EVALUATION OF LCC20 PACKAGES ON TEXAS INSTRUMENTS LM158A OPERATIONAL AMPLIFIERS UNDER EXTREME TEMPERATURE AND WIDE THERMAL CYCLING

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Introduction

The Texas Instruments LM158AFK devices consist of two independent, high-gain, frequency-compensated operational amplifiers designed to operate from a single supply in the range of 3 to 30V. Their low supply-current drain is independent of the magnitude of the supply voltage [1]. These LCC20, Leadless Ceramic Chip Carrier, 20-pin packaged devices are specified for operation over the full military temperature range of –55 °C to +125 °C, and are ideal for use in transducer circuits and DC amplification stages.

Test Setup

Three circuit boards, each populated with an LM158AFK chip, metal film resistors, and COG ceramic bypass capacitors, were constructed for evaluation in the temperature range of +90 °C to -185 °C. The circuits were designed in a non-inverting unity-gain amplifier configuration. The LM158AFK device, which had an LCC20 package, was mounted on the printed circuit board by soldering wire connections between its pins and the external circuit components using a gauge 32 size wire. A photograph of the chip along with some of the manufacturer's specified properties are shown in Table I [1]. These military-grade devices were evaluated for packaging durability and electrical performance. The electrical properties, which included signal gain and phase shift, were measured as a function of temperature from +90 °C to -185 °C in the frequency range of 1 kHz to 10 MHz. At each test temperature, the devices were allowed to soak for 15 minutes before any measurements were made. A LeCroy LT374 digital oscilloscope was used to capture the waveforms of the input and output signals of the amplifier circuit.

Table I. The LCC20 packaged LM158AFK chip with selected properties.

LM158AFK IC		
Parameter	**Symbol**	**Value**
Input Bias Current	I_B	15 nA
Input Voltage	V_I	-0.3 – 32 V
High Level Output Voltage	V_{OH}	28 V
Low Level Output Voltage	V_{OL}	5 V
Common Mode Rejection Ratio	CMRR	80 dB
Output Current	I_O	20 mA

Limited thermal cycling was also performed on the LM158AFK devices. These tests consisted of subjecting the three devices to 10 thermal cycles in the temperature range between +90 °C and -125 °C. A temperature ramp rate of 10 °C/min was used throughout this cycling activity. Physical inspection, electrical characterization, and Fein focus x-ray imaging of the packages were performed before and after completion of the thermal cycling.

Results and Discussion

As was mentioned earlier, three devices of LM158AFK operational amplifiers were investigated in this work. The data obtained on all three devices were very similar; therefore, the results of only one device are presented in this report.

Packaging and Material

Microscopic examination and Fein focus x-ray scanning were performed on the three devices before and after the thermal cycling run. All of these tests have revealed no evidence of layer delamination, surface and internal cracking, connection breakage, or external solder joint fatigue for any of the three devices. It can be concluded, therefore, that the exposure to extreme temperatures (namely +90 °C and –185 °C), and thermal cycling (10 cycles between +90 °C and -125 °C) did not produce any effect on the devices' material or their packaging integrity.

Electrical Performance

The devices were characterized in terms of their gain and phase as a function of frequency at test temperatures of +25, +90, -55, -100, -125, -150, and -185 °C. Figure 1 shows the gain of the amplifier at selected test temperatures in the frequency range of 1 kHz to 10 MHz. The roll-off frequency, which corresponds to a gain of -3 dB, occurs at about 100 kHz. It can be seen that the gain does not exhibit any significant change with variation in the temperature from +90 °C to -185 °C. Similar trend is observed in the phase shift property of the amplifier, as it seems to undergo no changes with change in temperature, as depicted in Figure 2.

The amplifier's gain as a function of frequency at test temperatures of 90, 25, -125, and –185 °C is shown in Figure 3. The depicted results represent those obtained before as well as after the thermal cycling. The results presented in this figure indicate that this applied thermal cycling has had a negligible effect on the gain behavior of the amplifier at any given test temperature and at all frequencies. Similarly, the phase shift did not undergo any changes due to thermal cycling, as shown in Figure 4.

