

EV Design:  
Spreadsheets in Excel  
version 1.1  
courtesy of Doug Wilson (wilsd01@bwco.com)

(This document and the Excel spreadsheets in this folder are formatted with Palatino font.)

I created these Excel spreadsheets to help me in designing an electric conversion for myself. I am making them available to you in the hope that they will make the design process easier for you. The spreadsheets are largely based on the equations and data presented by Bob Brant in his book, *Build Your Own Electric Vehicle* (Tab Books, Blue Ridge Summit, PA, ISBN 0-3806-4231-5 pbk.). This book is excellent and really helped me by bringing all the pertinent info together in one location. You may have a hard time figuring out how to use the EV Design spreadsheets if you do not have a copy of Brant's book at your side. My spreadsheets follow closely the layout of Brant's tables 6-10 (pp. 155) and 6-11 (pp. 157) and figure 6-9 (pp. 158). I have expanded on his plot of torque vs. speed with a plot of current vs. speed which I found helped me think about how battery power is consumed as you drive.

Contents of distribution

You should find the following files in this distribution:

EVWorkBk.xls      collection of all EV Design spreadsheets in a workbook  
EVDesign.xls    basic design data plus some helpful tables  
TorqReq.xls     torque required to move car up various slopes  
TrqAvail.xls    torque available from motor at various speeds  
TorqChrt.xls    torque required and available plotted  
AmpsReq.xls    torque values converted to amps at pack voltage  
AmpsChrt.xls    like Torque Chart but in units of amps  
Motors directory holding speed-torque curves for spreadsheets  
MtrChrts       directory with plots of motor data from Motors directory  
MiscInfo       directory containing odd snippets of info; make a contribution!  
EVMacros.xlm    (hidden) macro sheet used for user interface  
MotorLst.xls    (hidden) temp sheet used to build dialog popup menus  
Spreadsheet format

These files were created with Excel 4.0 on a Macintosh. The spreadsheets have been tested with Excel for Windows 4.0a without any problems. My apologies to Macintosh users for the DOS file names but it does provide compatibility. The spreadsheets are collected into an Excel workbook so, if you open EVWorkBk.xls, you will have all the spreadsheets available. I have positioned the windows to conveniently open on my 16" monitor. You may need to reposition them for your monitor. Most of the spreadsheets are linked to use data from the other sheets. I have also turned on cell protection on the worksheets so that you do not unintentionally overwrite calculation cells. No password was used so feel free to adapt the calculations and layouts to your own needs but please do not distribute incomplete or modified versions of the spreadsheets.

Entering a new design

To generate data for your choice of car, motor and batteries, open EVWorkBk.xls and select the Setup EV choice on the EV Design menu.

You will get the following dialog box that summarizes the parameters you need to specify to generate a design using the EV Design spreadsheets:

You will need to enter the following data:

- Car model
- Weight of original car and weight you can remove (engine, muffler, radiator, etc.)
- Drive train efficiency (0.9 for rear wheel drive; 0.91 for front wheel drive)
- Design speed for calculating design RPM, optimum gear ratio and design horsepower
- Model electric motor you will use
- Gear ratios from your user or service manual
- Battery voltage, weight and pack size
- Tire type and outer diameter
- Coefficient of drag, Cd
- Rolling resistance, Cr
- Relative wind coefficient, Crw
- Frontal area of the car (I just measured the outline with a tape measure.)
- Average wind velocity for your area

Select the type motor you want to evaluate from the pop-up menu. The appropriate data for Motor Current, Motor Torque and Motor RPM will be entered for you on the Torque Available Worksheet.

You will likely find it necessary to tweak the labels on the plots to line up with the correct curves or to avoid overwriting other information.

Motor data files

If you do not see the motor you want to evaluate on the pop-up list, you can enter data for a new motor in the Motors folder. The motor data can be extracted from the manufacturer's current vs. torque curves, e.g. see figure 7-8 (pp. 185) in Brant. There are six names defined on a motor data spreadsheet that are used by command macros to update motor information on the main spreadsheets. These names are Model\_Motor, Torque, Current, RPM, Voltage and Motor\_Weight. You may enter data for any number of battery pack voltages. When you specify a battery pack voltage in a design, the motor data for the first voltage that is less than or equal to the design voltage is used for the calculations. In the current version, the TrqAvail.xls worksheet will have blank or unused rows if you use a different number of rows in the motor data worksheet than is in the original template. The charts will also look a bit ragged because of unused data points in the tables. Look at one of the existing tables and enter data in a similar manner for your motor. You may want to keep a chart of the torque/speed curves at different voltages in the MtrChrts directory.

