EFU output current

D.B.Mortimore

5/5/2014

The aim of this work is to investigate the possibility of increasing the output current of the Electric Fishing Box produced by East Anglian Electrical Services.

Current measurements

In order to measure the peak current of modulated outputs, an oscilloscope was used to measure the voltage drop across a resistor in series with the load. The existing EFU circuitry was used for this purpose and the voltage measurements were taken at pin 4 of the PIC microprocessor 16F877A (signal labelled IO). This signal is derived from a differential amplifier monitoring the voltage drop across a 0.05R/20W resistor in series with the load. The signal IO is amplified and gain adjusted (during initial board testing) such that the output voltage (V) is related to the load current (I) by $V = 0.2I + 0.1$. The ability to measure the peak voltage accurately (and hence current) was improved by using a digital storage scope with automatic readout of the maximum signal level. This was further enhanced by using 64x signal averaging. Examples of the waveforms (without averaging) are shown in figures 1 to 8.

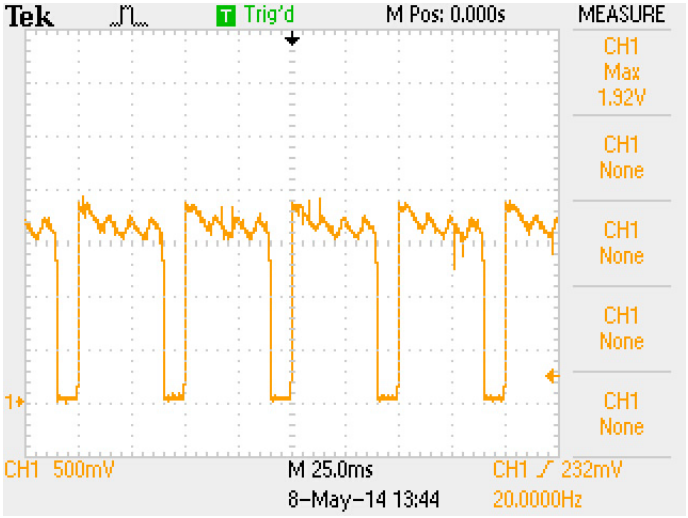

Figure 1: Voltage at IO representing the output current waveform: 220V / 80% / 20Hz

Measurements on standard box[1]

In order to characterise the standard EFU, a series of measurements of peak output current versus peak output voltage were performed for a variety of output modulation frequencies and duty cycles. A room heater was used as the load set at 240V/2KW. Table 1 shows the output peak current at a

[1] The EFU unit used for these measurements is identified as 'board set D' which comprises the boards with serial numbers 08311023, 08321023 and 0831023. This is the unit which was repaired by the replacement of component ASA00B18-L (IC9 on the system power board).

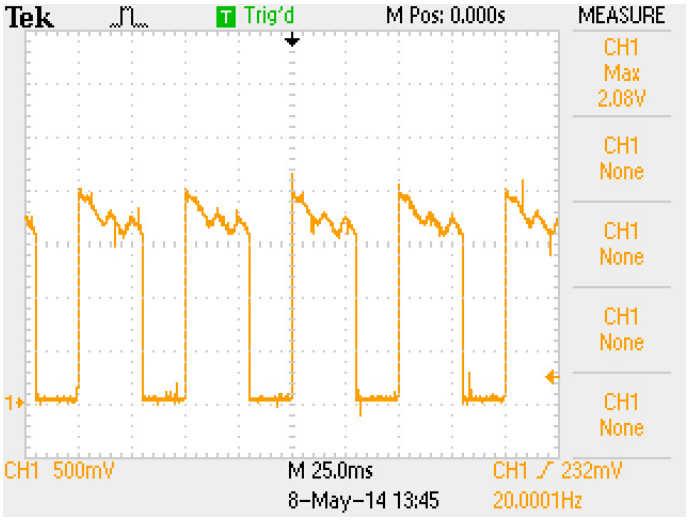

Figure 2: Voltage at IO representing the output current waveform: 280V / 60% / 20Hz