Waveforms of the input and the output signals of the amplifier at 1 kHz frequency are depicted at various temperatures in Figure 5. These waveforms were obtained at 90, 25, -125, -150, and –185 °C before the thermal cycling, and at 25 °C after completion of the thermal cycling. It can be seen that the amplifier maintained its unity gain at all temperatures but with a very slight variation in its input and output waveforms. The distortions are believed to occur due to some loading effects at this low frequency.

As the frequency was increased, however, the amplifier waveforms retained their shape but exhibited a gradual decrease in output voltage and an increase in phase between the input and output signals. This behavior is typical of most operational amplifiers and is device-dependent for gain, bandwidth, and frequency operational specifications. The waveforms of the input and output signals of the amplifier obtained at 10, 300, and 500 kHz are depicted at various temperatures in Figures 6, 7, and 8, respectively. It is important to note that the data, which are depicted in these figures at 25 °C, for both before and after the thermal cycling, are replicated, which indicates that the operational behavior of these devices was not altered by the exposure of these packages to extreme temperatures.

Conclusion

Three devices of the Texas Instruments LM158AFK operational amplifier were evaluated for potential use at low temperature for space applications such as Mars, Galaxy Explorer, and Next Generation Space Telescope missions. These devices, which had LCC20 packages, were military grade rated for operation in the temperature range of –55 °C to +125 °C. The devices were characterized for physical integrity and packaging reliability under exposure to extreme temperatures. Electrical evaluation in terms of signal gain and phase shift was also carried out in the temperature range of +90 °C to -185 °C. Limited thermal cycling was also performed on the three devices. The results from this work indicate that these devices experienced no physical degradation with regard to wire bonds, the internal material used by these devices or their exterior packaging, and they exhibited excellent stability in their electrical performance with temperature. Thus, these devices may be capable of operation at extreme temperatures beyond their manufacturer's specification of 55 °C. Further testing and long term comprehensive characterization are needed, however, to fully establish their potential use and to determine their reliability for extreme temperature applications specified for particular space missions.

References

1. Texas Instruments Inc., LM158AFK Dual General Purpose Bipolar Operational Amplifiers.

Acknowledgments

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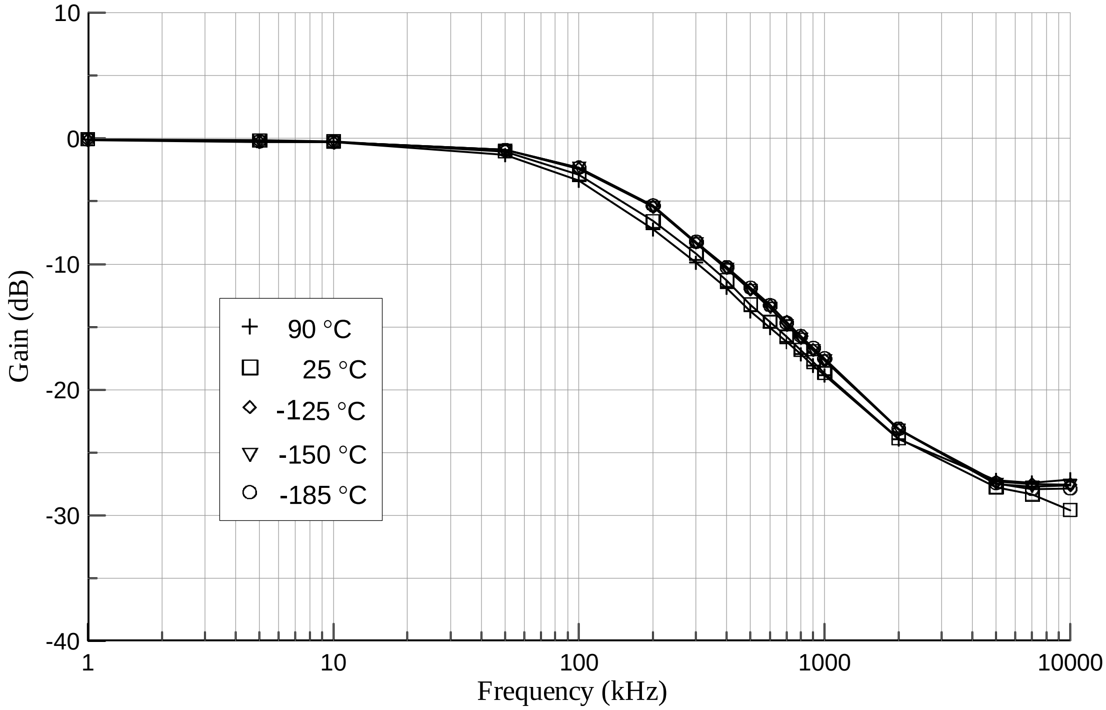

