To our customers,

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April 1st, 2010
Renesas Electronics Corporation

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# HA1630Q01/02/03 Series

## Low Voltage Operation CMOS Quad Operational Amplifier

REJ03D0802-0100
Rev.1.00
Mar 10, 2006

### Description

The HA1630Q01/02/03 are dual CMOS Operational Amplifiers realizing low voltage operation, low input offset voltage and low supply current. In addition to a low operating voltage from 1.8V, these device output can achieve full swing output voltage capability extending to either supply. Available in an ultra-small TSSOP-14 package that occupies only 1/2 the area of the SOP-14 package.

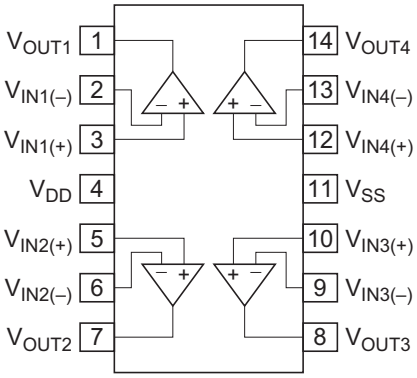
### Features

- Low power and single supply operation — $V_{DD}$ = 1.8 to 5.5 V
- Low input offset voltage — $V_{IO}$ = 4.0 mV Max
- Low supply current (per channel) — $I_{DD}$ = 15 µA Typ (HA1630Q01)
  $I_{DD}$ = 50 µA Typ (HA1630Q02)
  $I_{DD}$ = 100 µA Typ (HA1630Q03)
- Maximum output voltage — $V_{OH}$ = 2.9 V Min (at $V_{DD}$ = 3.0 V)
- Low input bias current — $I_{IB}$ = 1 pA Typ

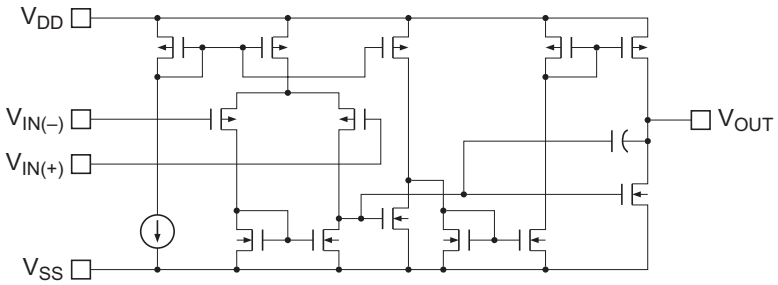
### Ordering Information

| Type No. | Package Name | Package Code |
|---|---|---|
| HA1630Q01T | TTP-14D | PTSP0014JA-B |
| HA1630Q02T | TTP-14D | PTSP0014JA-B |
| HA1630Q03T | TTP-14D | PTSP0014JA-B |

## Pin Arrangement




## Equivalent Circuit (per one channel)



## Absolute Maximum Ratings

(Ta = 25°C)

| Items | Symbol | Ratings | Unit | Note |
|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | 7 | V | |
| Differential input voltage | $V_{IN(diff)}$ | $-V_{DD}$ to $+V_{DD}$ | V | |
| Input voltage | $V_{IN}$ | –0.3 to $+V_{DD}$ | V | 1 |
| Power dissipation | $P_T$ | 400 | mW | |
| Operating temp. Range | Topr | –40 to +85 | °C | |
| Storage temp. Range | Tstg | –55 to +125 | °C | |

Note: 1. Do not apply Input Voltage exceeding $V_{DD}$ or 7 V.

## Electrical Characteristics

($V_{DD}$ = 3.0 V, Ta = 25°C)

| Items | Symbol | Min | Typ | Max | Unit | Test Condition |
|---|---|---|---|---|---|---|
| Input offset voltage | $V_{IO}$ | — | — | 4.0 | mV | Vin = 1.5 V |
| Input offset current | $I_{IO}$ | — | (1.0) | — | pA | Vin = 1.5 V |
| Input bias current | $I_{IB}$ | — | (1.0) | — | pA | Vin = 1.5 V |
| Output high voltage | $V_{OH}$ | 2.9 | — | — | V | $R_L$ = 1 MΩ |
| Output source current | $I_{O\ SOURCE}$ | 6 | 12 | — | µA | $V_{OH}$ = 2.5 V (HA1630Q01) |
| | | 25 | 50 | — | | $V_{OH}$ = 2.5 V (HA1630Q02) |
| | | 50 | 100 | — | | $V_{OH}$ = 2.5 V (HA1630Q03) |
| Output low voltage | $V_{OL}$ | — | — | 0.1 | V | $R_L$ = 1 MΩ |
| Output sink current | $I_{O\ SINK}$ | — | (0.8) | — | mA | $V_{OL}$ = 0.5 V (HA1630Q01) |
| | | — | (1.0) | — | | $V_{OL}$ = 0.5 V (HA1630Q02) |
| | | — | (1.2) | — | | $V_{OL}$ = 0.5 V (HA1630Q03) |
| Common mode input voltage range | $V_{CM}$ | –0.1 to 2.1 | — | — | V | |
| Slew rate | SR | — | (0.125) | — | V/µs | $C_L$ = 20 pF (HA1630Q01) |
| | | — | (0.50) | — | | $C_L$ = 20 pF (HA1630Q02) |
| | | — | (1.00) | — | | $C_L$ = 20 pF (HA1630Q03) |
| Voltage gain | $A_V$ | 60 | 80 | — | dB | |
| Gain bandwidth product | BW | — | (200) | — | kHz | $C_L$ = 20 pF (HA1630Q01) |
| | | — | (680) | — | | $C_L$ = 20 pF (HA1630Q02) |
| | | — | (1200) | — | | $C_L$ = 20 pF (HA1630Q03) |
| Power supply rejection ratio | PSRR | 60 | 80 | — | dB | |
| Common mode rejection ratio | CMRR | 60 | 80 | — | dB | |
| Supply current | $I_{DD}$ | — | 60 | 120 | µA | $R_L$ = ∞ (HA1630Q01) |
| | | — | 200 | 400 | | $R_L$ = ∞ (HA1630Q02) |
| | | — | 400 | 800 | | $R_L$ = ∞ (HA1630Q03) |

Note: 1. ( ) : Design specification

## Table of Graphs

| Electrical Characteristics | | | HA1630Q01 Figure | HA1630Q02 Figure | HA1630Q03 Figure | Test Circuit |
|---|---|---|---|---|---|---|
| Supply current | $I_{DD}$ | vs Supply voltage | 1-1 | 2-1 | 3-1 | 2 |
| | | vs Ambient temperature | 1-2 | 2-2 | 3-2 | |
| Output high voltage | $V_{OH}$ | vs Output source current | 1-3 | 2-3 | 3-3 | 4 |
| | | vs Supply voltage | 1-4 | 2-4 | 3-4 | |
| Output source current | $I_{O\ SOURCE}$ | vs Ambient temperature | 1-5 | 2-5 | 3-5 | 6 |
| Output low voltage | $V_{OL}$ | vs Output sink current | 1-6 | 2-6 | 3-6 | 5 |
| Output sink current | $I_{O\ SINK}$ | vs Ambient temperature | 1-7 | 2-7 | 3-7 | 6 |
| Input offset voltage | $V_{IO}$ | Distribution | 1-8 | 2-8 | 3-8 | 1 |
| | | vs Supply voltage | 1-9 | 2-9 | 3-9 | |
| | | vs Ambient temperature | 1-10 | 2-10 | 3-10 | |
| Common mode input voltage range | $V_{CM}$ | vs Ambient temperature | 1-11 | 2-11 | 3-11 | 7 |
| Power supply rejection ratio | PSRR | vs Frequency | 1-12 | 2-12 | 3-12 | 1 |
| Common mode rejection ratio | CMRR | vs Frequency | 1-13 | 2-13 | 3-13 | 7 |
| Voltage gain & phase angle | $A_V$ | vs Frequency | 1-14 | 2-14 | 3-14 | 10 |
| Input bias current | $I_{IB}$ | vs Ambient temperature | 1-15 | 2-15 | 3-15 | 3 |
| | | vs Input voltage | 1-16 | 2-16 | 3-16 | |
| Slew Rate (rising) | SRr | vs Ambient temperature | 1-17 | 2-17 | 3-17 | 9 |
| Slew Rate (falling) | SRf | vs Ambient temperature | 1-18 | 2-18 | 3-18 | |
| Slew rate | | Large signal transient response | 1-19 | 2-19 | 3-19 | |
| | | Small signal transient response | 1-20 | 2-20 | 3-20 | |
| Total harmonic distortion + noise | (0 dB) | vs. Output voltage p-p | — | 2-21 | 3-21 | 8 |
| | (40 dB) | vs. Output voltage p-p | — | 2-22 | 3-22 | |
| Maximum p-p output voltage | | vs Frequency | 1-21 | 2-23 | 3-23 | |
| Voltage noise density | | vs Frequency | 1-22 | 2-24 | 3-24 | |

