a constant (permitting us to heavily filter out any ripple caused by parasitic inductance), whereas the battery's current is not. In order to obtain an accurate average current reading from the DC source (battery), it is imperative that a non-inductive CSR be used, and that the probes be placed as close as possible to its body. In the simulation, there is 200nH of parasitic inductance associated with the CSR. I found that the resulting added ripple caused an error of only a few percent, but folks should be aware of this potential pitfall nonetheless.

As we are permitted to heavily filter (average) the battery voltage measurement (because in reality it is a constant voltage when measured directly across its terminals), for a similar reason (i.e. a fixed CSR) we are also permitted to heavily “filter” the value of the CSR resistor. In the simulation, when we apply averaging to both the voltage across and current through (using the PSpice current probe) the CSR, then divide this average voltage by the average current (Ohm’s law), the result is in fact the resistive value as marked on the CSR.

In the case as applied to the oscillator circuit, this has been verified as shown in a previous installment of the analysis, i.e. the CSR value used for computing average current is 0.25 Ohms.

So finally, we are left with an extremely simple, accurate, and accessible method for obtaining the average INPUT power measurement Pin(avg) for any DC source;

Pin(avg) = VBAT(avg) x VCSR(avg)/CSR, which reads;

The average (DC source) input power is equal to the average battery voltage, times the average CSR voltage, divided by the CSR value (as marked or measured).

A special note for anyone wishing to verify the proper orientation of the measurement probes placed across the battery and the CSR:

Remove any switching or oscillating circuitry such that your inductive/resistive load is powered directly and only by the DC source. Leave the CSR in the circuit, and measure the voltage across both the battery and CSR. **Note the polarity of the voltage and orientation of the probes for each.**

Re-introduce your switching/oscillating circuitry and be sure to connect the measurement probes **EXACTLY** the same way as the previous test. Make the same notes and compare the polarities noted in each test case.

If you wish to prove that your DC source is acquiring energy or charge, this simple comparison test will without a doubt, reveal the truth.

Excerpts from a private discussion (my text in black):

When dealing with nearly a pure DC voltage (which is the case when measuring directly on the battery terminals), the phase of the battery voltage is 0º, and COS0 = 1 for a PF=1. Therefore it makes no difference what phase the current wave form is exhibiting, because there is always a 0º phase difference between the voltage (DC) and the current.

If there happens to be some ripple on the battery voltage measurement (due either to wire resistance or inductance, or both), it can be filtered with an RC low-pass to achieve the average battery voltage, which again has a 0º phase difference wrt the current.

A stable max/min type wave form makes no difference to the average value measured by a DMM or scope, provided that the wave form is periodic, does not vary in duty cycle, and is of reasonably high frequency. They will produce the correct average of any wave form provided the above conditions are met.

I do not agree as it eliminates the return of power to the battery when the current is considered AC.

Think about it carefully *****; it does not do that at all.

In fact, taking the average of the battery current, regardless if it is AC, yields **a net average direction of current** over all.

If on average there is more current leaving than returning to the battery over a single cycle, then taking the average of the current wave form will indeed indicate exactly that.

Let's look at a simple example:

Say we scope across a 1-Ohm CSR and the rectangular wave form is as follows:
Period T=1ms
A1=+6V for 0.4ms
A2=-2V for 0.6ms

```
 _____ +6V
|     |
|     |
|     |
      |_______|
             -2V
```

What is the net average amplitude and direction of the current in this example?

To determine this, we simply calculate the AVERAGE over 1 cycle.

So, +2.4 + -1.2 = +1.2V

When the above wave form is averaged or low-pass-filtered, then measured with a DC meter, it will indicate +1.2V. So 1.2V/1 Ohm = 1.2A. If our battery was 12V, then the average INPUT power would be 12V x 1.2A = 14.4W.

Precisely the same result will be obtained if the CSR wave form is sampled by an oscilloscope and multiplied by the sampled 12V battery voltage, then have the MEAN of the product taken by the scope.

The mean of Inst V * I is more accurate and I don't see how you will get any Physics or EE professor to agree with your concept.

I invite you to check the above math and indicate any error; I doubt you'll find one. The results are precisely the same as MEAN[P(t)], because essentially the same processing is being applied in both cases.

In terms of convincing a physics professor or EE, indeed the math speaks for itself, and if they believe in math, they will see it clearly.