Figure 1. Gain versus frequency at various temperatures.

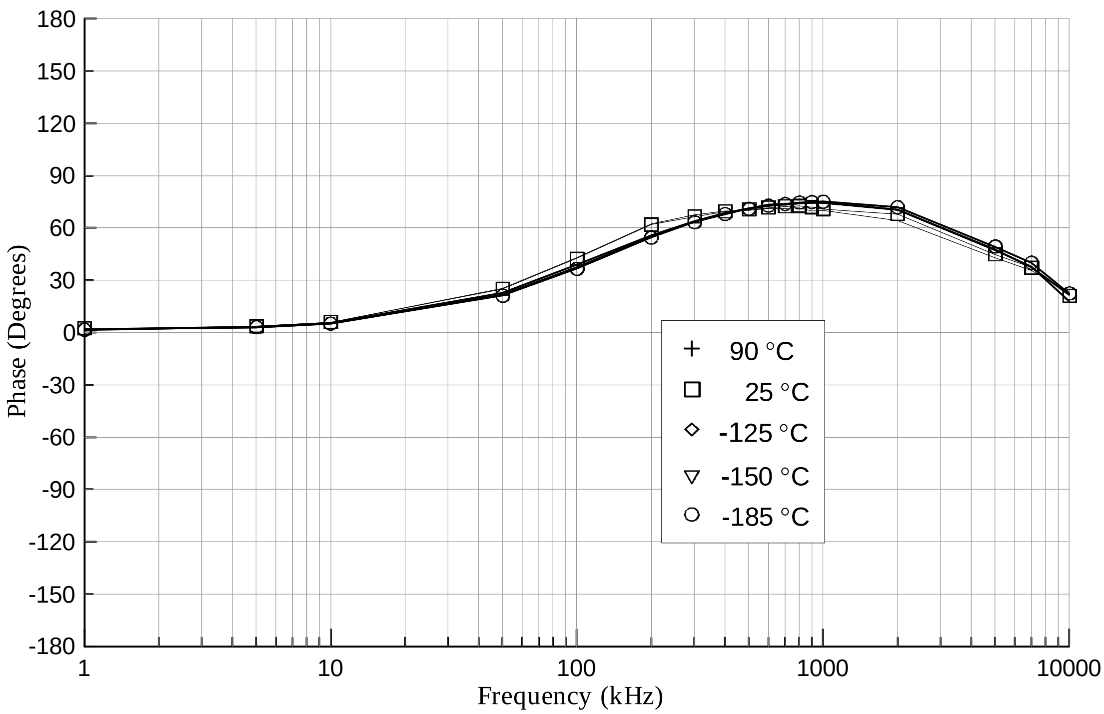

Figure 2. Phase shift versus frequency at various temperatures.

