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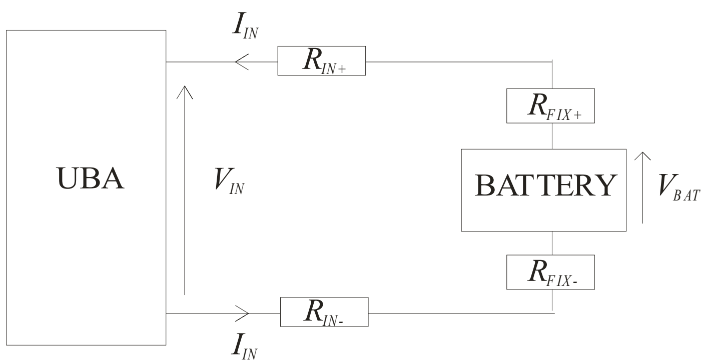
Battery Resistance Wire Compensation

This paper presents the calculations that UBA Console uses to compensate for the voltage drop due to wire resistance during battery discharge. The online help that comes with the UBA S/W gives additional information.

Single Channel

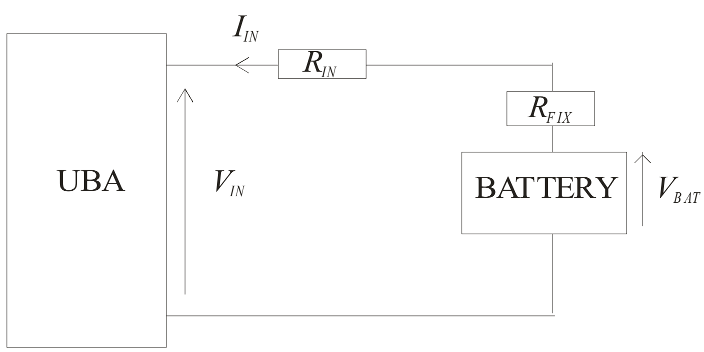
Here's a representation of the circuit when discharging a battery using a single UBA channel:



R_{IN+} and R_{IN-} are the wire resistance from the UBA input to the battery fixture (or battery holder), and R_{FIX+} and R_{FIX-} is the fixture resistance which includes battery contact resistance and the cabling inside the fixture.

Without any loss of accuracy for this single channel example we can combine the resistances to get:

$R_{IN} = R_{IN+} + R_{IN-}$
$R_{FIX} = R_{FIX+} + R_{FIX-}$



Which gives:

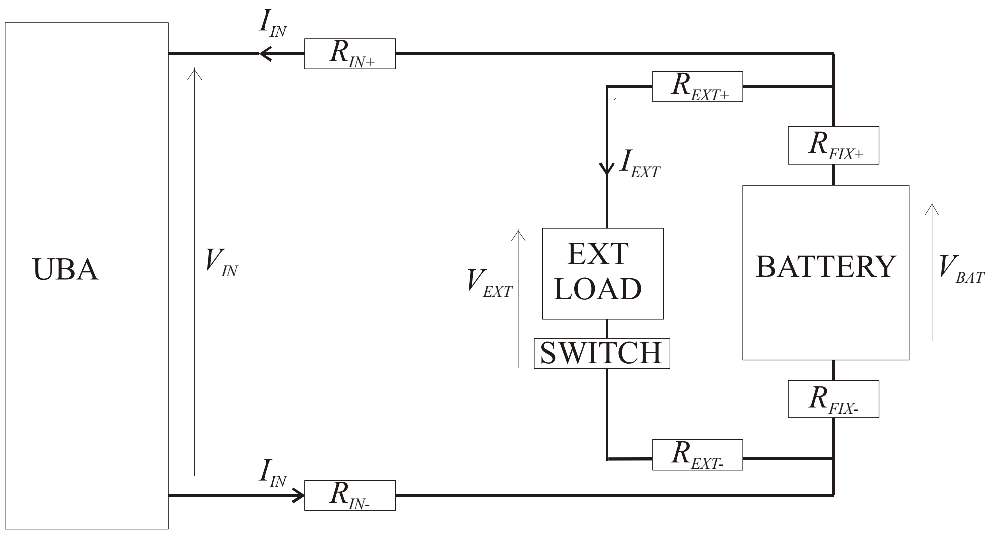
$$V_{BAT} = V_{\mathrm{IN}} + I_{\mathrm{IN}}(R_{\mathrm{IN}} + R_{FIX})$$