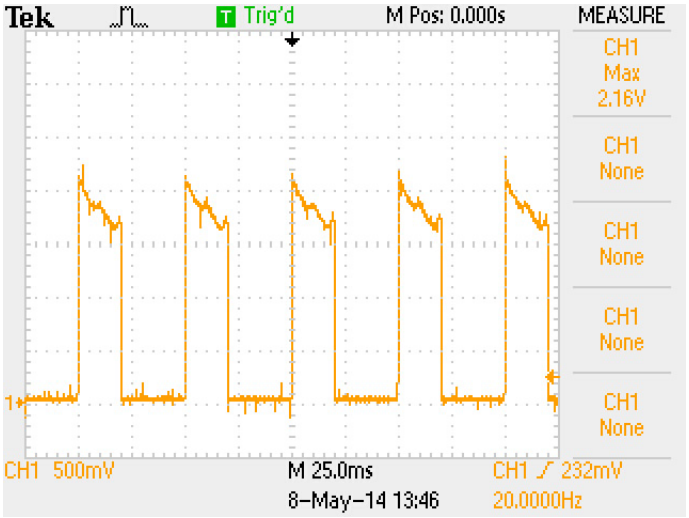

Figure 3: Voltage at IO representing the output current waveform: 300V / 40% / 20Hz

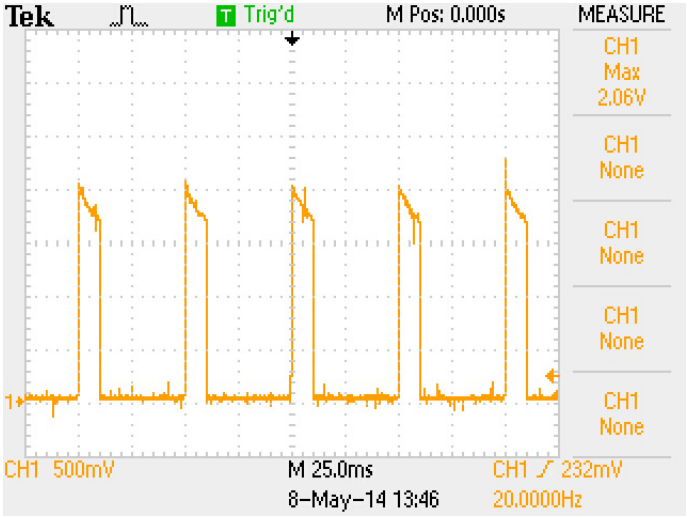

Figure 4: Voltage at IO representing the output current waveform: 240V / 20% / 20Hz

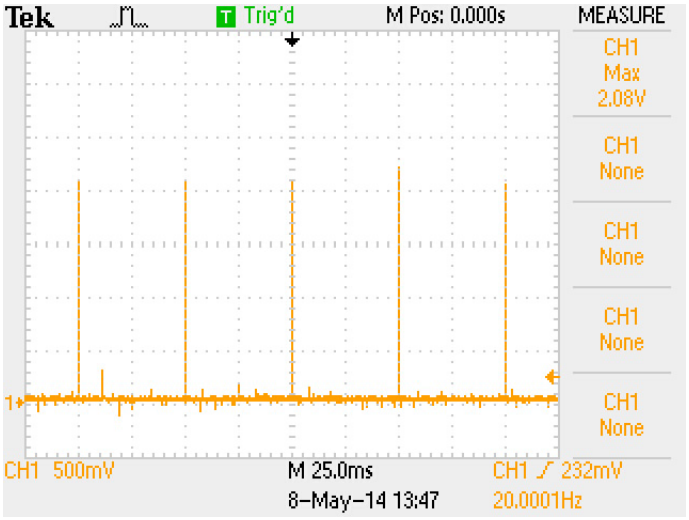

Figure 5: Voltage at IO representing the output current waveform: 260V / 1% / 20Hz

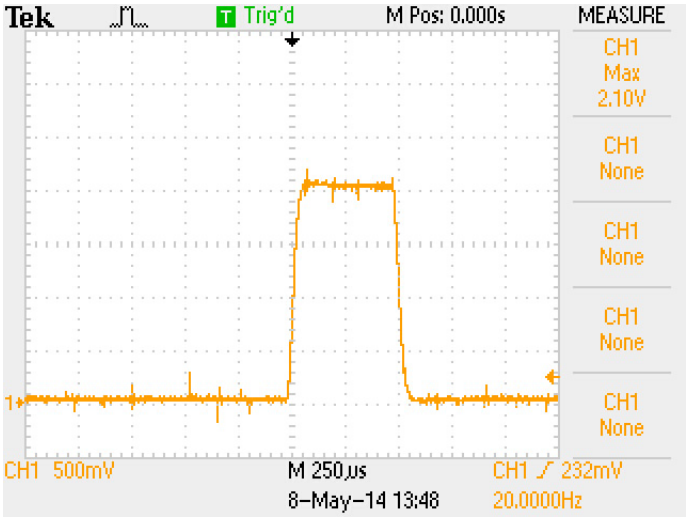

Figure 6: Voltage at IO representing the output current waveform: 260V / 1% / 20Hz (as above but with faster timebase)