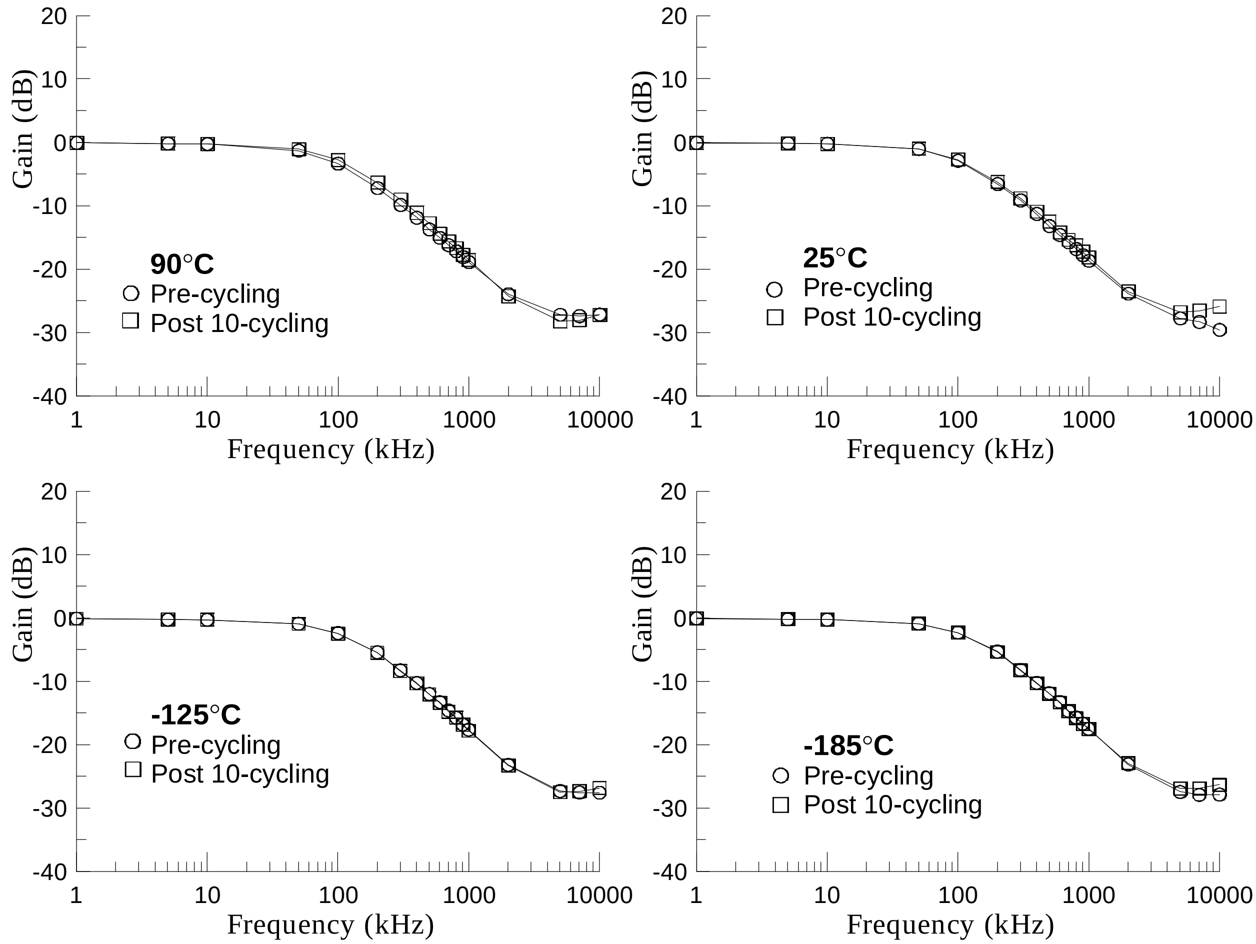

Figure 3. Pre- and post-cycling characteristics of gain versus frequency for various temperatures.

