

University of Canterbury Competitive Robotics (UCCR1)

Inside The iMAX B6 Balance Charger

VEX Texas Instruments Electronics Online Challenge





Jack Wilkie

Table of Contents

Introduction	2
Disassembly	2
Analysis	4
Conclusion	6

Introduction

This iMAX B6 Battery Charger charges, discharges, and balances a range of battery types safely and quickly. It was expected to have a variety of power, sensing, and control electronics to help it perform its multitude of functions. These electronics were examined to learn how it works.

Disassembly

The charger was first disassembled, and chip markings were documented (Figures 1 to 12). The chips were identified, and presented in Table 1.



Figure 1: Main circuit board with screen soldered above.



Figures 2,3, and 4: Texas Instruments LM2904 Dual Op-amp, LM324 Quad Op-amp, and LM393 Dual Comparator.



Figures 5 and 6: Alpha & Omega AO4468N-Channel MOSFET, and AO4407A P-Channel MOSFET.

Inside The iMAX B6 Balance Charger



Figures 7 and 8: NXP HEF4051BT 8-channel Analog Multiplexer/De-multiplexer, and Atmel ATMEGA32L 8-bit AVR Microcontroller.



Figures 9 to 12: Various transistors. The undetailed markings made identification difficult and potentially inaccurate.

Marking/Model	Manufacturer	Description	Datasheet URL
(Quantity)		-	(Shortened)
LM2904 (2)		Dual Op-Amp	https://goo.gl/vbGn4s
LM324 (1)	Texas Instruments	Quad Op-Amp	https://goo.gl/HJNkZL
LM393 (1)		Dual Comparator	https://goo.gl/JpcPMk
AO4468 (3)	Alpha & Omoga	N-Channel MOSFET	https://goo.gl/iisdLJ
AO4407A (1)	Alpha & Offega	P-Channel MOSFET	https://goo.gl/8kfss9
HEF4051BT (1)	NXP Semiconductors	8-channel Analog Multiplexer/De-multiplexer	https://goo.gl/4QCikZ
ATMEGA32L (1)	Atmel	8-bit AVR Microcontroller	https://goo.gl/pKW8bh
64/DTC114YUA (9)	ROHM Semiconductors	NPN Digital Transistor (Built-In Bias)/Inverter	https://goo.gl/g7vyi5
2AG/MMBT3906 (1)	Unisonic Technologies	PNP Transistor	https://goo.gl/e1yPqF
2V (6)	Multiple Found	PNP Darlington Transistor (High-Gain)	https://goo.gl/eXse92
1AM (4)	~	NPN Transistor	https://goo.gl/kjG5Qt
IRFZ44N (1)	International Rectifier	Power MOSFET	https://goo.gl/kYkXWN
L7805CV (1)	STMicroelectronics	5V Voltage Regulator	https://goo.gl/5eVr9m

			r			۰ I				
lable	1:	LIST	OŤ	all	cnips	tound	on	the	board	٦.

Analysis

The ATMEGA32L is the brain of the charger, and controls the charger in response to user input. The connected buttons and screen provide a user interface. As the microcontroller cannot use the 12V input, the L7805CV voltage regulator provides it with a stable 5V. The microcontroller has 8 analog inputs, but the HEF4051BT multiplexer expands this to effectively 15, to accommodate the many analog inputs.

The MOSFETs control high-current power. The Alpha & Omega MOSFETs (Figure 13) switch large currents, but only fully on or off. The IRFZ44N Power MOSFET was connected in series with a 5Ω discharging resistor between the battery terminals, and was thermally coupled to the chassis with a pad to dissipate heat. This suggests the IRFZ44N regulates the discharge of batteries, producing resistive heat, but preventing the resistor from overheating itself.



Figure 13: Alpha & Omega AO4468 N-Channel MOSFET connected to high-current traces. The lack of heatsink indicates it turns fully on or off to minimize resistive heating.

The charger uses a buck-boost converter (Figure 14) to convert the 12V input voltage into the required voltage for charging. As this device charges a wide range of batteries, from 1-cell NiMH (1.2V) to 6-cell LiPo (over 25V), this circuitry is needed to provide stable output at many voltages.



Figure 14: Buck-boost converter consisting of the large inductor, with a capacitor on the output and input, switched by MOSFETs, and controlled by the microcontroller.

The LM2904 and LM324 demonstrate the versatility of op-amps. The LM2904 closest to the output (Figure 15) was likely a low-pass filter, as used for filtering high-frequency noise from the power electronics. The 2 capacitors per op-amp meant they were likely second-order filters (Figure 16), which are more effective than first-order filters. In contrast, the LM324 (Figure 17) ones were probably configured as amplifiers (Figure 18), which would help amplify microcontroller outputs to control the power electronics.



Figure 15: LM2904 Dual Op-amp with resistors and capacitors. These op-amps may be configured as filters as these require capacitors, and are a common usage for op-amps.



Figure 16: Example second order low-pass filter using an op-amp, two capacitors, and two resistors. A low pass filter lets low-frequencies 'pass' and blocks high-frequencies. (Source: https://en.wikipedia.org/wiki/File:Sallen-Key_Lowpass_General.svg)



Figure 17: LM324 Quad Op-amp surrounded by resistors, possibly indicating amplifier configuration.



Figure 18: Possible non-inverting op-amp amplifier configuration. This type of amplifier sets the output voltage to a multiple (called the 'gain') of the input voltage.

(Source: https://commons.wikimedia.org/wiki/File:Op-Amp_Non-Inverting_Amplifier.svg)

The PNP Darlington Transistors are in series with the resistors across each connected cell (Figure 19). These switch current through the load resistors to discharge that cell, or slow the charging rate, allowing the charger to balance the cells while charging. The Darlington Transistors have a high current gain (up to 20000x), so a small current at the base controls a large current across the collector/emitter. Digital Transistors control these, and isolate the microcontroller from the power electronics.



Figure 19: Position of Darlington transistor in balance charger circuitry, pinout determined from datasheet. The base switches current from the collector to the emitter on and off.

Conclusion

From disassembling and analyzing the charger, several interesting things were determined about its operation. Firstly, the discharging circuit uses a resistor in series with a MOSFET, where the MOSFET is used to regulate the discharge rate, and stop the resistor overheating. Secondly, a buck-boost converter gives a wide range of output voltages, above and below the supply voltage, required for charging the multitude of supported batteries. And lastly, the balance charging works by partially loading/bypassing the fastest charging battery cells.

(Word count: 493. Excluding cover page, captions, and parts list)