## Main Characteristics (HA1630Q01)

Figure 1-1. HA1630Q01
Supply Current vs. Supply Voltage

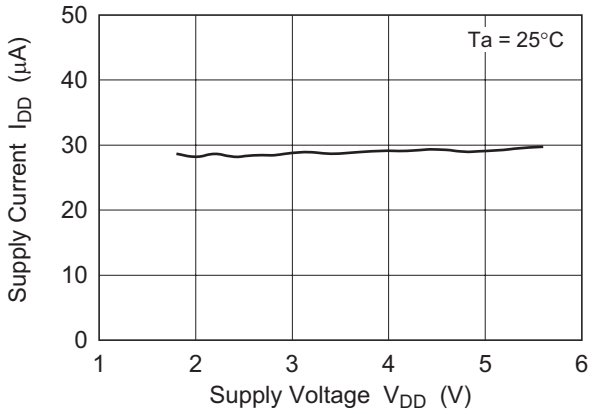



Figure 1-2. HA1630Q01
Supply Current vs. Ambient Temperature

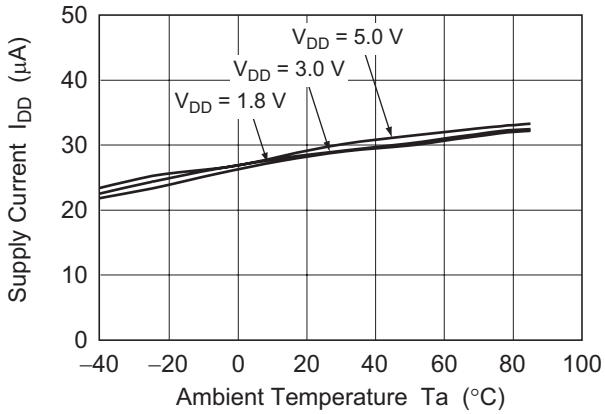



Figure 1-3. HA1630Q01
Output High Voltage vs. Output Source Current

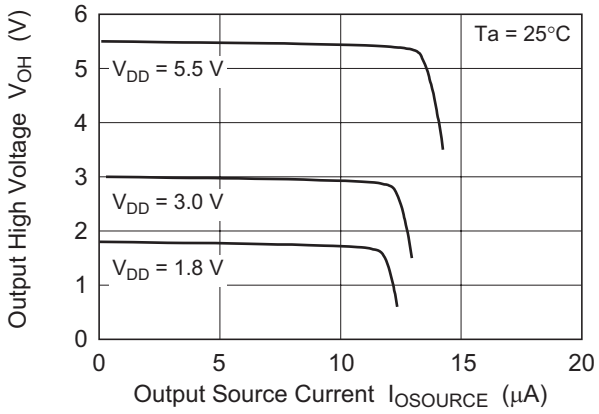



Figure 1-4. HA1630Q01
Output High Voltage vs. Supply Voltage

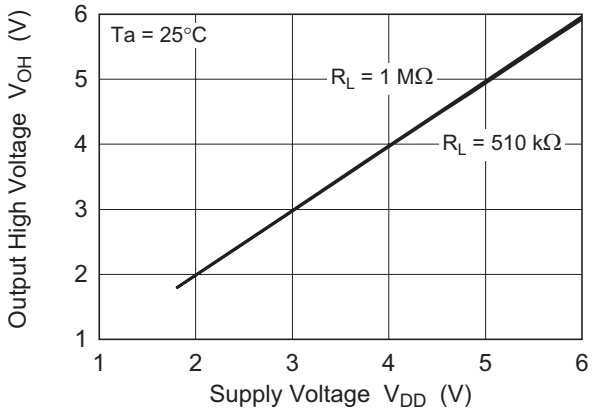



Figure 1-5. HA1630Q01
Output Source Current vs. Ambient Temperature

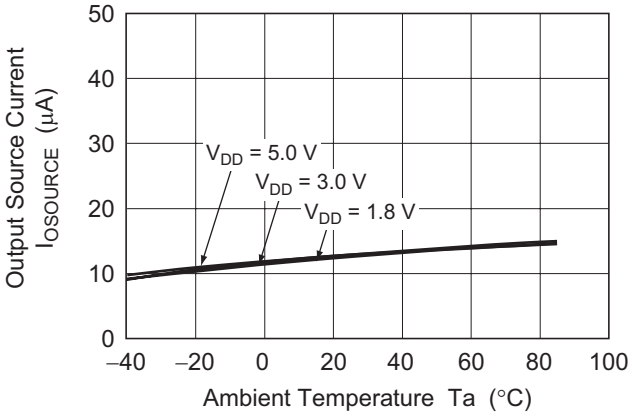


Figure 1-6. HA1630Q01
Output Low Voltage vs. Output Sink Current

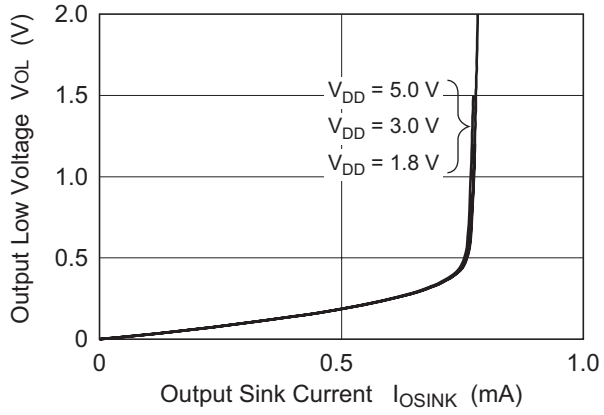



Figure 1-7. HA1630Q01
Output Sink Current vs. Ambient Temperature

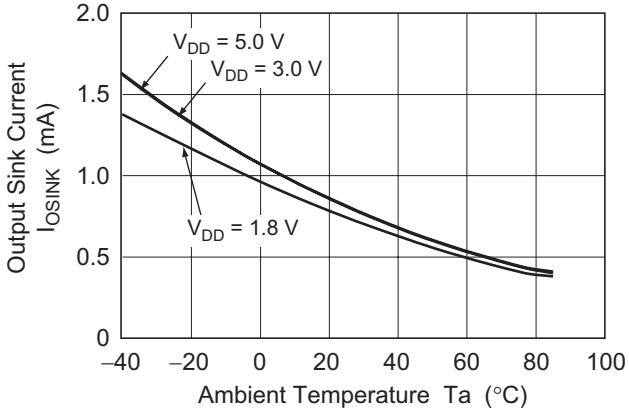



Figure 1-8. HA1630Q01
Input Offset Voltage Distribution

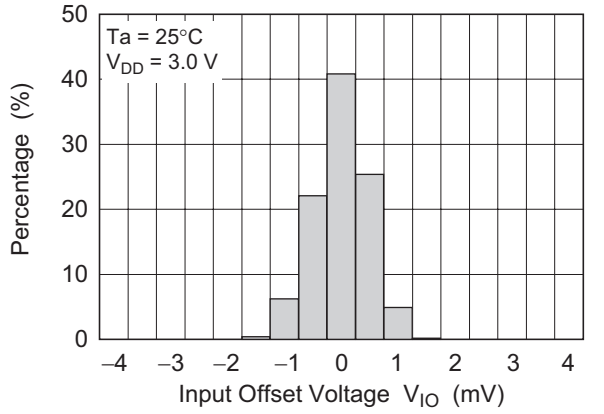



Figure 1-9. HA1630Q01
Input Offset Voltage vs. Supply Voltage

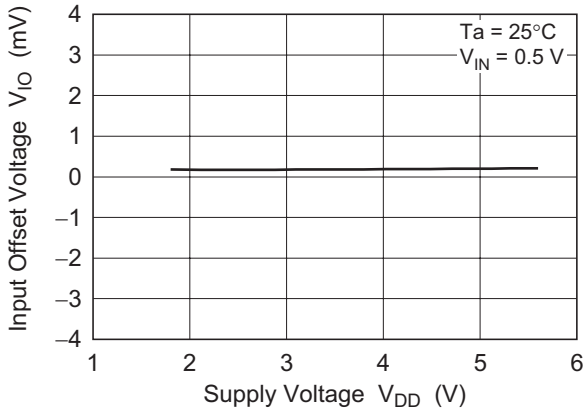



Figure 1-10. HA1630Q01
Input Offset Voltage vs. Ambient Temperature

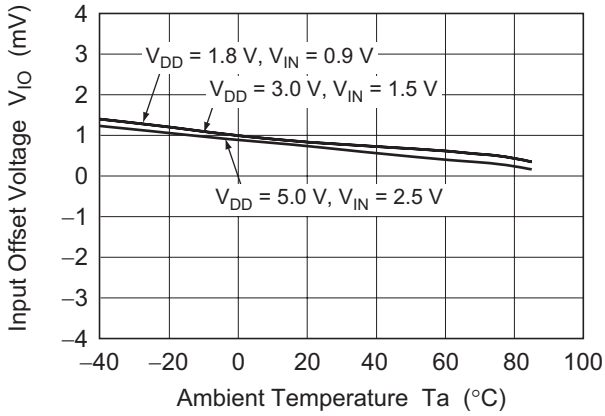



Figure 1-11. HA1630Q01
Common Mode Input Voltage vs.