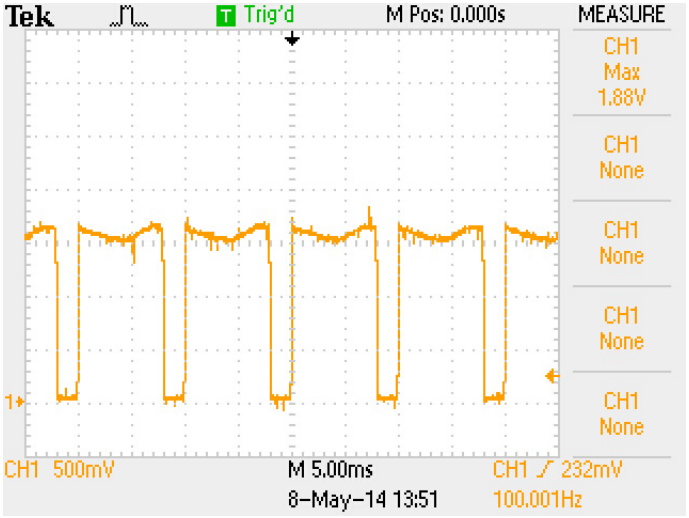

Figure 7: Voltage at IO representing the output current waveform: 260V / 80% / 100Hz (Note the faster modulation frequency)

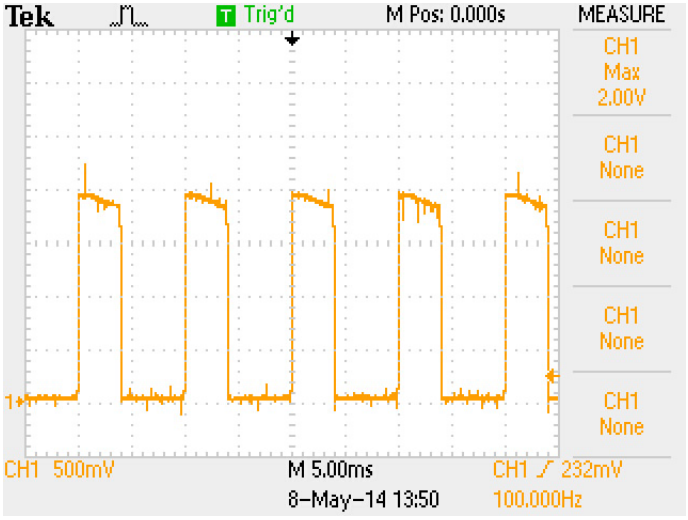

Figure 8: Voltage at IO representing the output current waveform: 260V / 40% / 100Hz (Note the faster modulation frequency)

frequency of 20Hz for duty cycles of 100%, 40%, 10% and 1%. The results obtained at other modulation frequencies (10Hz, 50Hz and 100Hz) are very similar.

Freq = 20Hz	Duty cycle / %			
Voltage	100	40	10	1
50	1.55	2	1.8	1.8
100	3.35	4.2	3.8	3.7
150	5.2	6.6	5.8	5.6
200	7.1	8	7.8	7.5
250	6.4	6.3	6.3	6.3
300	5.3	5.2	5.2	5.2

Table 1: Peak output current vs peak output voltage at 20Hz for various duty cycles. The figures in red indicate activation of the overload protection system.

A graph of the data is shown in figure 9. The solid red line represents the maximum allowed current defined by a maximum of 10A or output power of 1600W. It is immediately obvious that the EFU takes no account of duty cycle when calculating the maximum allowed current. Even when the duty cycle is less than 100%, the maximum current is still set at the DC value.

Program modifications[2]

In order to increase the current output, yet still remain within the power limit (of 1600W), it is proposed to scale the maximum allowed current according to the duty cycle. For example, a 50% duty cycle will allow twice as much current for the same mean power dissipation.