R_{IN} is specified in the calibration file for that UBA in the following line:

```
BatteryLeadR: RLEAD Rcc
```

Where R_{LEAD} is the same as R_{IN} and R_{CC} is for combined channels (explained later). R_{FIX} is specified each time in the UBA Console **Multitester** or the **Start a Battery Analysis** windows. Because R_{IN} and R_{FIX} are summed when calculating the battery voltage, their individual values don't matter. For combined channels (explained later), their individual values do matter.

Single Channel with External Load



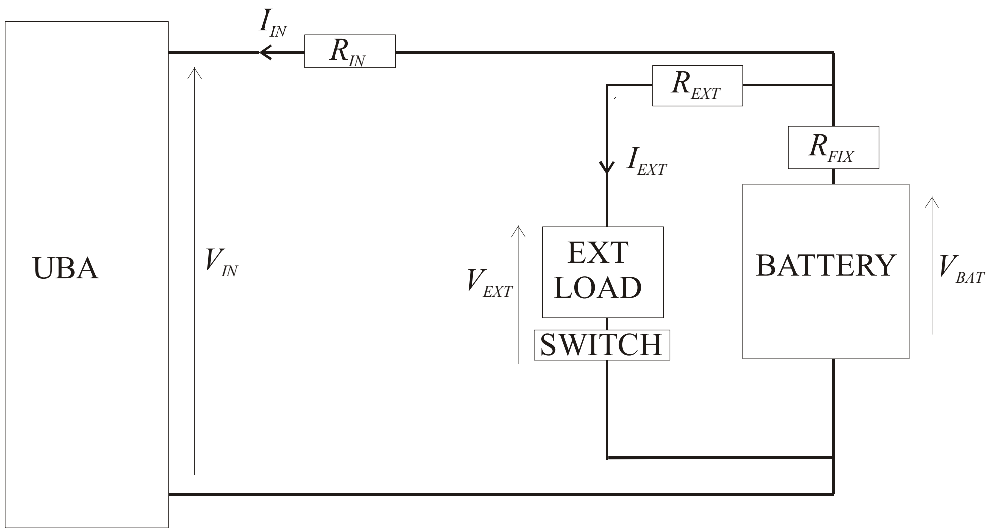
The above circuit represents a battery that is being discharged by both the UBA and an external load.

R_{IN+} and R_{IN-} are the resistance from the UBA input to the battery fixture.
R_{FIX+} and R_{FIX-} is the fixture (or battery holder) resistance which includes battery contact resistance and any cabling inside the fixture.
R_{EXT+} and R_{EXT-} is the resistance from the battery fixture to the external load.

Without any loss of accuracy (for a single channel) we can combine the resistances:

$R_{IN} = R_{IN+} + R_{IN-}$
$R_{FIX} = R_{FIX+} + R_{FIX-}$
$R_{EXT} = R_{EXT+} + R_{EXT-}$

With the combined resistances the circuit now looks like this:



Now VBAT can be calculated as follows:

$$V_{BAT} = V_{\mathrm{IN}} + I_{\mathrm{IN}} R_{\mathrm{IN}} + (I_{\mathrm{IN}} + I_{EXT}) R_{FIX}$$

Where:

V_{BAT} is the calculated battery voltage
V_{IN} is the voltage at the UBA battery input
I_{IN} is the UBA load current
R_{IN} is the resistance of the wire lead (positive and negative leads combined)
R_{FIX} is fixture resistance (positive and negative inputs combined)
I_{EXT} is external load current
R_{EXT} is the resistance of wire from battery to external load (positive and negative leads combined)

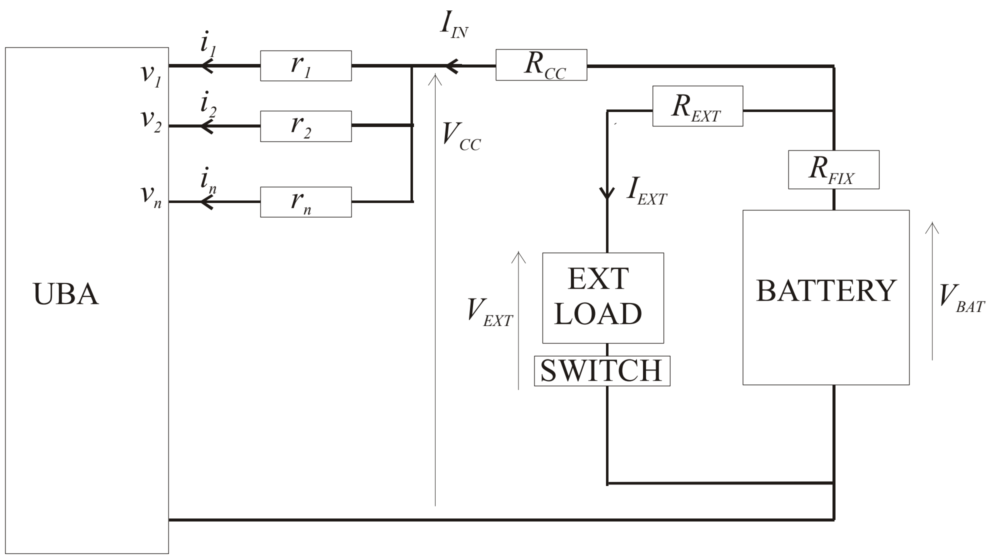
And

$$V_{EXT} = V_{\mathrm{BAT}} - (I_{\mathrm{IN}} + I_{\mathrm{EXT}}) R_{\mathrm{FIX}} - I_{EXT} R_{EXT}$$

V_{EXT} is used by the UBA S/W to calculate the external load current when it's given as a function of the external load voltage (for example a resistor).

Combined Channel

A combined channel setup requires that the resistance of each channel's wire be taken into account. This is shown below:



The resistance of the individual wires connecting to the UBA is represented by r_1, r_2, ... r_n.

Given V_{CC} which is the voltage at the point where the battery inputs are combined, the battery voltage is calculated using the following formula:

$$V_{BAT} = V_{CC} + I_{IN} R_{CC} + (I_{IN} + I_{EXT}) R_{FIX}$$

Where VCC can be calculated from the voltage of any of the inputs as follows:

$$V_{CC} = v_1 + i_1 r_1 = v_2 + i_2 r_2 = ...$$

For increased accuracy, we average of the calculated V_{CC} voltages.
Removing V_{CC} gives:

$$V_{BAT} = \frac{1}{n} \sum (v_i + i_i r_i) + I_{IN} R_{CC} + (I_{INT} + I_{EXT}) R_{FIX}$$

Where:

V_{BAT} is the calculated battery voltage
n is the number of combined channels (1 for no combined channels)
v_i is the voltage at channel *i* input.
i_i is the current at each channel *i* input
r_i is the wire resistance of each battery wire
I_{IN} is the total current flowing into the UBA
R_{CC} is the wire resistance from fixture to junction when wires split up into individual channels
R_{FIX} is the fixture resistance
I_{EXT} is the external load current
R_{EXT} is the resistance of wire from battery to external load

And to calculate V_{EXT} we use the same formula as for a single channel:

$$V_{EXT} = V_{\mathrm{BAT}} - (I_{\mathrm{IN}} + I_{\mathrm{EXT}}) R_{\mathrm{FIX}} - I_{EXT} R_{EXT}$$

The combined channel input resistances r_1, r_2, r_3, ... are different then lead resistance in that they are usually special cables that combine the inputs. As such they are specified as the second parameter in the BatteryLeadR line in the calibration file.