Ambient Temperature

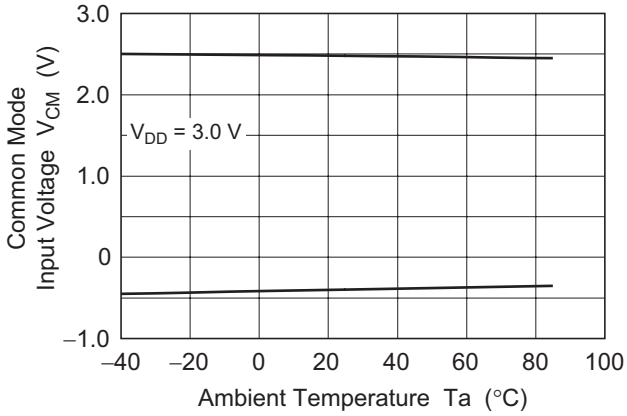


Figure 1-12. HA1630Q01
Power Supply Rejection Ratio vs. Frequency

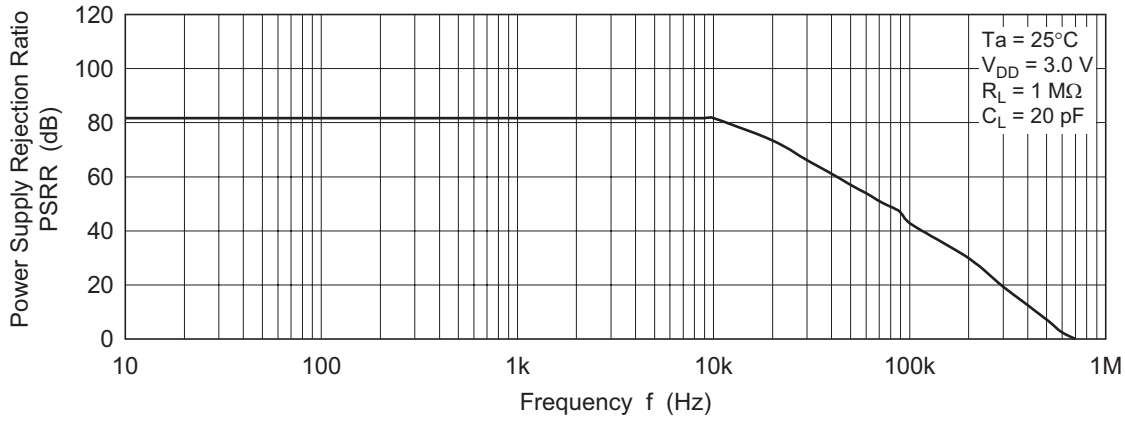



Figure 1-13. HA1630Q01
Common Mode Rejection Ratio vs. Frequency

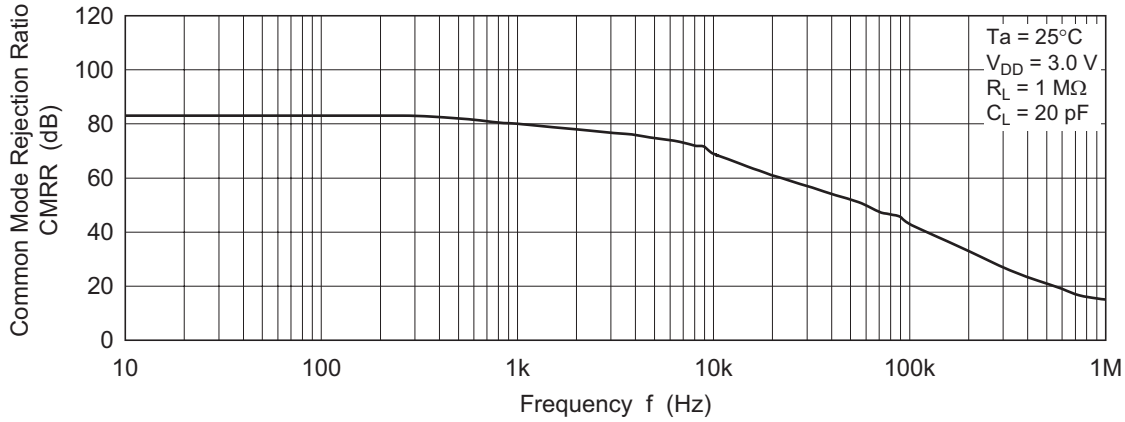



Figure 1-14. HA1630Q01
Open Loop Voltage Gain and Phase Angle vs. Frequency

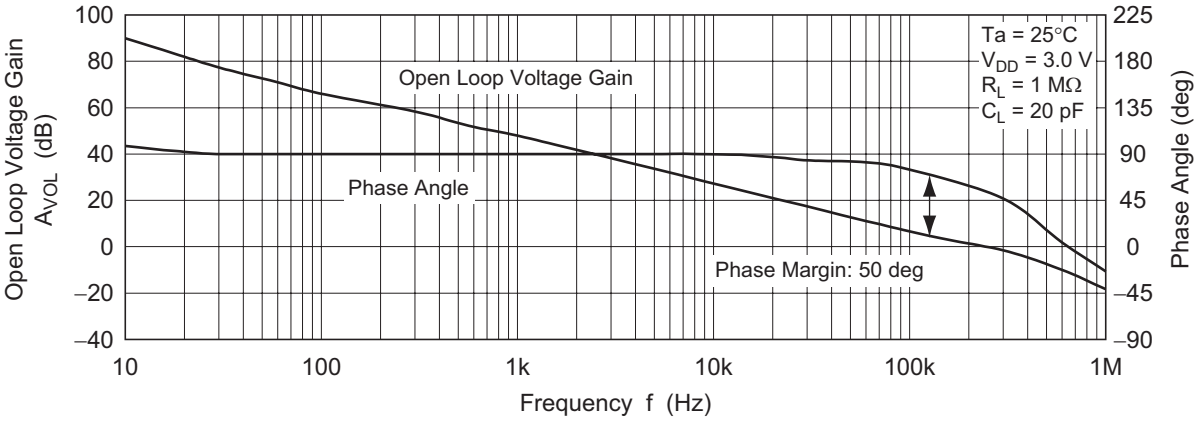


Figure 1-15. HA1630Q01
Input Bias Current vs. Ambient Temperature

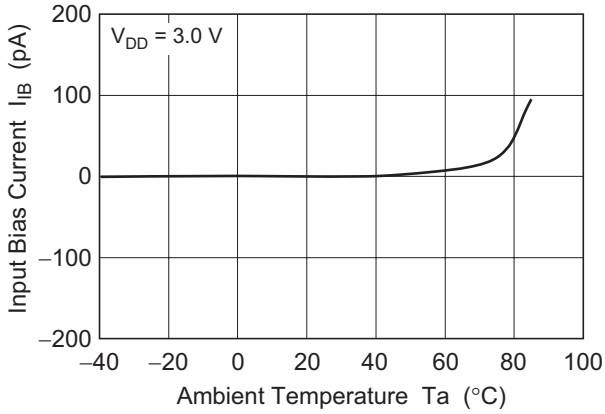



Figure 1-16. HA1630Q01
Input Bias Current vs. Input Voltage

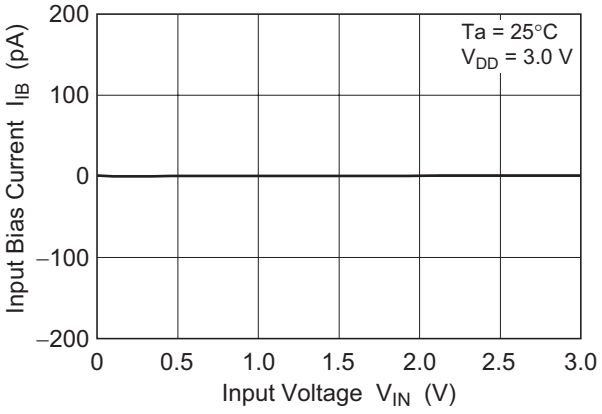



Figure 1-17. HA1630Q01
Slew Rate (rising) vs. Ambient Temperature

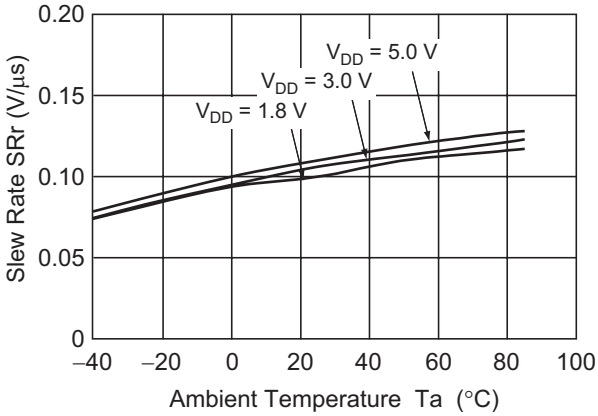



Figure 1-18. HA1630Q01
Slew Rate (falling) vs. Ambient Temperature

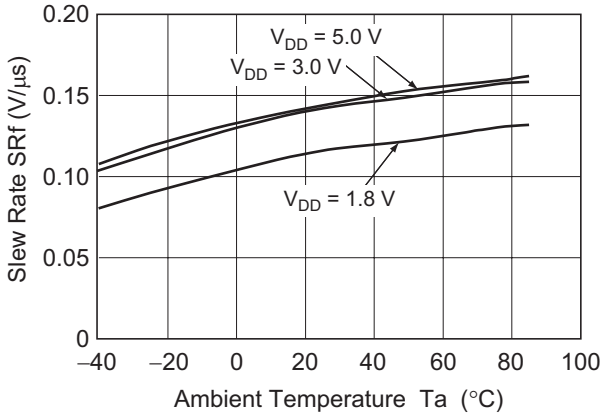



Figure 1-19. HA1630Q01
Large Signal Transient Response

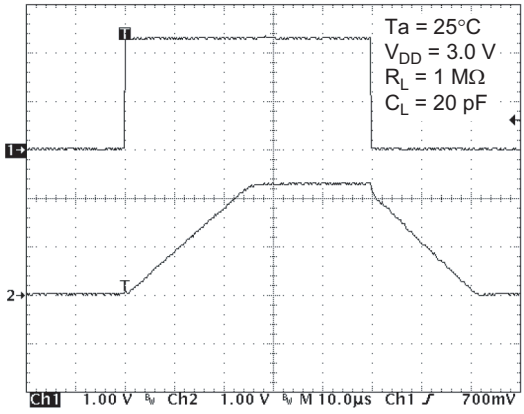



Figure 1-20. HA1630Q01
Small Signal Transient Response

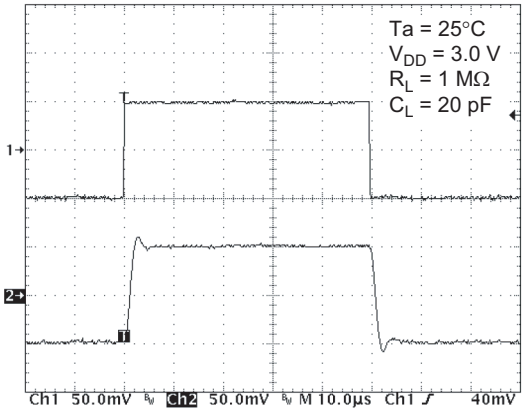


Figure 1-21. HA1630Q01
Voltage Output p-p vs. Frequency

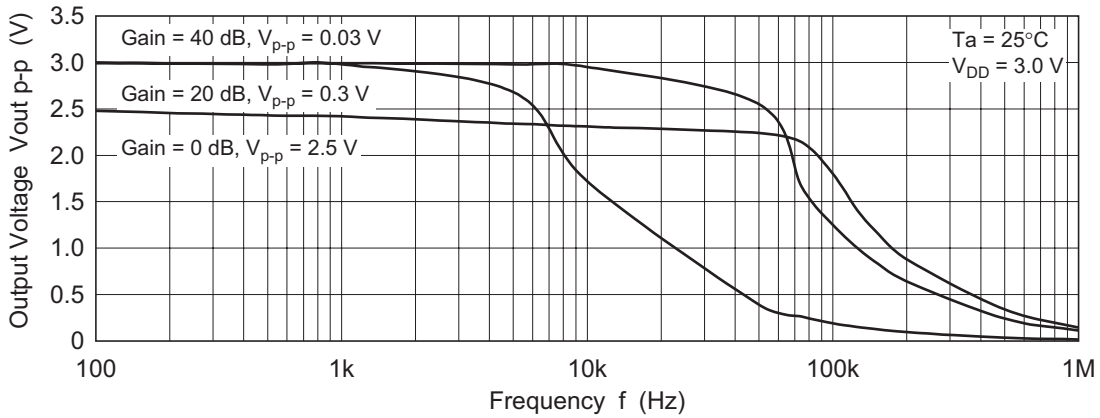
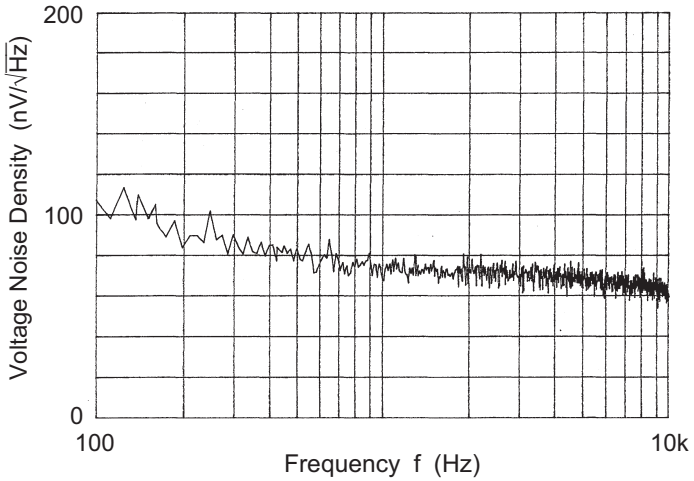