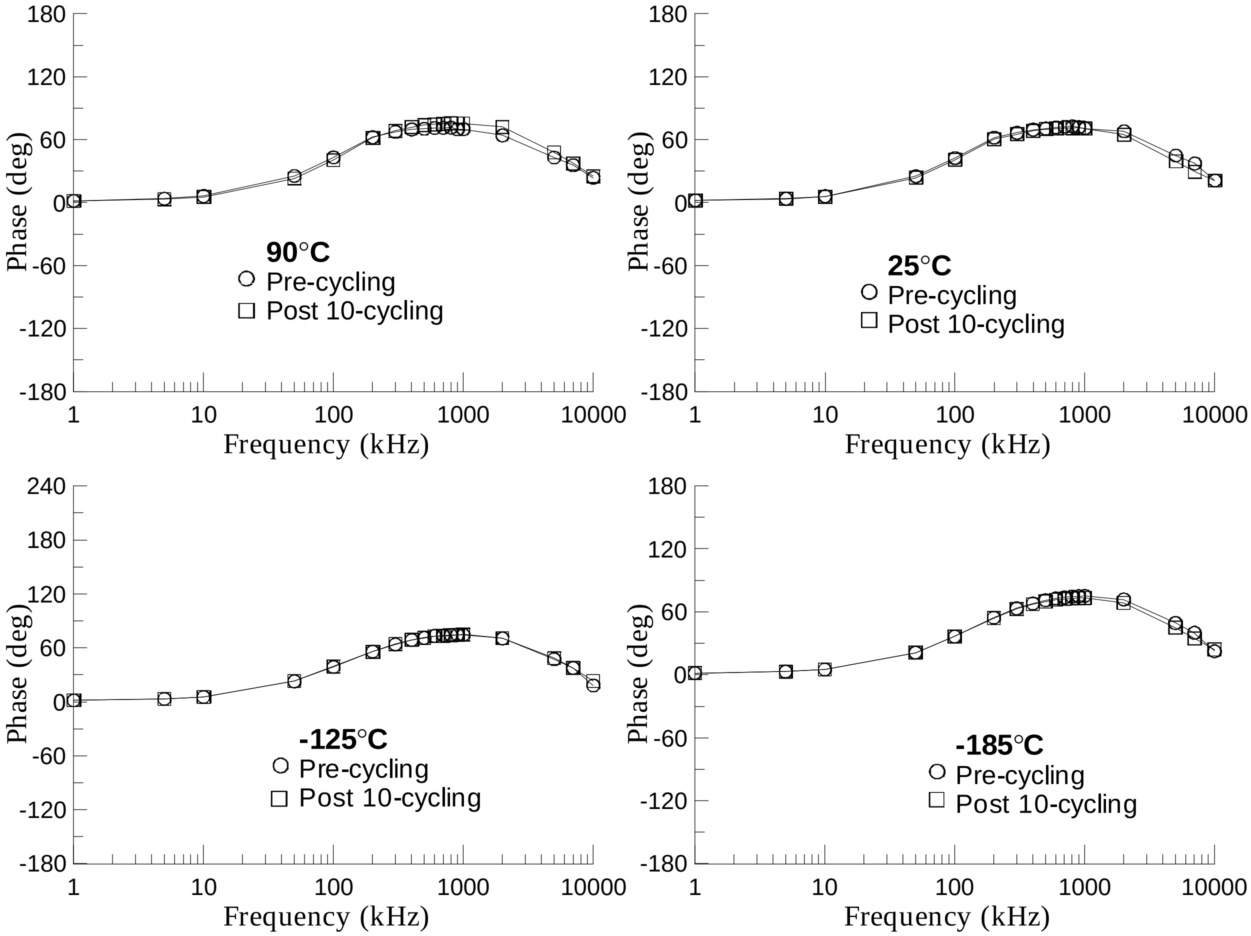

Figure 4. Pre- and post-cycling characteristics of phase versus frequency for various temperatures.