In the below example, the lead resistance (both positive lead and negative leads in series) is 16mR and the combined channel wiring is only 10mR as it's usually shorter, but still includes both the positive and negative leads in series:

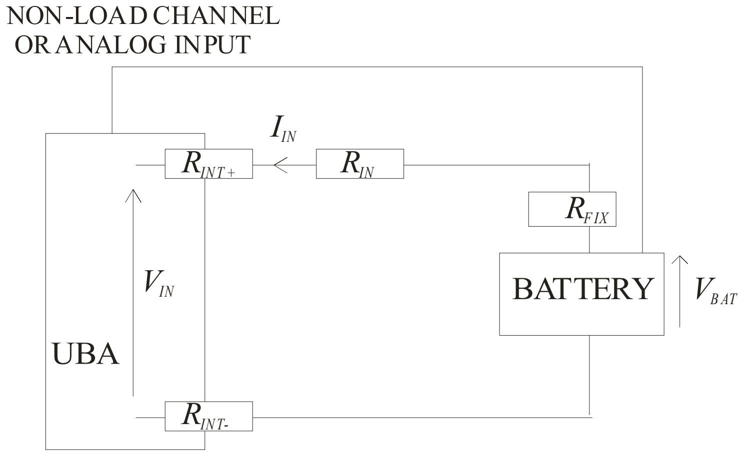
```
BatteryLeadR: .016 .010     ; regular & combined channel
```

Note: the above calculations suffer from a small error due to assumption that current flow through each channel's positive and negative lead is equal (i.e. i_i flows through both R_{IN+i} and R_{IN-i},) which for combined channels isn't necessarily correct. We know the current through the positive lead (I_{IN+i},) but the current through the negative lead I_{IN-i} is unknown, we only know the total return current. The formula holds if all the negative leads have identical resistance, but if any of them have a lower resistance (i.e. shorter or thicker) then those leads would have a higher current flow which gives a lower resistance then what the UBA calculates by assuming the negative lead current is the same as the positive.

In addition the UBA calculations assume that all the negative leads are used, when in fact, you can combine channels and only use one negative lead. For this reason you should connect a negative battery lead for each channel

UBA Internal Wiring Resistance

Up to now we've ignored any internal wiring resistance of the UBA or on the input connector. But there is a few milliohms and it can be compensated for.



In the above circuit we show the internal wiring as R_{INT+} and R_{INT-}. . R_{INT+} is easy to handle as it's in series with R_{IN} and thus can be added to it. R_{INT-} can't be grouped with R_{IN} due to the special case where the battery voltage is monitored by a low current third wire, such as the other battery input or the external analog input (on the back of the UBA).

In addition, if you're using a low current third wire then R_{IN} and R_{FIX} aren't compensated for, just R_{INT-}. If you want the S/W to include R_{IN-} (i.e. the negative test lead) then you have to add it to R_{INT-}.

For example for channel 1:

```
BatteryLeadR:  0.016 0.010  ; regular & combined channel
BatteryInputR: 0.007 0.008  ; negative & positive input
```

Here we have 16mR battery cables and a 7mR negative input internal resistance.
If you will be using a low current third wire then you can split the lead resistance into 8mR for each lead which gives:

```
BatteryLeadR:  0.008 0.010  ; regular & combined channel
BatteryInputR: 0.015 0.005  ; negative & positive input
```

Thus the lead resistance has dropped in half from 16mR to 8mR and the negative input increased by the dropped amount of 8mR from 7mR to 15mR.