Figure 1-22. HA1630Q01
Voltage Noise Density vs. Frequency



## Main Characteristics (HA1630Q02)

Figure 2-1. HA1630Q02
Supply Current vs. Supply Voltage

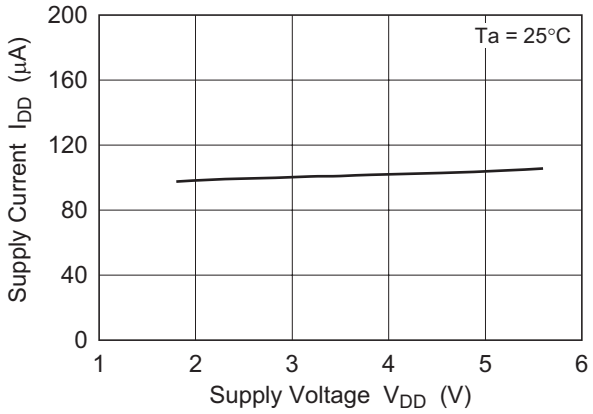



Figure 2-2. HA1630Q02
Supply Current vs. Ambient Temperature

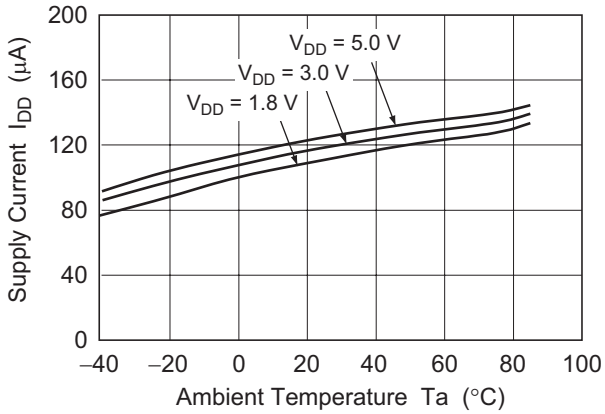



Figure 2-3. HA1630Q02
Output High Voltage vs. Output Source Current

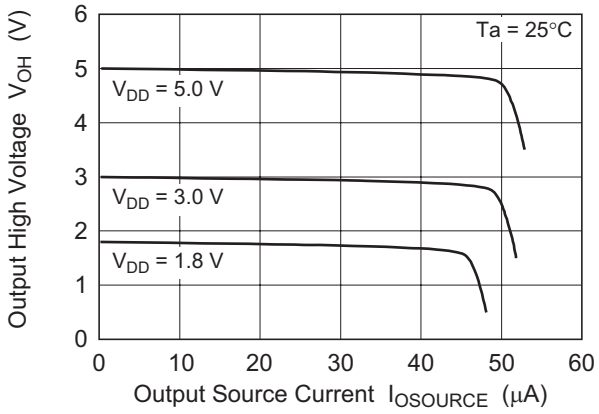



Figure 2-4. HA1630Q02
Output High Voltage vs. Supply Voltage

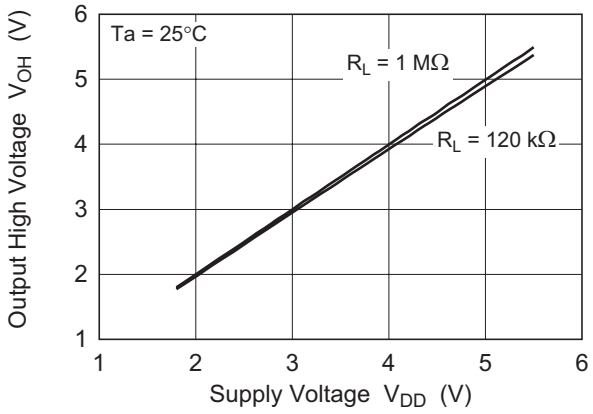



Figure 2-5. HA1630Q02
Output Source Current vs. Ambient Temperature

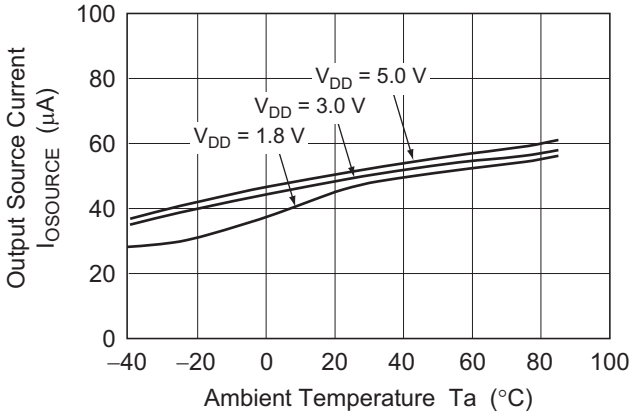


Figure 2-6. HA1630Q02
Output Low Voltage vs. Output Sink Current

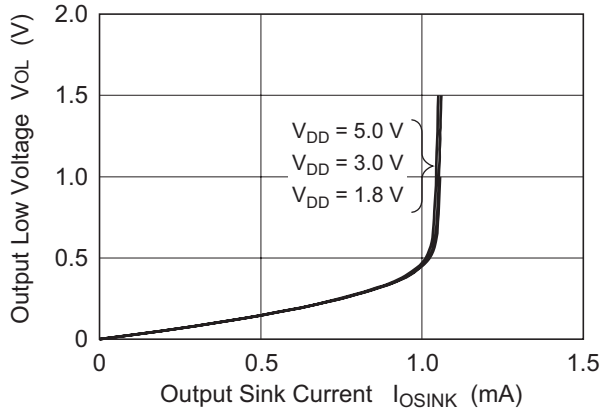



Figure 2-7. HA1630Q02
Output Sink Current vs. Ambient Temperature

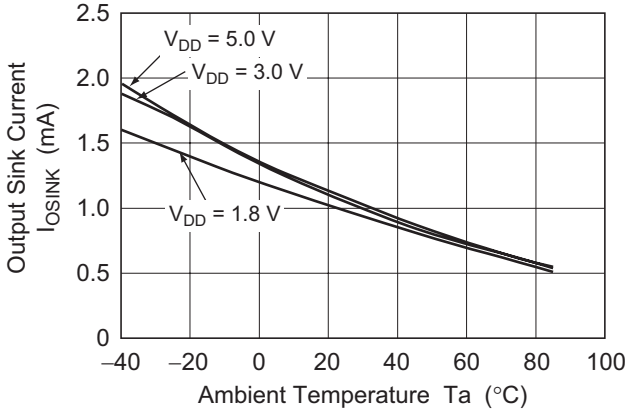



Figure 2-8. HA1630Q02
Input Offset Voltage Distribution

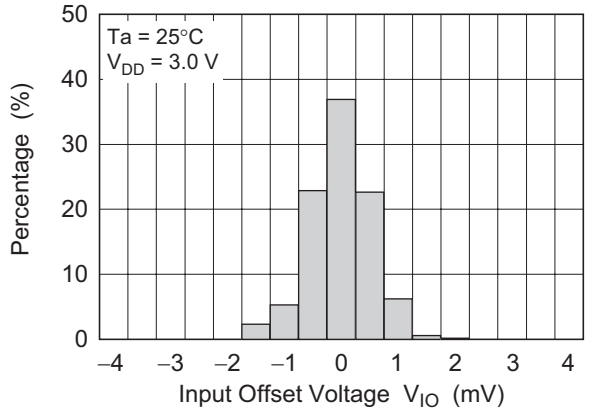



Figure 2-9. HA1630Q02
Input Offset Voltage vs. Supply Voltage

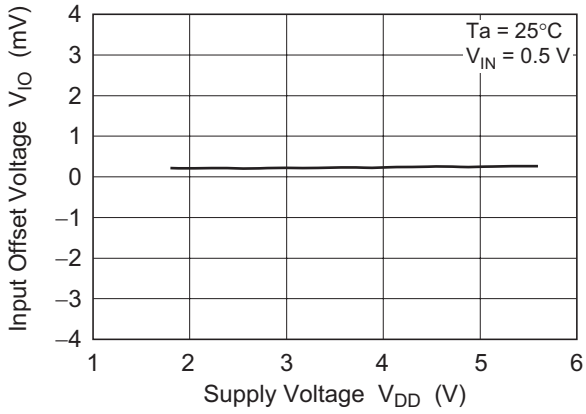



Figure 2-10. HA1630Q02
Input Offset Voltage vs. Ambient Temperature

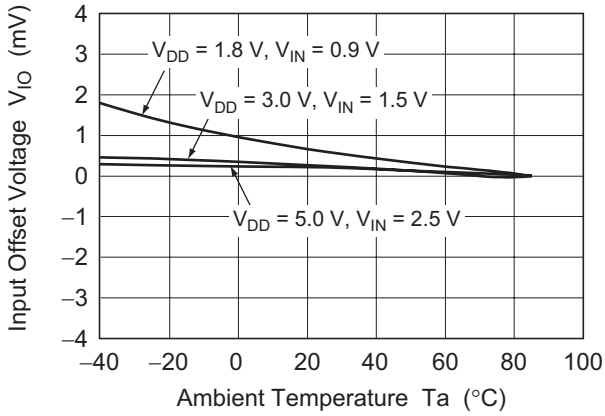



Figure 2-11. HA1630Q02
Common Mode Input Voltage vs.
Ambient Temperature

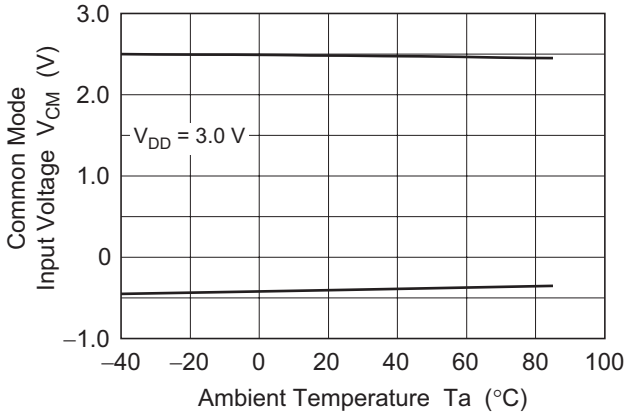


Figure 2-12. HA1630Q02
