Inductor and Capacitor Selection for Low-Current (250mA Out) & Low-Voltage (5V In) Power Supply:

$$L = \frac{(V_{In} - V_{Out})V_{Out}}{V_{In} f I_{Ripple}}; \qquad L_{Max} = L(0.5V_{In}) = \frac{(V_{In} - 0.5V_{in})0.5V_{In}}{V_{In} f I_{Ripple}} = \frac{0.25V_{In}}{f I_{Ripple}} = \frac{5V_{In}}{f I_{Load}}$$

$$I_{Ripple} = 0.05 I_{Load}; \qquad L_{Max}(V_{In} = 5V) = \frac{5 \cdot 5V}{96000Hz \cdot 0.25A} = 1.04\ mH$$

$$V_{Ripple} = 0.01V_{Out}; \text{Assume } ESR_C = 0.5\Omega \text{ for very low end capacitor}$$

$$C_{Out} = \frac{0.05 I_{Load} V_{Out}}{V_{In} f \left(V_{Ripple} - 0.05 I_{Load} \cdot ESR_C\right)} = \frac{0.05 I_{Load} V_{Out}}{V_{In} f (0.01V_{Out} - 0.05 I_{Load} \cdot ESR_C)}$$

$$C_{Out}\left(V_{Out_{Min}} = 0.65V\right) = 67.7\mu F \rightarrow \text{Use } 100\mu F \text{ or higher}$$

Inductor and Capacitor Selection for High-Current (3A Out) & High-Voltage (12V In) Power Supply:

$$L = \frac{(V_{In} - V_{Out})V_{Out}}{V_{In} f I_{Ripple}}; \;\; L_{Max} = L(0.5V_{In}) = \frac{(V_{In} - 0.5V_{in})0.5V_{In}}{V_{In} f I_{Ripple}} = \frac{0.25V_{In}}{f I_{Ripple}} = \frac{5V_{In}}{6 f I_{Load}}$$

$$I_{Ripple} = 0.3 I_{Load}$$

$$L_{Max}(V_{In} = 12V) = \frac{5 \cdot 12V}{6 \cdot 96000Hz \cdot 3A} = 34.7\ \mu H \rightarrow \text{Use } 47\mu H \text{ or higher}$$

$$V_{Ripple} = 0.01V_{Out}; \text{Assume } ESR_C = 0.007\Omega \text{ for a cheap } 100\mu F \text{ capacitor}$$

$$C_{Out} = \frac{0.3 I_{Load} V_{Out}}{V_{In} f \left(V_{Ripple} - 0.3 I_{Load} \cdot ESR_C\right)} = \frac{0.3 I_{Load} V_{Out}}{V_{In} f (0.01V_{Out} - 0.3 I_{Load} \cdot ESR_C)}$$

$$C_{Out}\left(V_{Out_{Min}} = 1.00V\right) = 211\mu F \rightarrow \text{Use } 220\mu F \text{ or higher at } 7m\Omega\ ESR$$

$$\text{If Two } 100\mu F\ (7m\Omega) \text{ are paralleled then } V_{Out_{Min}} = 0.55V$$

Programming:

PIC18F14K50 can be programmed (with standard programming tool such as PICkit 2) with the HID bootloader ("PIC18F14K50 Custom Bootloader.hex") firmware to use USB connection to re-program the main firmware. The bootloader is optional and more information can be found here: http://www.libstock.com/projects/view/55/microchip-hid-bootloader-template-and-adc-over-usb-for-pic18f-and-pic24f-pic18f14k50-pic18f27j53-pic18f2553-pic18f4553-pic24fj64gb002-tested

Digital Buck Converter Program Modification:

Each unique device (same Bill Of Materials) may need to change the following (each can be change through USB interface):

- VInADCFactor: Affected by the feedback resistors, use accurate feedback resistors (low tolerance values) will negate the effect
- VOffset: Seems to be a result of voltage drops in the circuit and the microcontroller itself (maybe due to rounding errors).