Special Cases

Accessory Analog Input

The accessory analog input can either measure the battery voltage in a 3-wire or a 4-wire configuration. For a 3-wire configuration, the battery voltage feeds directly, or via a simple amplifier/attenuator, into the accessory input. For a 4-wire configuration the battery voltage is measured either by an isolated or differential amplifier.

3-Wire configuration
If you're connecting to the battery in a 3-wire configuration (as in the circuit in the previous section) then use the model 3 ExtVAmp configuration (see the **External Devices Reference Manual** for more information), i.e.:

```
*ExtVAmp:    name     model aichan  Vin0 Vout0   Vin_n Vout_n
ExtVAmp:  2xAmp-3Wire   3     0      0.0   0.0    1.0  2.0
```

The calculation used is:
$V_{BAT} = f(V_{ACC}) + I_{LOAD} * R_{IN-}$

Where V_{ACC} is the analog input on the accessory connector and *f()* is the transfer function specified in the calibration file (as piecewise continuous Vin_i and $Vout_i$ pairs).

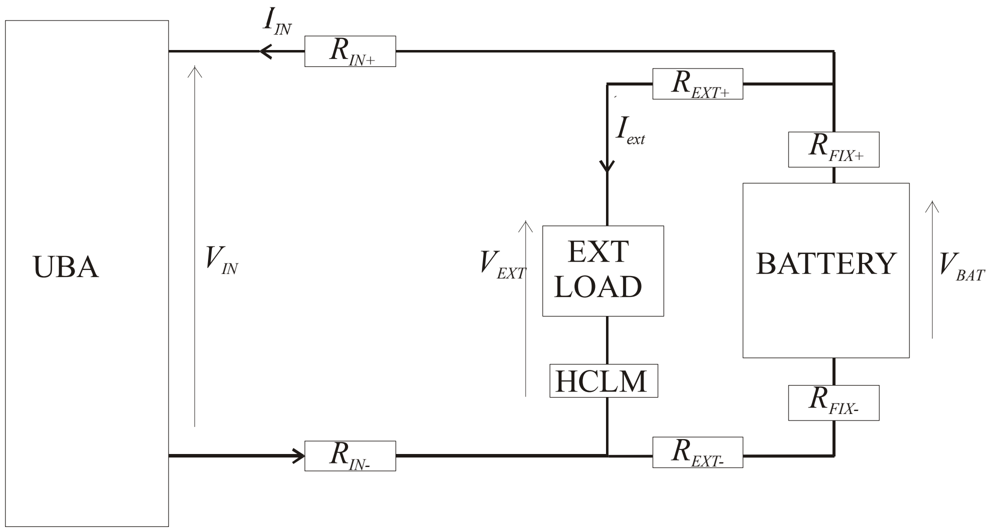
If you use the analog input on the accessory connector in a 4-wire amplifier configuration then UBA Console assumes that the battery voltage is being monitored directly and doesn't apply any resistance compensation. This is shown as:

$V_{BAT} = f(V_{ACC})$

```
*ExtVAmp:    name     model aichan  Vin0 Vout0   Vin_n  Vout_n
ExtVAmp:  2xAmp-4Wire   2     0      0.0   0.0    1.0    2.0
```

Old UBA HCLM

A special case exists for the old Vencon High Load Current Unit (HCLM). The HLCM has its negative connected directly to the UBA, which causes any UBA load current (I_{IN}) to flow through R_{EXT-}.



But this circuit can be simplified just as the non-HCLM circuit using these formuli:

$R_{IN} = R_{IN+} + R_{IN-}$
$R_{EXT} = R_{EXT+}$
$R_{FIX} = R_{FIX+} + R_{FIX-} + R_{EXT-}$

The difference being that R_{EXT-} is added to R_{FIX} instead of to R_{EXT}.
The new HLCM (has all the parts mounted on one PCB) has a constrained floating ground so it acts similar to a regular external load.