Once you have created a correctly formatted worksheet of your motor data in the Motors directory, the new model will be available the next time you start up the spreadsheets.

Summary of Motor Data

I currently have data only on Advanced DC motors. The following is a summary of the included design data:

Amps

Hp

Model

Wt (lbs)

Volts

cont

1 hr.

peak

cont

1 hr

peak

A89-4001\*

50

36-72

80

100

300

6

6.4

27

K91-4003\*

55

48-96

100

130

360

8

10

35

L91-4003†

82

72-120

122

135

~450

16

17.9  
72

203-06-4001†  
107  
72-120  
165  
180  
~500  
21.7  
24  
83

FB1-4001†  
183  
72-144  
170  
185  
~535  
28.5  
30.4  
100

\* data from KTA services, unspecified operating voltage

† data from Advanced DC Electric Vehicle Application Guide, (controller losses not included)  
Commentary on Build Your Own Electric Vehicle

This is a great book for the do-it-yourselfer or for anyone needing to evaluate an electric vehicle design. I found the introductory chapters on the environmental issues a touch tedious but they do make the reference more complete. I went back to many of the original references cited by Brant for his technical information. He has done an outstanding job simplifying and condensing the basic drag and torque required calculations. I had no problems in translating those calculations into the spreadsheets in this distribution. Brant's description of motor types and fundamentals is complete and likewise easy to follow. I found the chapter on controllers one of the most interesting. The material is again inclusive. I was somewhat disturbed to find that much of the material in this chapter was not even paraphrased but taken verbatim from the Motorola technical papers. As an electrical engineer, I had hoped Brant could have added a little more of his own insights into the designs presented. The battery chapter was perhaps one of the weakest of the book. His presentation of the design decisions was excellent but practical maintenance advice was scarce or even incorrect. For example, in the two sentences given on battery measurements, he states that for "voltmeter and hydrometer" measurements you should monitor your batteries in a "rested" condition. A measurement of the voltage under load is a much better indicator of state of charge. The section on chargers was excellent with very good practical advice on the considerations in selecting a charger and how to use it in charging a battery pack. After the buildup of the rest of the book, the single chapter on the featured truck conversion was almost a letdown. I would consider Mike Brown's Convert It (Future Books, Ft. Lauderdale, FL, ISBN 1-879857-94-4) as an essential adjunct to this volume for those needing more practical advice about the details of a conversion. I learned a tremendous amount from this book and

found it an excellent springboard to further reading on the subject.  
Errata from Build Your Own Electric Vehicle  
I have found several errors in Brant's book.

1) Equation 12. Brant gives the equation for torque available at the wheels as follows:

$$12. \quad \text{Torquewheel} = \text{Torquemotor}/(\text{overall gear ratio} \times \text{overall drivetrain efficiency})$$

He consistently presents the equation in this form but the correct equation, which he apparently used to generate his tables, should have the motor torque multiplied by the gear ratio and efficiency rather than divided. The equation should read as follows:

$$\text{Torquewheel} = \text{Torquemotor} \times (\text{overall gear ratio} \times \text{overall drivetrain efficiency})$$

The error in the original equation is clear when one realizes that the torque of the motor should be reduced by the drivetrain losses (efficiency  $\approx 0.9$ ). Also, since there are multiple turns of the motor for every turn of the wheel, the wheel torque is made higher, not lower, by the overall gear ratio which is between 2 and 11 for my car.

2) The tire dimension table, Table 6-7, on page 143 is obviously incorrect for the lower half of the table.

Release History

1.0	1 Jan 94	Initial test release
1.1	18 May 94	First release including menu, build dialog & full motor data

Request for data

I am not an expert on EV design or on Excel programming. I would appreciate any comments, corrections or changes related to the spreadsheets. I am starting to run down the following information but if you have it, especially in electronic form, it would save me some legwork:

- I could use design data for U.S. Battery, Exide or GNB batteries to include for those wanting to try them.
  - It would be nice to have reliable Cd values for individual cars. Does anyone know of a source?
- Future directions
- Expand motor, battery, Cd and Cr data. In particular, Nelco, Lynch and Solectria motors are in progress.
  - EV range estimation from a description of the route driven.
  - Spreadsheet to calculate Cd and Cr from coast down rate on a level surface.

Author

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