AN3632

Constant-Current Driver Using the Analog Signal Conditioning (OPAMP) Peripheral

Introduction

Author: Lloyd D. Clark, Ph.D., Microchip Technology Inc.

It is sometimes preferable to drive an electronic component, for example, a light-emitting diode (LED), with constant current and not constant voltage. A microcontroller (MCU) containing the Analog Signal Conditioning (OPAMP) peripheral can be used to implement a constant-current driver using just one external resistor. The OPAMP peripheral also provides the ability to adjust the current setting under firmware control.

Features

- Constant-Current Drive
- Adjustable Current Under Firmware Control
- Low Bill of Materials – Only One External Resistor Required

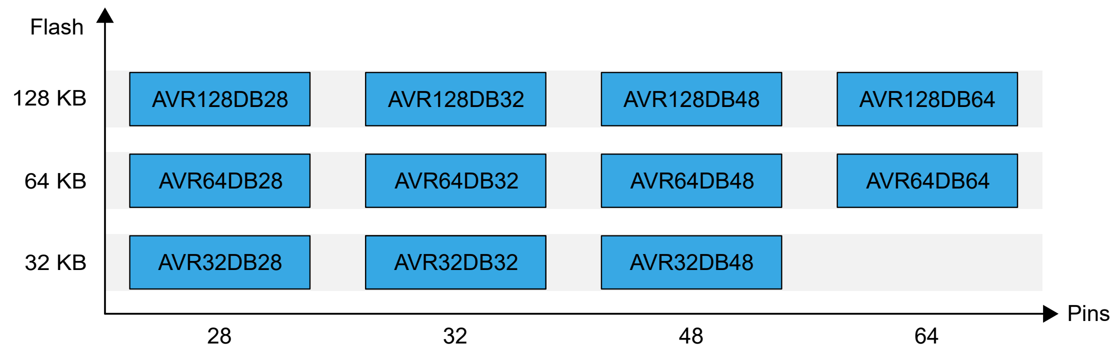
Table of Contents

1. Relevant Devices

This section lists the relevant devices for this document. The following figures show the different family devices, laying out pin count variants and memory sizes:

- Vertical migration upwards is possible without code modification, as these devices are pin-compatible and provide the same or more features
- Horizontal migration to the left reduces the pin count and, therefore, the available features
- Devices with different Flash memory sizes typically also have different SRAM and EEPROM

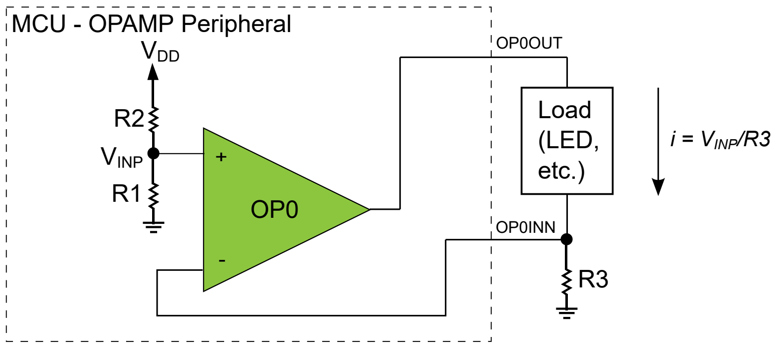
Figure 1-1. AVR® DB Family Overview



2. Constant-Current Driver Using OPAMP Peripheral

The microcontroller's (MCU's) OPAMP peripheral can be used to provide a constant-current drive to a load, for example, a light-emitting diode (LED). The schematic diagram of the constant-current driver is shown in the figure below. Only one component is required in addition to the load and MCU: Resistor R3 for converting current into voltage. The remainder of the constant-current driver is provided by the OPAMP peripheral inside the MCU.

Figure 2-1. Schematic Diagram of a Constant-Current Driver Using OPAMP Peripheral



As shown in the schematic diagram, op amp OP0 inside the MCU's OPAMP peripheral is configured with the non-inverting input (+) connected to the wiper of the internal resistor ladder. The top of the resistor ladder is internally connected to V_{DD}, and the bottom is internally connected to ground. Therefore, the resistor ladder acts as a voltage divider that generates a reference voltage, V_{INP}, on the non-inverting input of the op amp. The value of the reference voltage can be determined using the resistor divider formula: $V_{INP} = (R1/(R2+R1))V_{DD}$.

The output of the op amp, OP0OUT, is connected to one side of the load, and the other side of the load is connected to both R3 and the inverting input (-) OP0INN. Since the op amp input has a high impedance, the current flowing through the load will also flow through R3 to ground. The voltage generated across R3 will be proportional to the current through R3. The feedback loop created will cause the op amp to adjust its output voltage such that the voltage on its inverting input is the same as that on its non-inverting input, V_{INP}. The current flowing through R3 and the load will then be $i = V_{INP}/R3$.

As an example with realistic component values, consider the scenario where V_{DD} is 3.3V, and R3 is 205Ω. If the resistor ladder wiper setting is selected as WIP7 so that R2 is 15R and R1 is 1R, the ratio $R1/(R2+R1)$ is (1/16), and V_{INP} will be $(1/16)V_{DD}$ or 0.21V. The constant current through the load will then be $V_{INP}/R3$ or 1.0 mA.