Each unique circuit (different Bill Of Materials) may need to change the following (each can be change through USB interface):

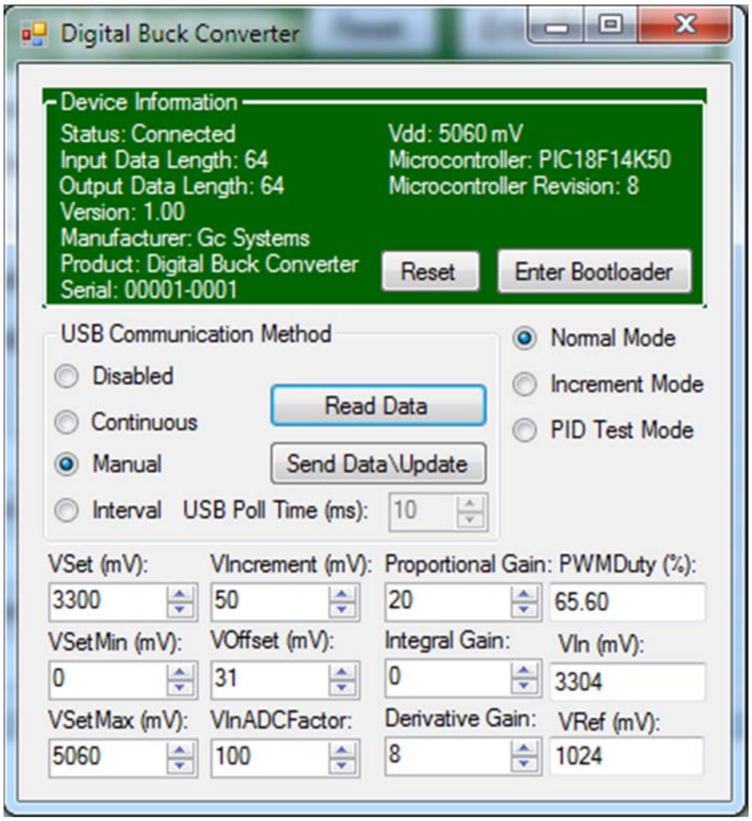
- VInADCFactor: Affected by the feedback resistors, use accurate feedback resistors (low tolerance values) will negate the effect
- VOffset: Seems to be a result of voltage drops in the circuit and the microcontroller itself (maybe due to rounding errors).
- Proportional Gain: Changes response time of the power supply. Effective Gain = 1/PGain.
- Integral Gain: Changes the amount of error and response time. Effective Gain = 1/IGain.
- Derivative Gain: Changes the amount overshoot and effect of noise. Effective Gain = 1/DGain.

Calibration:

The “Calibration” excel spreadsheet can be used to calibrate the output by determining VInADCFactor and VOffset. VOffset should be set to zero and VInADCFactor should be set to the nominal multiplication factor multiplied by a 100 (ie. 200 for half-voltage divider input) in the settings (firmware hardcoded or through USB). The “Increment Mode” function can be selected in the PC Interface to automatically set all test points listed in the excel file. Enter the actual values at each set point and a VInADCFactor and VOffset will be produced.

Proportional, Integral, Derivative (PID) Performance Testing:

To test out how well the power supply does, apply various loads and the “PID Test Mode” can be used to alternate (between 25% and 75% of VSetMax) the set-point (step input) every 500ms to. PGain, IGain and DGain are divisors so the effective gains are actually inverted meaning that increasing any of the gains will reduce its effect. PGain is required and IGain & DGain are optional so they can be set to zero without a divide by zero error. The examples use a PD controller to increase responsiveness (PGain) and reduce overshoot (DGain). Adding an IGain did not help and actually made the response worse. The firmware uses the PID gains to affect the rate of change of the PWM Duty Cycle.



Status: Connected
Input Data Length: 64
Output Data Length: 64
Version: 1.00
Manufacturer: Gc Systems
Product: Digital Buck Converter
Serial: 00001-0001
Vdd: 5060 mV
Microcontroller: PIC18F14K50
Microcontroller Revision: 8

○ Disabled
○ Continuous
● Manual
○ Interval USB Poll Time (ms): 10

● Normal Mode
○ Increment Mode
○ PID Test Mode

VSet (mV):	VIncrement (mV):	Proportional Gain:	PWMDuty (%):
3300	50	20	65.60
VSetMin (mV):	**VOffset (mV):**	**Integral Gain:**	**VIn (mV):**
0	31	0	3304
VSetMax (mV):	**VInADCFactor:**	**Derivative Gain:**	**VRef (mV):**
5060	100	8	1024

Controlling the Power Supply:

The HID interface for Windows allows setting the Output Voltage, the minimum & maximum voltage set points (important if external switches are used), the voltage increments of the output voltage if hardware switches are used, the Voltage Offset & Feedback Voltage Factor for calibration. It will also provide the instantaneous PWM Duty Cycle and the input voltage. It also shows the set voltage of the internal reference.

Operating mode can be switched as well between:

- Normal
- Automatic Voltage Incrementing (0.25V every 4 seconds) which is useful for making calibration measurements semi-automatic
- PID Test Mode to alternate the set point between 25% and 75% of maximum set point voltage every 500ms. A normal trigger mode setting in an oscilloscope will show the rise and fall voltage curves of the power supply.