The PIC controlling the maximum current is the 16F877A (IC2 on the EFU-LF Control Board). The assembler code used for this processor is 083048A.ASM. Within this program the maximum allowed current, I_{max} is calculated. A new version of the program is created, 083048B.ASM, in

[2] By studying the assembler code it became obvious (due to the inline math calculations) that the tool used for compilation was GPASM (part of the GPUTILS collection). The latest version of this tool was downloaded and tested. Unfortunately this did not work as the following error message was obtained - "Error 118 - overwriting previous addess contents". A search on the internet showed that this was a problem that others have also experienced - an old program that did compile no longer compiles with a recent version of the compiler. Apparently this is due to more stringent checking of the source code. The problem can be corrected but will require a substantial rewrite of the code. A quicker and easier solution is to use an old compiler - the version Gerald used. This was searched for, found and copied from Geralds PC.

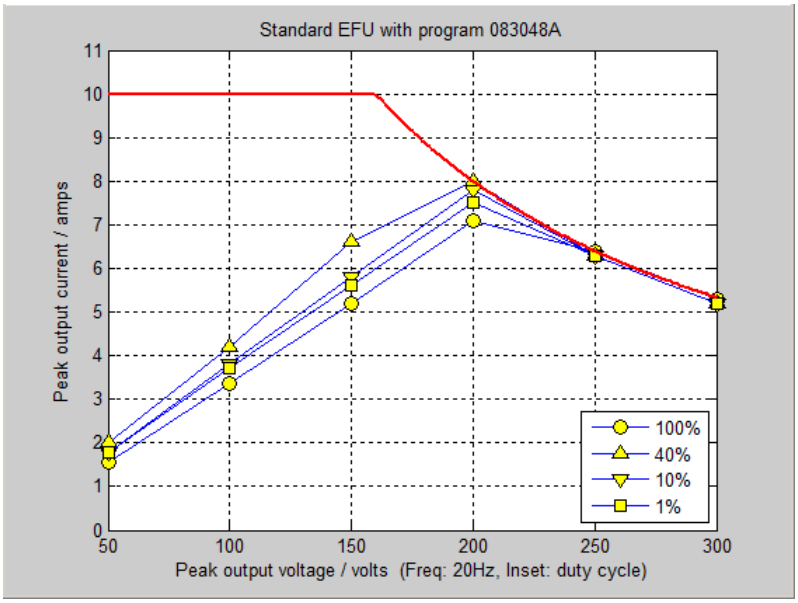

Figure 9: Peak output current vs peak output voltage at 20Hz for various duty cycles

which the maximum allowed current I_{max} is replaced by $I_{max} \times \frac{100}{\varphi}$ where φ is the duty cycle in percent. Therefore at DC (φ =100) the output will be the same as 083048A.ASM. At lower duty cycles the output current will be higher up to a maximum of 10A. The new program is compiled and a new 16F877A is programmed using the USB programmer 'UsbPicProg'.

The new program is given the version number 2.02. When the EFU starts up, the panel display shows the version number as 2.01 / 2.02 instead of as previously 2.01 / 2.01.

Measurements on box with modified program

The new measurements of peak current are shown in table 2. Again, results for other modulation frequencies are very similar. A graph of this data is shown in figure 10. Peak output current is now seen to rise to 10A at duty cycles less than 100%. The mean output current as a function of voltage is shown in figure 11, with all values being within the mean power limit of 1600W.

Freq = 20Hz	Duty cycle / %			
Voltage	100	40	10	1
50	1.55	2	1.8	1.8
100	3.35	4.25	3.8	3.65
150	5.2	6.5	5.8	5.6
200	7.2	8.5	7.8	7.5
250	6.3	10	9.8	9.4
300	5.1	10	10	10

Table 2: Peak output current vs peak output voltage at 20Hz for various duty cycles. The figures in red indicate activation of the overload protection system.