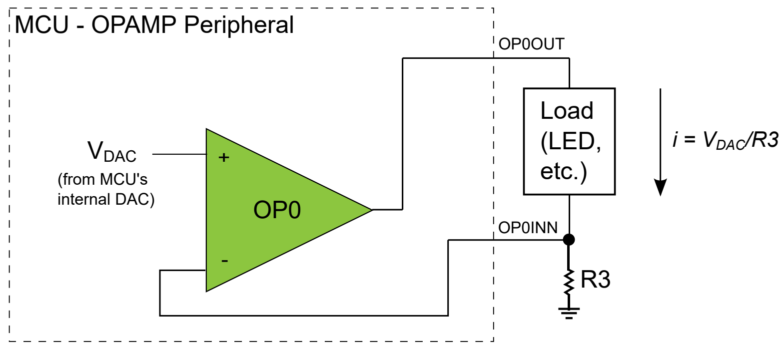
Because the OPAMP peripheral has eight different selections for the wiper position, determined by the value written to the MUXWIP bit field in the OPAMP.OPnRESMUX register, it is possible to select eight different current values under firmware control. The following table displays the current value provided by each MUXWIP bit field value.

Table 2-1. MUXWIP Selection of Current Value

MUXWIP Selection	Description	Voltage Divider Ratio	Current Value
WIP0	R1 = 15R, R2 = 1R	15/16	$0.9375\ V_{DD}/R3$
WIP1	R1 = 14R, R2 = 2R	14/16	$0.875\ V_{DD}/R3$
WIP2	R1 = 12R, R2 = 4R	12/16	$0.75\ V_{DD}/R3$
WIP3	R1 = 8R, R2 = 8R	8/16	$0.5\ V_{DD}/R3$
WIP4	R1 = 6R, R2 = 10R	6/16	$0.375\ V_{DD}/R3$
WIP5	R1 = 4R, R2 = 12R	4/16	$0.25\ V_{DD}/R3$
WIP6	R1 = 2R, R2 = 14R	2/16	$0.125\ V_{DD}/R3$
WIP7	R1 = 1R, R2 = 15R	1/16	$0.0625\ V_{DD}/R3$

If more precise control of the current value is required, the MCU's digital-to-analog converter (DAC) can be internally connected to the non-inverting (+) input of the op amp as shown in the figure below. This is achieved by writing the DAC setting to the MUXPOS bit field of the OPAMP.OPnINMUX register. In this case, the current value is given by the formula $i = V_{DAC}/R3$, where V_{DAC} is the output voltage of the DAC.

Figure 2-2. Schematic Diagram of a Constant-Current Driver using OPAMP and DAC



3. OPAMP Configuration Code

Just a few lines of code are required to configure the OPAMP peripheral to implement the constant-current driver:

```
    // Set up the timebase of the OPAMP peripheral
    OPAMP.TIMEBASE = 3; // Number of CLK_PER cycles that equal one us, minus one (4-1=3)

    //Connect OP0 to wiper and pin connected to sense resistor
    OPAMP.OP0INMUX = OPAMP_OP0INMUX_MUXPOS_WIP_gc | OPAMP_OP0INMUX_MUXNEG_INN_gc;
    //Connect resistor ladder to VDD and ground so the wiper functions as a voltage divider
    OPAMP.OP0RESMUX = OPAMP_OP0RESMUX_MUXBOT_GND_gc | OPAMP_OP0RESMUX_MUXWIP_WIP7_gc |
OPAMP_OP0RESMUX_MUXTOP_VDD_gc;
    // Configure OP0 Control A
    OPAMP.OP0CTRLA = OPAMP_OP0CTRLA_OUTMODE_NORMAL_gc | OPAMP_ALWAYSON_bm;

    // Enable the OPAMP peripheral
    OPAMP.CTRLA = OPAMP_ENABLE_bm;
```

After this code has been executed, the op amp stays active, and no further CPU intervention is required.

View Code Example on GitHub
Click to browse repository

4. Revision History

Doc. Rev.	Date	Comments
A	09/2020	Initial document release

The Microchip Website

Microchip provides online support via our website at www.microchip.com/. This website is used to make files and information easily available to customers. Some of the content available includes:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip design partner program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

Product Change Notification Service

Microchip's product change notification service helps keep customers current on Microchip products. Subscribers will receive email notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, go to www.microchip.com/pcn and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Embedded Solutions Engineer (ESE)
- Technical Support

Customers should contact their distributor, representative or ESE for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in this document.

Technical support is available through the website at: www.microchip.com/support

Microchip Devices Code Protection Feature

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable." Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Legal Notice

Information contained in this publication is provided for the sole purpose of designing with and using Microchip products. Information regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications.

THIS INFORMATION IS PROVIDED BY MICROCHIP “AS IS”. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL OR CONSEQUENTIAL LOSS, DAMAGE, COST OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION. Use of Microchip devices in life support and/or safety applications is entirely at the buyer’s risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PackeTime, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TempTrackr, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, FlashTec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, Vite, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BlueSky, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, INICnet, Inter-Chip Connectivity, JitterBlocker, KleerNet, KleerNet logo, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

ISBN: 978-1-5224-6647-5

Quality Management System

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.