Power Supply Rejection Ratio vs. Frequency

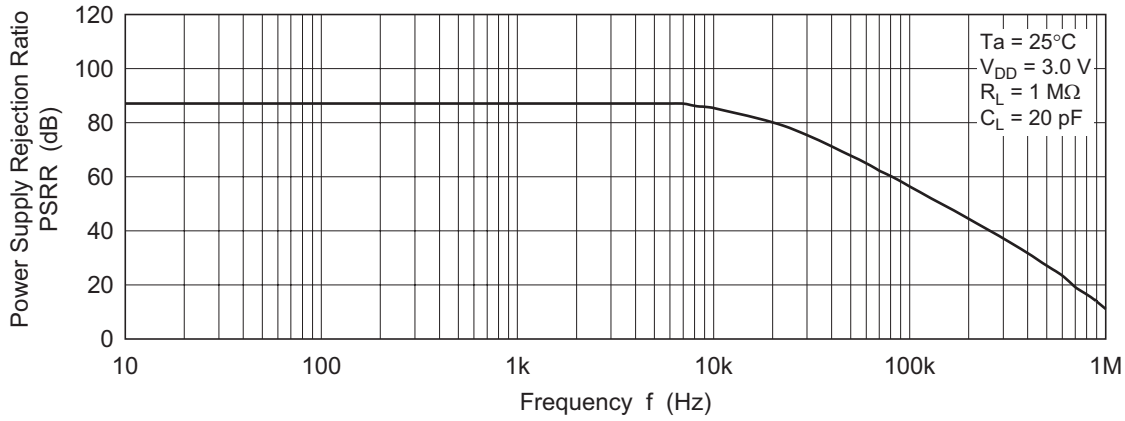



Figure 2-13. HA1630Q02
Common Mode Rejection Ratio vs. Frequency

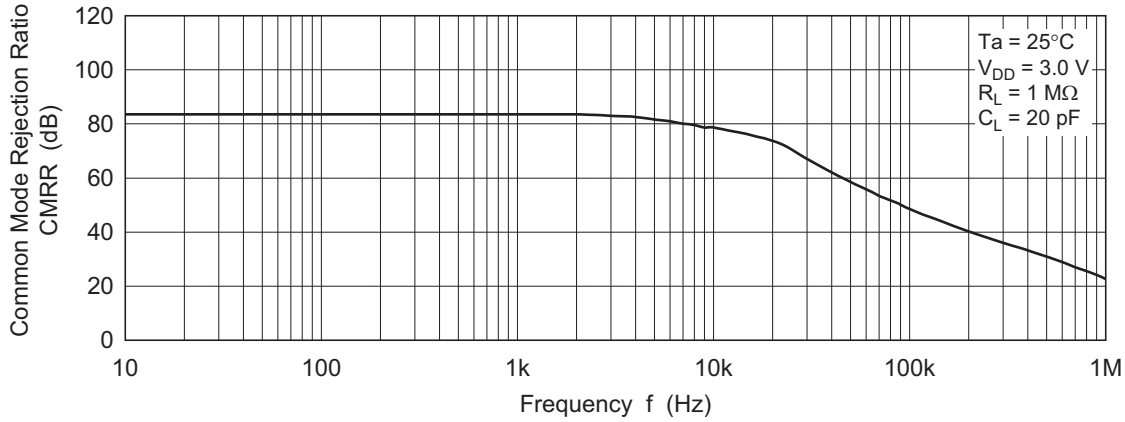



Figure 2-14. HA1630Q02
Open Loop Voltage Gain and Phase Angle vs. Frequency

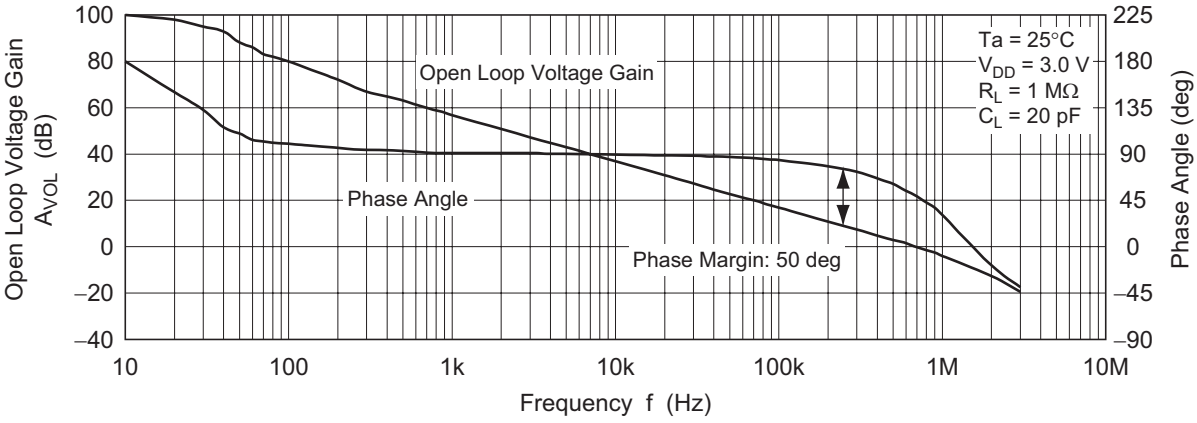


Figure 2-15. HA1630Q02
Input Bias Current vs. Ambient Temperature

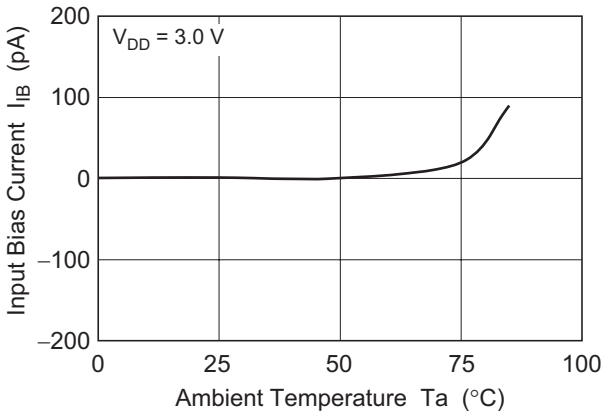



Figure 2-16. HA1630Q02
Input Bias Current vs. Input Voltage

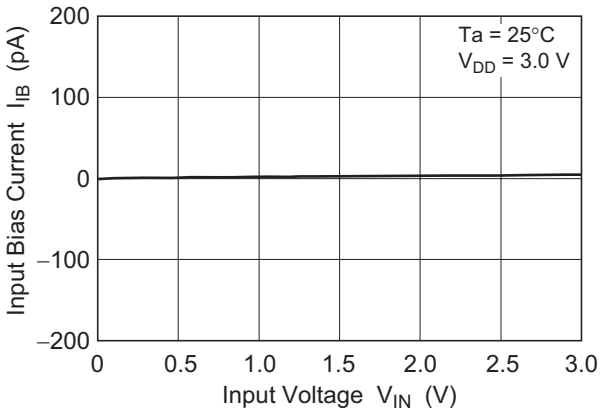



Figure 2-17. HA1630Q02
Slew Rate (rising) vs. Ambient Temperature

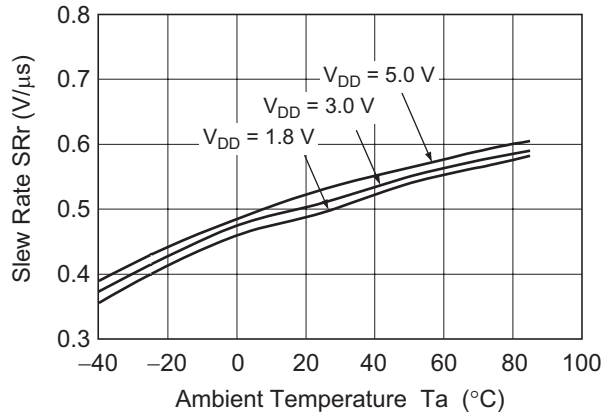



Figure 2-18. HA1630Q02
Slew Rate (falling) vs. Ambient Temperature

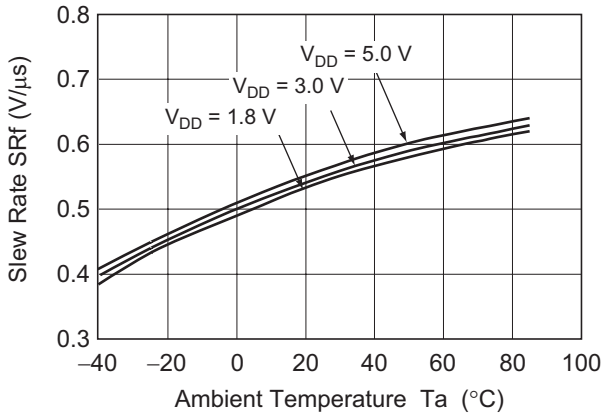



Figure 2-19. HA1630Q02
Large Signal Transient Response

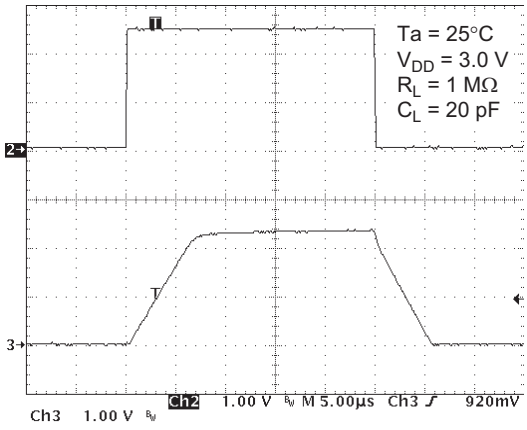



Figure 2-20. HA1630Q02
Small Signal Transient Response

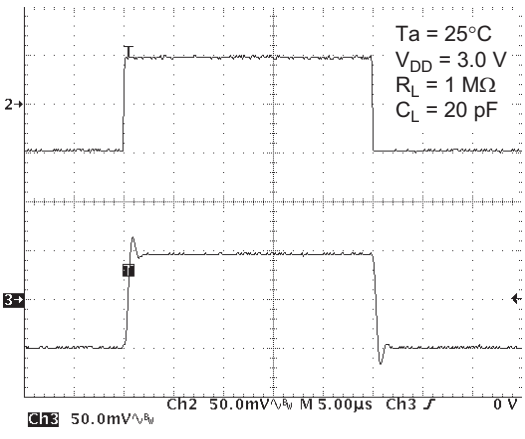


Figure 2-21. HA1630Q02
Total Harmonic Distortion + Noise vs.
Output Voltage p-p

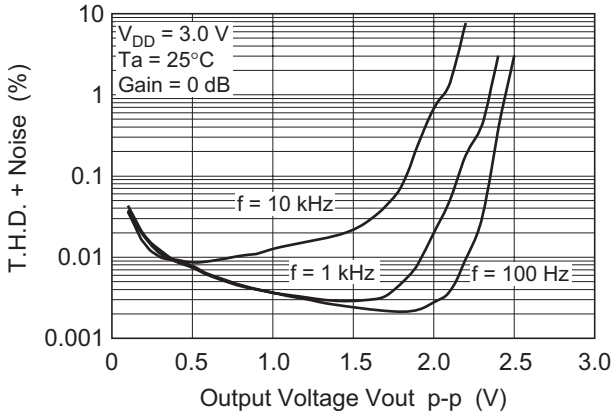



Figure 2-22. HA1630Q02
Total Harmonic Distortion + Noise vs.
Output Voltage p-p

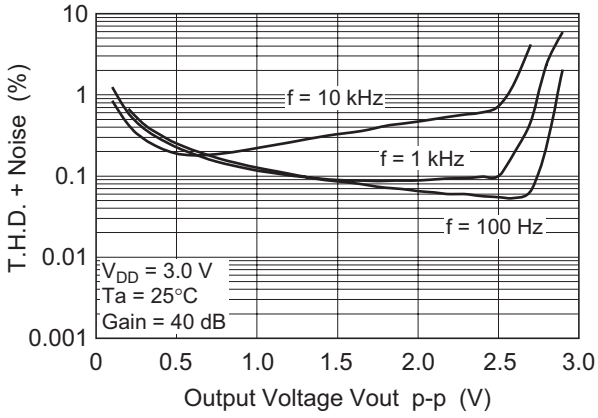



Figure 2-23. HA1630Q02
Voltage Output p-p vs. Frequency

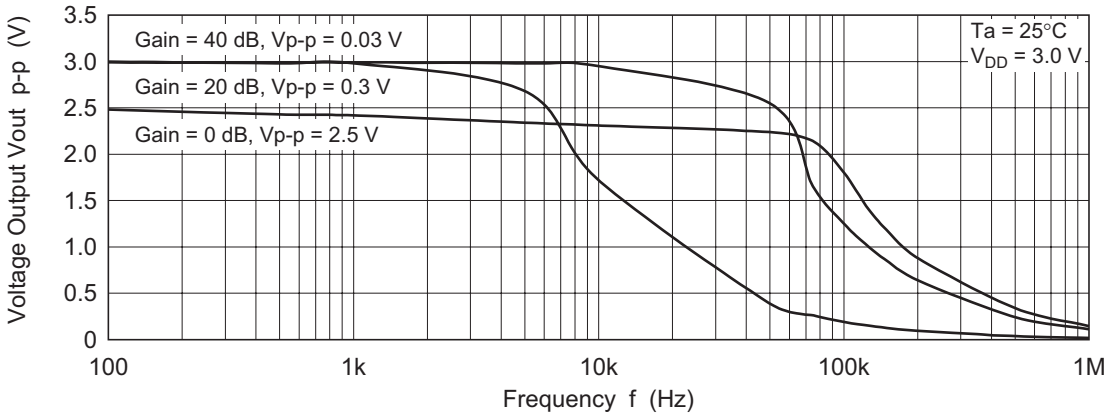
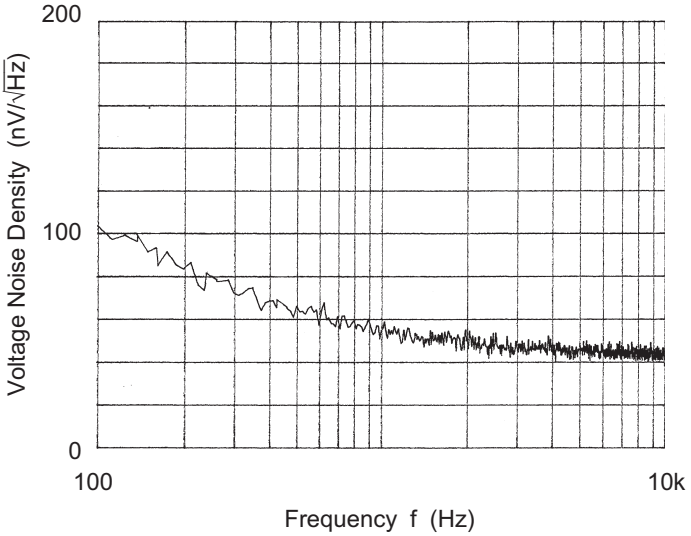