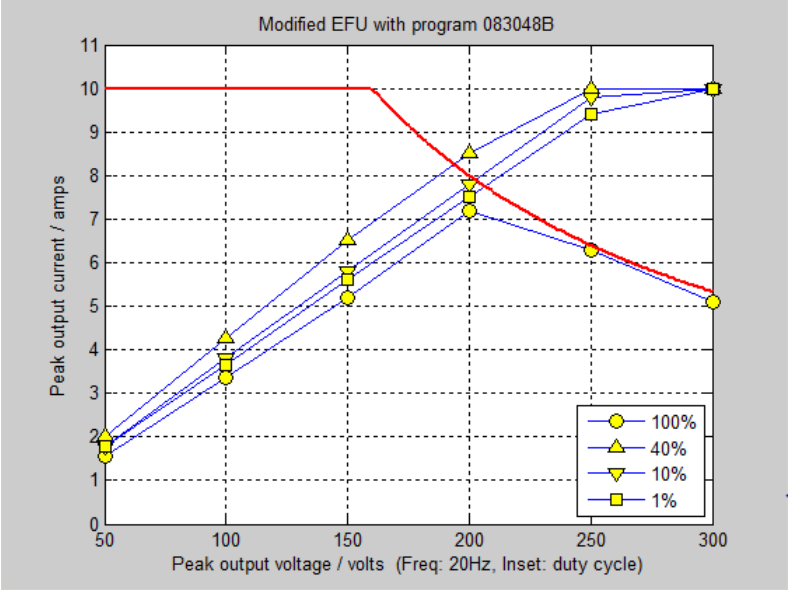

Figure 10: Peak output current vs peak output voltage at 20Hz for various duty cycles

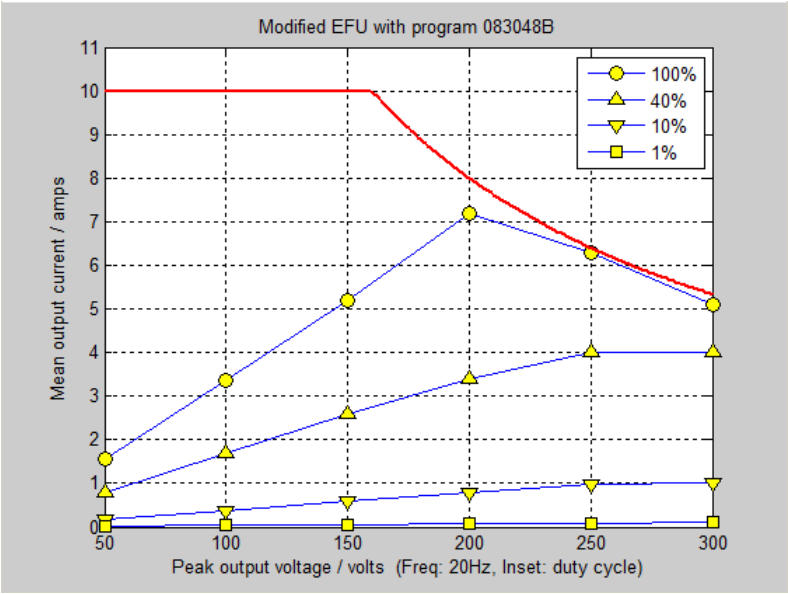

Figure 11: Mean output current vs peak output voltage at 20Hz for various duty cycles

Testing

Many measurements have been taken at a variety of operating parameters, voltage, current, duty cycle and modulation frequency over a period of several hours. The unit worked well and repeatably during this time. The unit, however, has not be tested operating continuously at high current/high voltage for times exceeding a few minutes. The unit has also not been tested with other loads.

Further work

Another area for investigation is to increase the maximum power limit from 1600W. This should be relatively straightforward to do by changing the appropriate value within the code. Careful monitoring of the component temperatures will be required in this case.

Further measurements on modified box

A series of more detailed measurements of peak output current as a function of peak output voltage and duty cycle were taken at a modulation frequency of 20Hz. These results are shown in table 3.

	Duty cycle / %										
Volts	100	90	80	70	60	50	40	30	20	10	1
60	1.90	2.10	2.20	2.30	2.40	2.45	2.45	2.35	2.25	2.20	2.20
80	2.60	2.85	3.10	3.20	3.30	3.35	3.30	3.15	3.15	2.95	2.90
100	3.35	3.70	3.95	4.15	4.20	4.25	4.20	4.05	4.00	3.80	3.65
120	4.05	4.50	4.90	5.10	5.20	5.20	5.10	4.95	4.80	4.60	4.45
140	4.80	5.30	5.80	6.10	6.20	6.20	6.00	5.80	5.60	5.40	5.20
160	5.55	6.30	6.70	6.90	7.10	7.10	6.80	6.70	6.40	6.20	6.00
180	6.30	7.10	7.40	7.70	8.00	7.90	7.70	7.50	7.30	7.00	6.80
200	7.20	7.80	8.30	8.60	8.70	8.70	8.60	8.30	8.10	7.80	7.50
220	7.10	8.00	8.70	9.10	9.20	9.20	9.10	9.10	8.90	8.60	8.20
240	6.90	7.20	8.30	9.20	9.40	9.60	9.80	9.80	9.70	9.40	9.00
260	6.10	6.80	7.70	8.80	9.40	9.60	9.80	9.90	9.90	9.90	9.80
280	5.60	6.10	6.90	7.90	9.40	9.60	9.80	9.90	9.90	9.90	9.90
300	5.05	5.70	6.40	7.40	8.70	9.60	9.80	9.90	9.90	9.90	9.90

Table 3: Peak output current (amps) as a function of peak output voltage (volts) and duty cycle (%). The modulation frequency is 20Hz.