Worldwide Sales and Service

AMERICAS	ASIA/PACIFIC	ASIA/PACIFIC	EUROPE
Corporate Office 2355 West Chandler Blvd. Chandler, AZ 85224-6199 Tel: 480-792-7200 Fax: 480-792-7277 Technical Support: www.microchip.com/support Web Address: www.microchip.com **Atlanta** Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455 **Austin, TX** Tel: 512-257-3370 **Boston** Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088 **Chicago** Itasca, IL Tel: 630-285-0071 Fax: 630-285-0075 **Dallas** Addison, TX Tel: 972-818-7423 Fax: 972-818-2924 **Detroit** Novi, MI Tel: 248-848-4000 **Houston, TX** Tel: 281-894-5983 **Indianapolis** Noblesville, IN Tel: 317-773-8323 Fax: 317-773-5453 Tel: 317-536-2380 **Los Angeles** Mission Viejo, CA Tel: 949-462-9523 Fax: 949-462-9608 Tel: 951-273-7800 **Raleigh, NC** Tel: 919-844-7510 **New York, NY** Tel: 631-435-6000 **San Jose, CA** Tel: 408-735-9110 Tel: 408-436-4270 **Canada - Toronto** Tel: 905-695-1980 Fax: 905-695-2078	**Australia - Sydney** Tel: 61-2-9868-6733 **China - Beijing** Tel: 86-10-8569-7000 **China - Chengdu** Tel: 86-28-8665-5511 **China - Chongqing** Tel: 86-23-8980-9588 **China - Dongguan** Tel: 86-769-8702-9880 **China - Guangzhou** Tel: 86-20-8755-8029 **China - Hangzhou** Tel: 86-571-8792-8115 **China - Hong Kong SAR** Tel: 852-2943-5100 **China - Nanjing** Tel: 86-25-8473-2460 **China - Qingdao** Tel: 86-532-8502-7355 **China - Shanghai** Tel: 86-21-3326-8000 **China - Shenyang** Tel: 86-24-2334-2829 **China - Shenzhen** Tel: 86-755-8864-2200 **China - Suzhou** Tel: 86-186-6233-1526 **China - Wuhan** Tel: 86-27-5980-5300 **China - Xian** Tel: 86-29-8833-7252 **China - Xiamen** Tel: 86-592-2388138 **China - Zhuhai** Tel: 86-756-3210040	**India - Bangalore** Tel: 91-80-3090-4444 **India - New Delhi** Tel: 91-11-4160-8631 **India - Pune** Tel: 91-20-4121-0141 **Japan - Osaka** Tel: 81-6-6152-7160 **Japan - Tokyo** Tel: 81-3-6880- 3770 **Korea - Daegu** Tel: 82-53-744-4301 **Korea - Seoul** Tel: 82-2-554-7200 **Malaysia - Kuala Lumpur** Tel: 60-3-7651-7906 **Malaysia - Penang** Tel: 60-4-227-8870 **Philippines - Manila** Tel: 63-2-634-9065 **Singapore** Tel: 65-6334-8870 **Taiwan - Hsin Chu** Tel: 886-3-577-8366 **Taiwan - Kaohsiung** Tel: 886-7-213-7830 **Taiwan - Taipei** Tel: 886-2-2508-8600 **Thailand - Bangkok** Tel: 66-2-694-1351 **Vietnam - Ho Chi Minh** Tel: 84-28-5448-2100	**Austria - Wels** Tel: 43-7242-2244-39 Fax: 43-7242-2244-393 **Denmark - Copenhagen** Tel: 45-4485-5910 Fax: 45-4485-2829 **Finland - Espoo** Tel: 358-9-4520-820 **France - Paris** Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79 **Germany - Garching** Tel: 49-8931-9700 **Germany - Haan** Tel: 49-2129-3766400 **Germany - Heilbronn** Tel: 49-7131-72400 **Germany - Karlsruhe** Tel: 49-721-625370 **Germany - Munich** Tel: 49-89-627-144-0 Fax: 49-89-627-144-44 **Germany - Rosenheim** Tel: 49-8031-354-560 **Israel - Ra'anana** Tel: 972-9-744-7705 **Italy - Milan** Tel: 39-0331-742611 Fax: 39-0331-466781 **Italy - Padova** Tel: 39-049-7625286 **Netherlands - Drunen** Tel: 31-416-690399 Fax: 31-416-690340 **Norway - Trondheim** Tel: 47-72884388 **Poland - Warsaw** Tel: 48-22-3325737 **Romania - Bucharest** Tel: 40-21-407-87-50 **Spain - Madrid** Tel: 34-91-708-08-90 Fax: 34-91-708-08-91 **Sweden - Gothenberg** Tel: 46-31-704-60-40 **Sweden - Stockholm** Tel: 46-8-5090-4654 **UK - Wokingham** Tel: 44-118-921-5800 Fax: 44-118-921-5820