Figure 2-24. HA1630Q02
Voltage Noise Density vs. Frequency



## Main Characteristics (HA1630Q03)

Figure 3-1. HA1630Q03
Supply Current vs. Supply Voltage

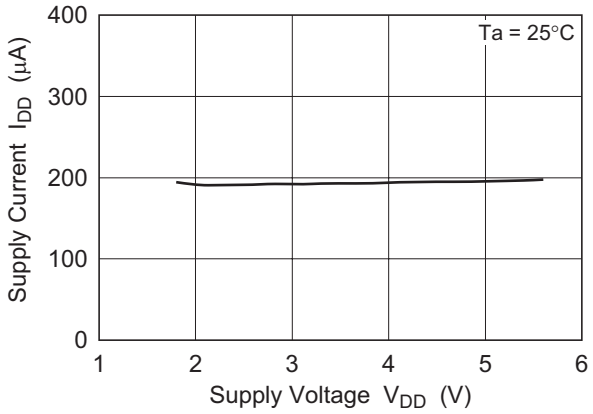



Figure 3-2. HA1630Q03
Supply Current vs. Ambient Temperature

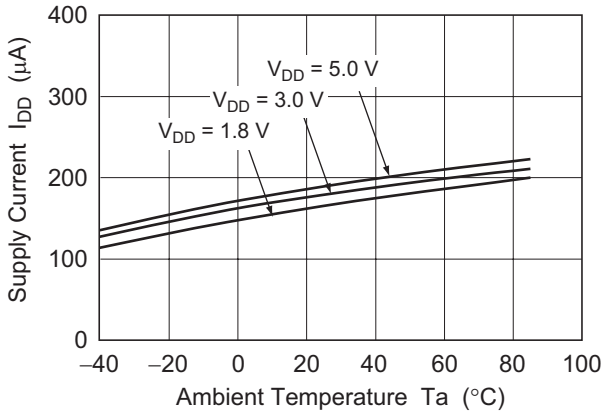



Figure 3-3. HA1630Q03
Output High Voltage vs. Output Source Current

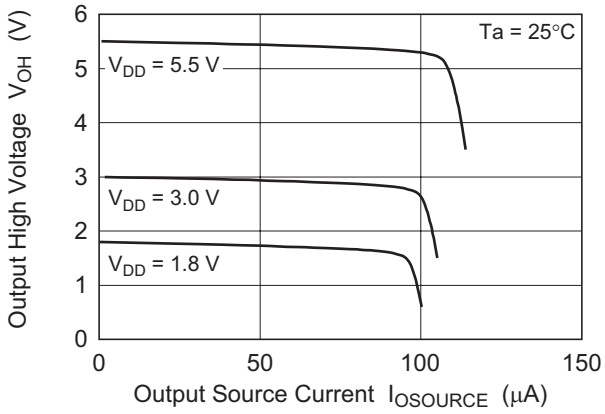



Figure 3-4. HA1630Q03
Output High Voltage vs. Supply Voltage

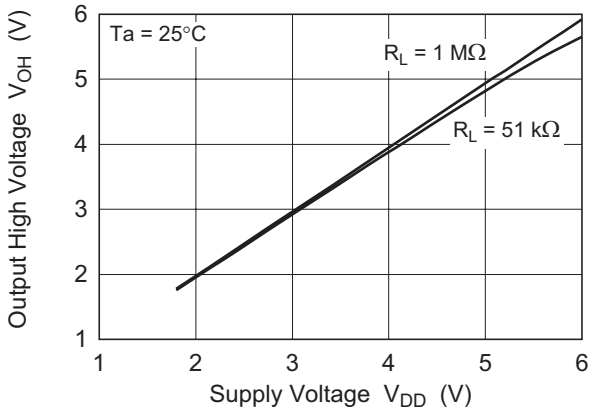



Figure 3-5. HA1630Q03
Output Source Current vs. Ambient Temperature

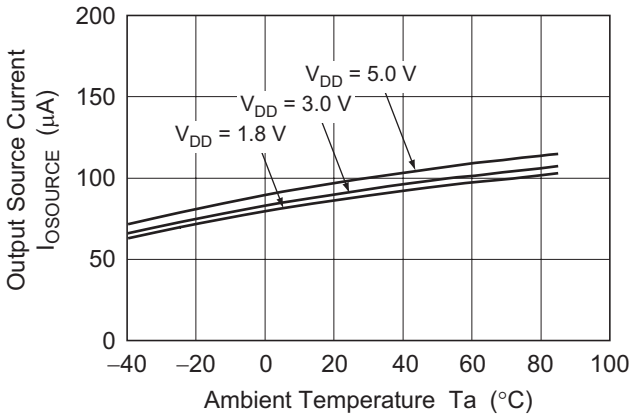


Figure 3-6. HA1630Q03
Output Low Voltage vs. Output Sink Current

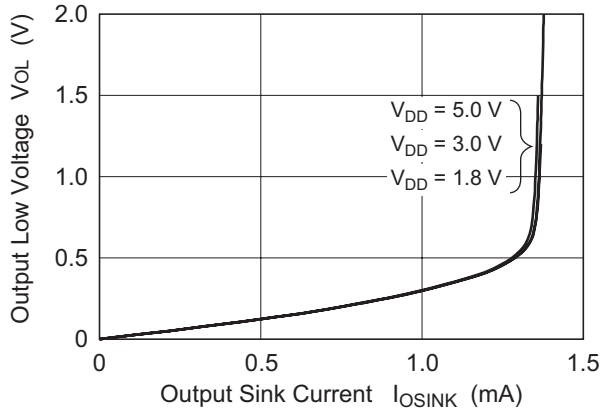



Figure 3-7. HA1630Q03
Output Sink Current vs. Ambient Temperature

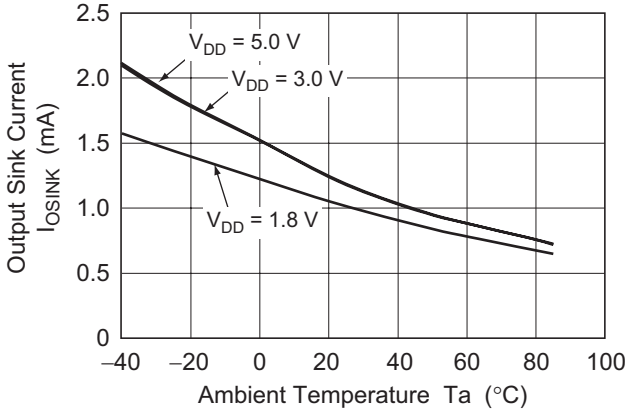



Figure 3-8. HA1630Q03
Input Offset Voltage Distribution

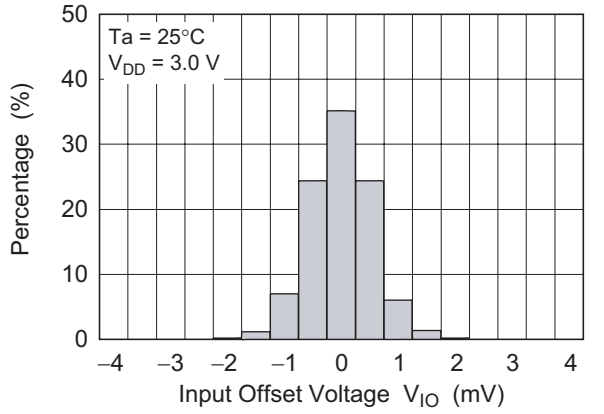



Figure 3-9. HA1630Q03
Input Offset Voltage vs. Supply Voltage

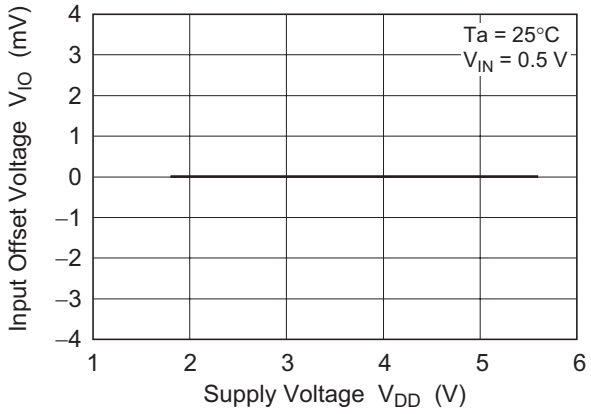



Figure 3-10. HA1630Q03
Input Offset Voltage vs. Ambient Temperature

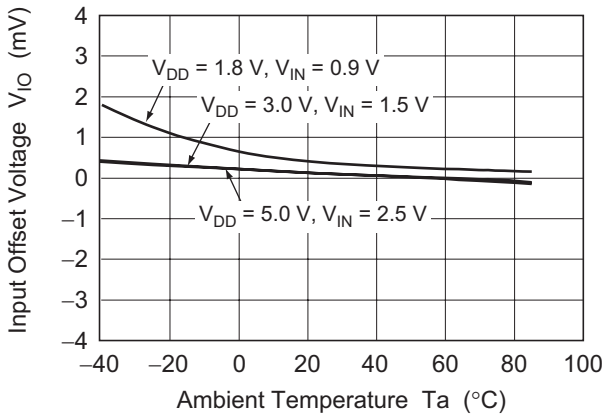



Figure 3-11. HA1630Q03
Common Mode Input Voltage vs.
Ambient Temperature

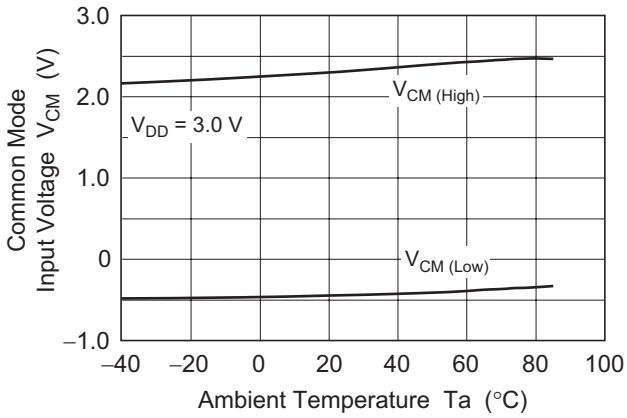


Figure 3-12. HA1630Q03
Power Supply Rejection Ratio vs. Frequency

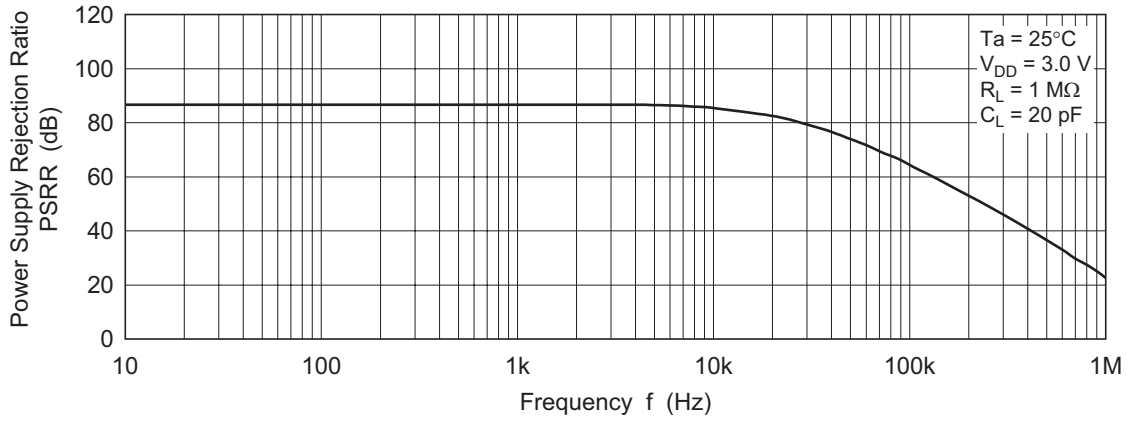



Figure 3-13. HA1630Q03
Common Mode Rejection Ratio vs. Frequency