A graph of some of this data is shown in figure 12. An alternative view of this data is the contour plot of figure 13. The contour lines represent the peak current in amps.

Extended test

With the load used above (2KW @ 240V), the EFU unit was set at 300V, 50% and 20Hz and the unit was switched on and left running for 20 minutes. The output current and component temperatures were monitored throughout the test. Output current remained steady at 9.6amps and the temperature of the components measured (using a Fluke infrared thermometer) was seen to remain fairly steady and were in the range from ambient to approximately

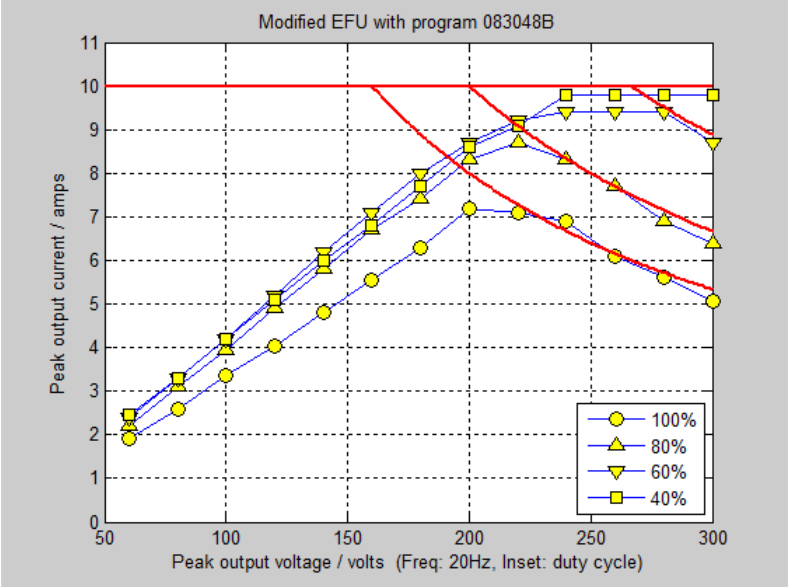

Figure 12: Peak output current vs peak output voltage at 20Hz for various of duty cycles. The three solid red lines at the top right hand of the graph represent the maximum current limit for a power dissipation of 1600W for the duty cycles 100%, 80% and 60%.

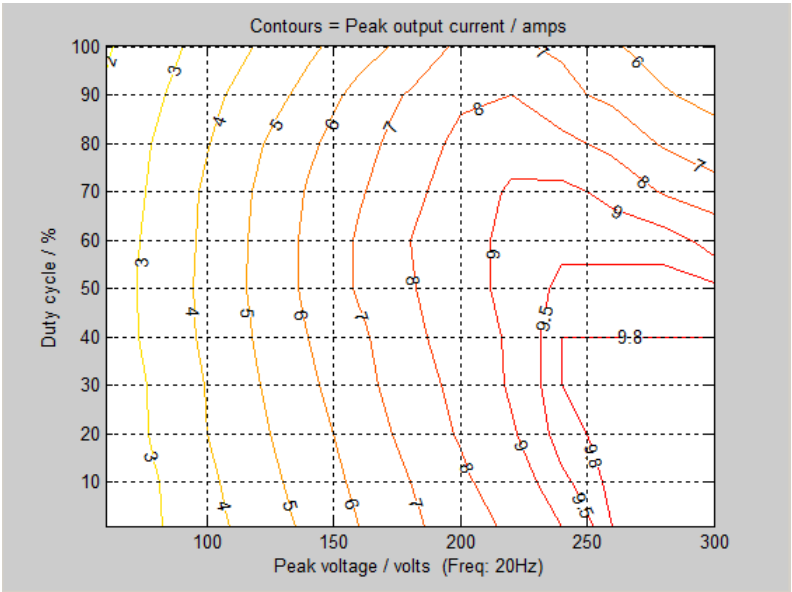

Figure 13: Peak output current contours for various peak output voltages and duty cycles. The modulation frequency is 20Hz.

34^{o}C. It must be emphasised that the temperature measurements were taken quickly for indication purposes only.