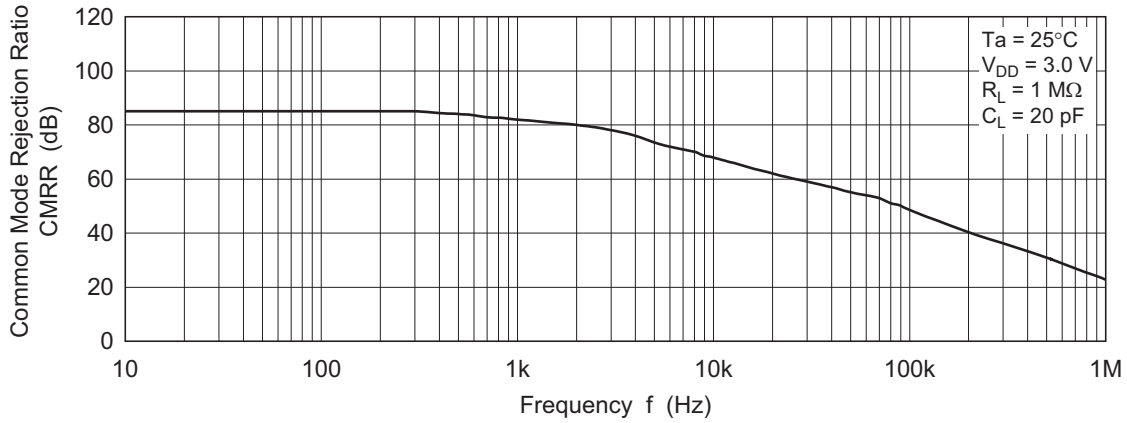



Figure 3-14. HA1630Q03
Open Loop Voltage Gain and Phase Angle vs. Frequency

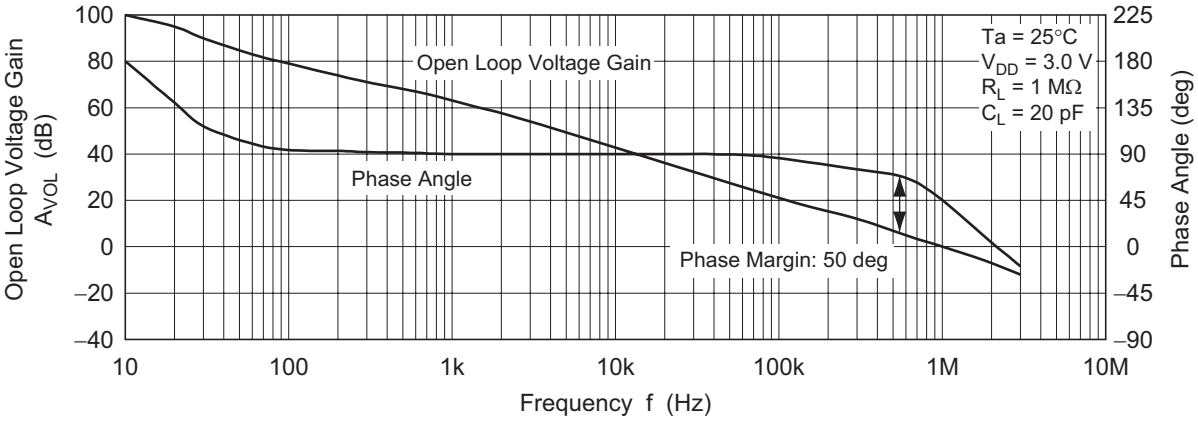


Figure 3-15. HA1630Q03
Input Bias Current vs. Ambient Temperature

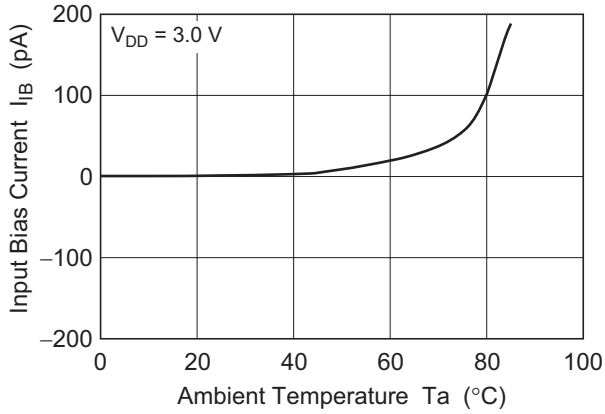



Figure 3-16. HA1630Q03
Input Bias Current vs. Input Voltage

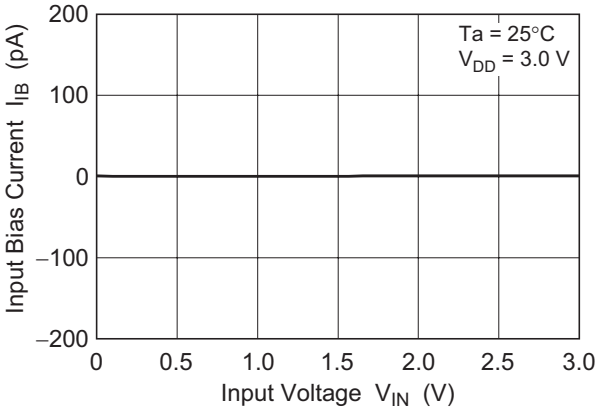



Figure 3-17. HA1630Q03
Slew Rate (rising) vs. Ambient Temperature

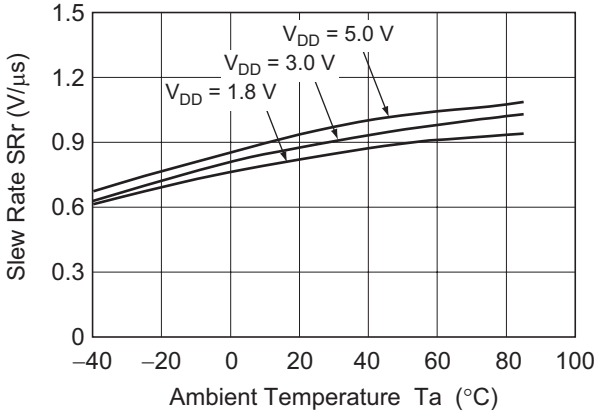



Figure 3-18. HA1630Q03
Slew Rate (falling) vs. Ambient Temperature

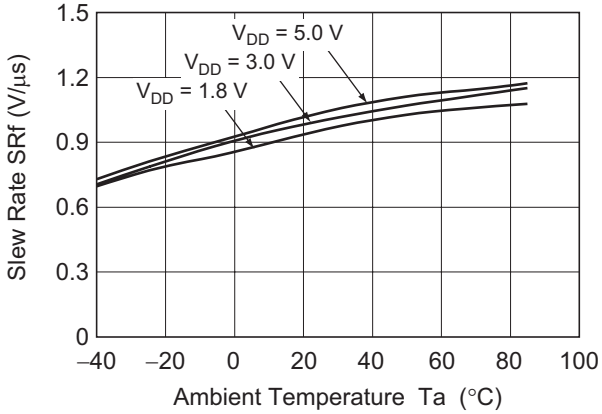



Figure 3-19. HA1630Q03
Large Signal Transient Response

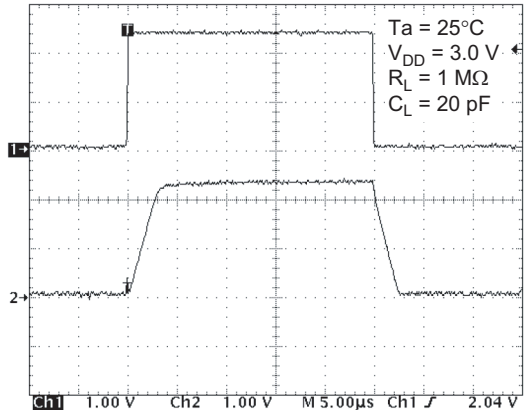



Figure 3-20. HA1630Q03
Small Signal Transient Response

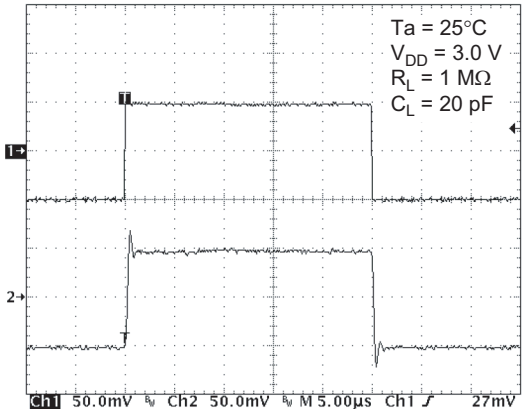


Figure 3-21. HA1630Q03
Total Harmonic Distortion + Noise vs.
Output Voltage p-p

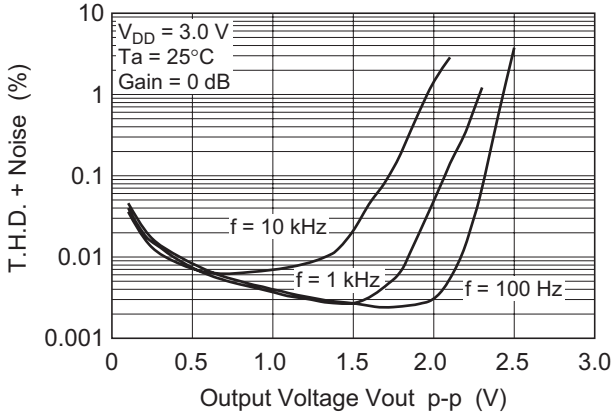



Figure 3-22. HA1630Q03
Total Harmonic Distortion + Noise vs.
Output Voltage p-p

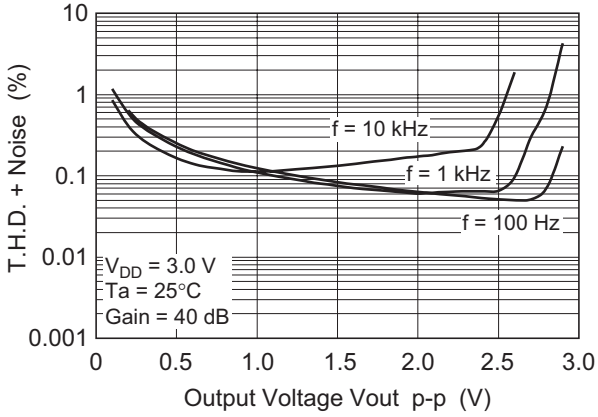



Figure 3-23. HA1630Q03
Voltage Output p-p vs. Frequency

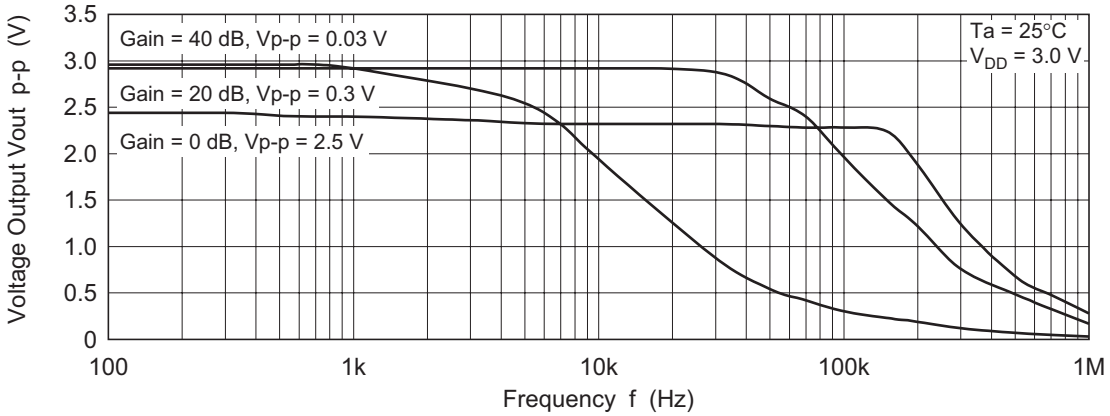
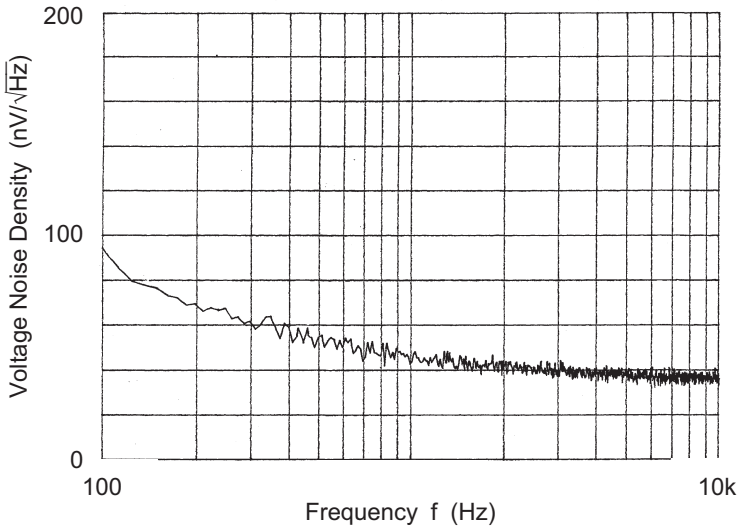
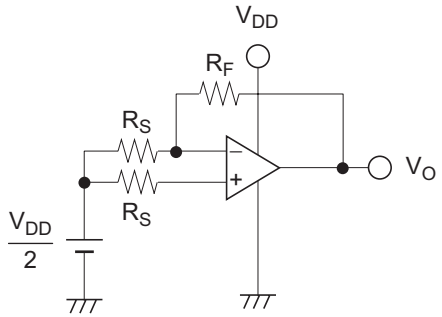



Figure 3-24. HA1630Q03
Voltage Noise Density vs. Frequency



## Test Circuits

1. Power Supply Rejection Ratio, PSRP & Voltage Offset, $V_{IO}$




$V_{IO}$

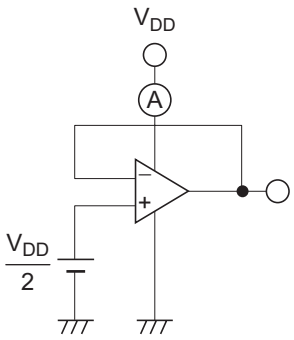
$$V_{IO} = \left(V_O - \frac{V_{DD}}{2}\right) \times \frac{R_S}{R_S + R_F}$$

PSRR

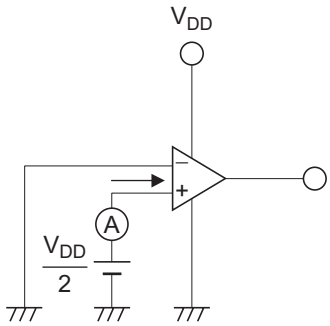
$$PSRR = -20\log\left(\left|\frac{V_{O1} - V_{O2}}{V_{DD1} - V_{DD2}}\right| \times \frac{R_S}{R_S + R_F}\right)$$

Measure $V_O$ corresponding to $V_{DD1}$ = 1.8 V and $V_{DD2}$ = 5.5 V

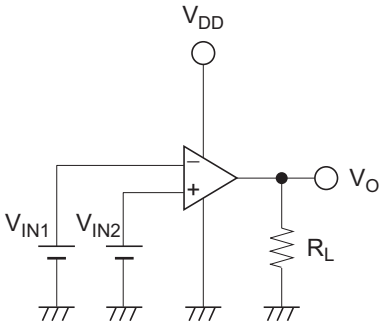
2. Supply Current, $I_{DD}$




3. Input Bias Current, $I_{IB}$



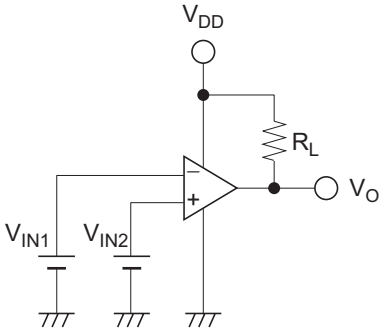

4. Output High Voltage, $V_{OH}$




$V_{OH}$

$R_L$ = 1 MΩ
$V_{IN1} = V_{DD} / 2 - 0.05$ V
$V_{IN2} = V_{DD} / 2 + 0.05$ V

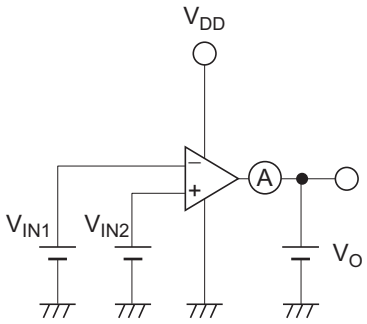
5. Output Low Voltage, $V_{OL}$




$V_{OL}$

$R_L$ = 1 MΩ
$V_{IN1} = V_{DD} / 2 + 0.05$ V
$V_{IN2} = V_{DD} / 2 - 0.05$ V

6. Output Source Current, $I_{OSOURCE}$ & Output Sink Current, $I_{OSINK}$



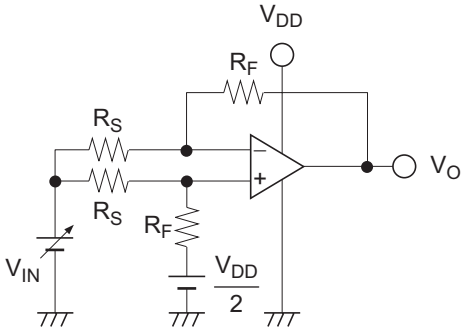

$I_{OSOURCE}$

$V_O = V_{DD} - 0.5$ V
$V_{IN1} = V_{DD} / 2 - 0.05$ V
$V_{IN2} = V_{DD} / 2 + 0.05$ V

$I_{OSINK}$

$V_O = + 0.5$ V
$V_{IN1} = V_{DD} / 2 + 0.05$ V
$V_{IN2} = V_{DD} / 2 - 0.05$ V

7. Common Mode Input Voltage, $V_{CM}$ & Common Mode Rejection Ratio, CMRR

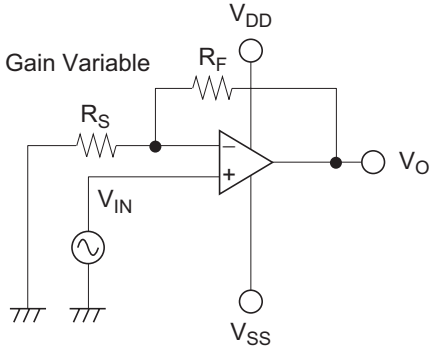


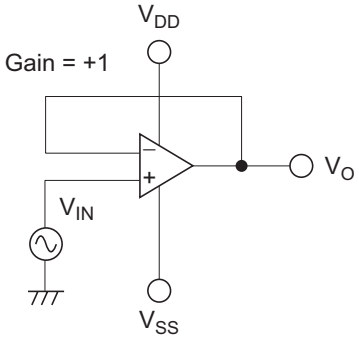

CMRR

$$CMRR = -20\log\left(\left|\frac{V_{O1} - V_{O2}}{V_{IN1} - V_{IN2}}\right| \times \frac{R_S}{R_S + R_F}\right)$$

Measure $V_O$ corresponding to $V_{IN1} = 0$ V and $V_{IN2} = 2.1$ V

8. Total Harmonic Distortion, THD

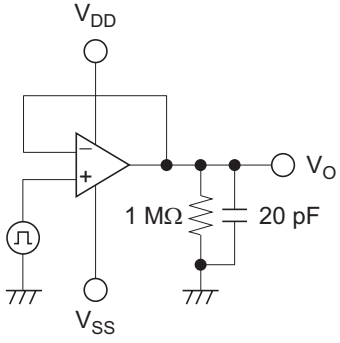


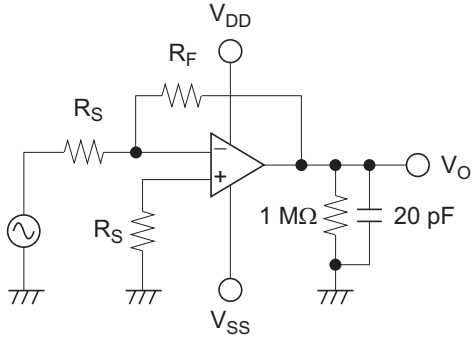

THD

Gain Variable
$1 + R_F / R_S = 100$
freq = 100 Hz, 1 kHz, 10 kHz

9. Slew Rate, SR

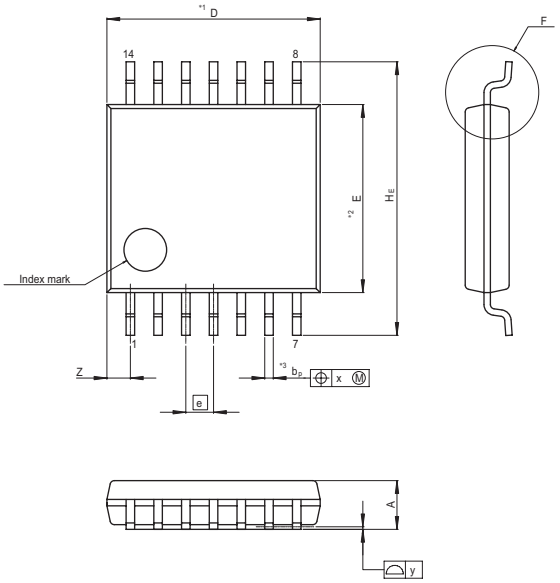


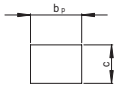

10. Gain, $A_V$ & Phase, GBW



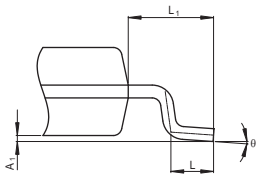
# Package Dimensions

| JEITA Package Code | RENESAS Code | Previous Code | MASS[Typ.] |
|---|---|---|---|
| P-TSSOP14-4.4x5-0.65 | PTSP0014JA-B | TTP-14DV | 0.05g |




Terminal cross section
( Ni/Pd/Au plating )




Detail F

NOTE)
1. DIMENSIONS"*1 (Nom)"AND"*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION"*3"DOES NOT INCLUDE TRIM OFFSET.

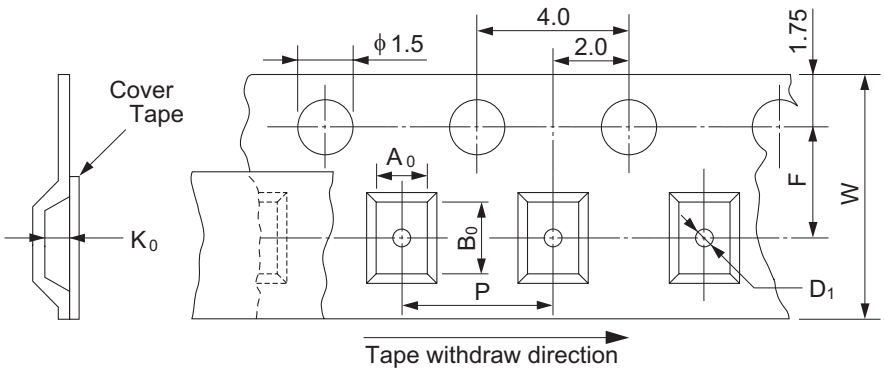
| Reference Symbol | Dimension in Millimeters | | |
|---|---|---|---|
| | Min | Nom | Max |
| D | — | 5.00 | 5.30 |
| E | — | 4.40 | — |
| $A_2$ | — | — | — |
| $A_1$ | 0.03 | 0.07 | 0.10 |
| A | — | — | 1.10 |
| $b_p$ | 0.15 | 0.20 | 0.25 |
| $b_1$ | — | — | — |
| c | 0.10 | 0.15 | 0.20 |
| $c_1$ | — | — | — |
| θ | 0° | — | 8° |
| $H_E$ | 6.20 | 6.40 | 6.60 |
| e | — | 0.65 | — |
| x | — | — | 0.13 |
| y | — | — | 0.10 |
| Z | — | — | 0.83 |
| L | 0.4 | 0.5 | 0.6 |
| $L_1$ | — | 1.0 | — |

## Taping & Reel Specification

[Taping]

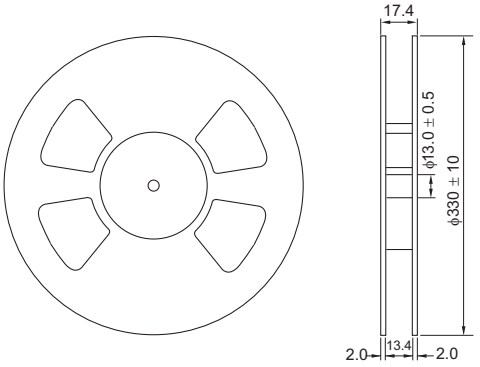
| Package Code | W | P | Ao | Bo | Ko | E | F | D1 | Maximum Storage No. |
|---|---|---|---|---|---|---|---|---|---|
| TSSOP-14 | 12 | 8 | 6.5 | 5.1 | 1.5 | — | 5.5 | 1.6 | 2,000 pcs/reel |
| | | | | | | | | | |

Unit: mm




[Reel]

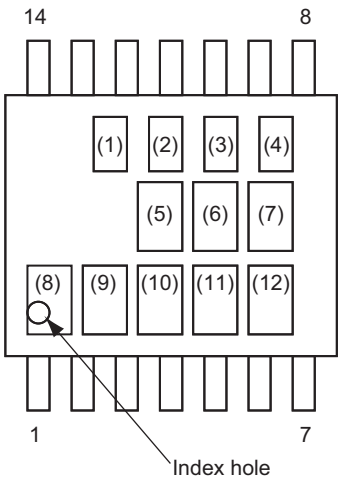
| Package | Tape width | W1 | W2 |
|---|---|---|---|
| TSSOP-14 | 12 | 17.4 | 13.4 |
| | | | |




[Ordering Information]

| Ordering Unit |
|---|
| 2,000 pcs |

## Mark Indication




| | | | |
|---|---|---|---|
| (1) to (4) | Week code | | |
| (5),(8) to (10) | Space | | |
| (6), (7)<br>(11), (12) | Product Name | 0Q01 | HA1630Q01 |
| | | 0Q02 | HA1630Q02 |
| | | 0Q03 | HA1630Q03 |

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Colophon .6.0

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