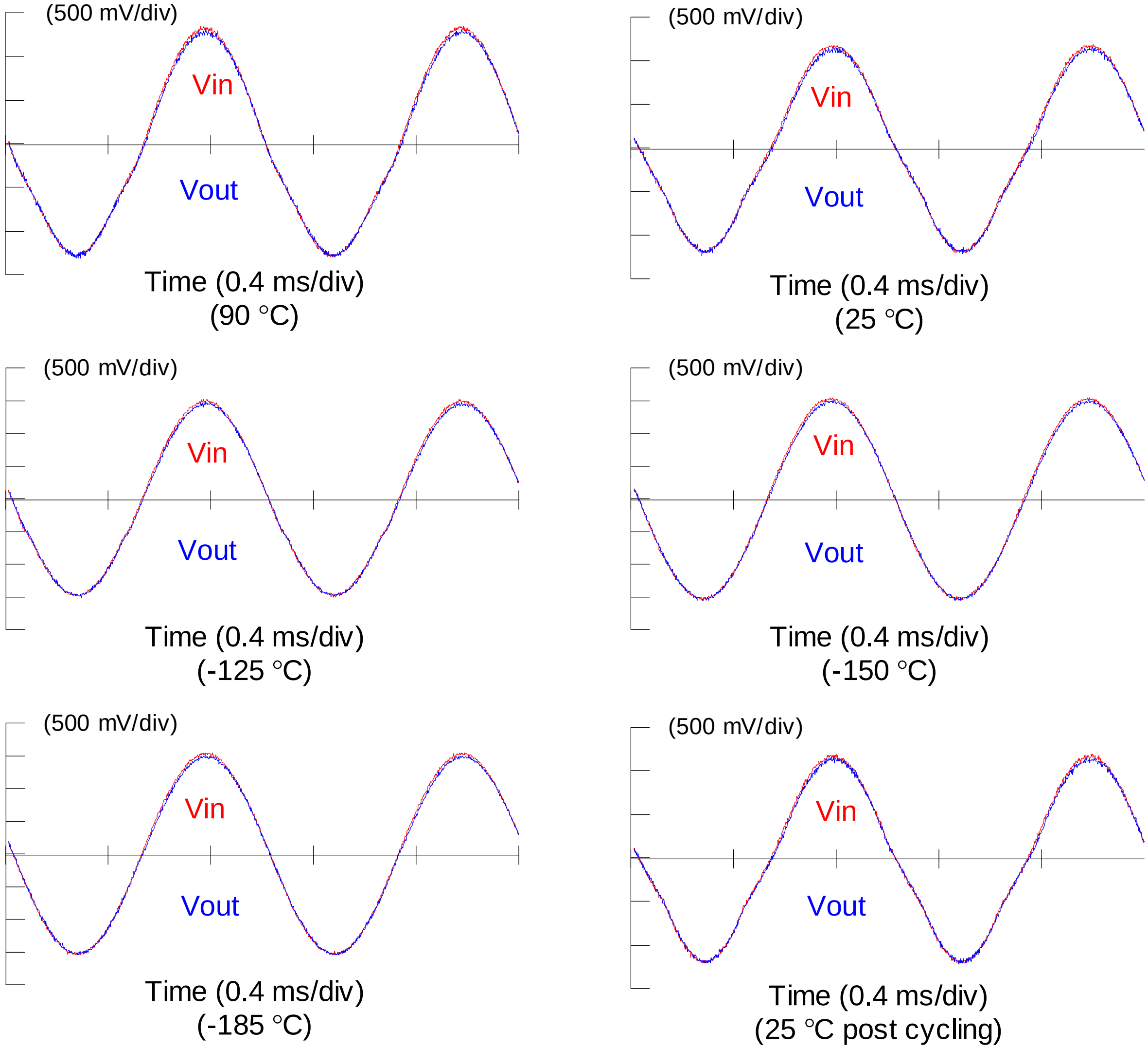

Figure 5. Input and output waveforms at various temperatures at 1 kHz.

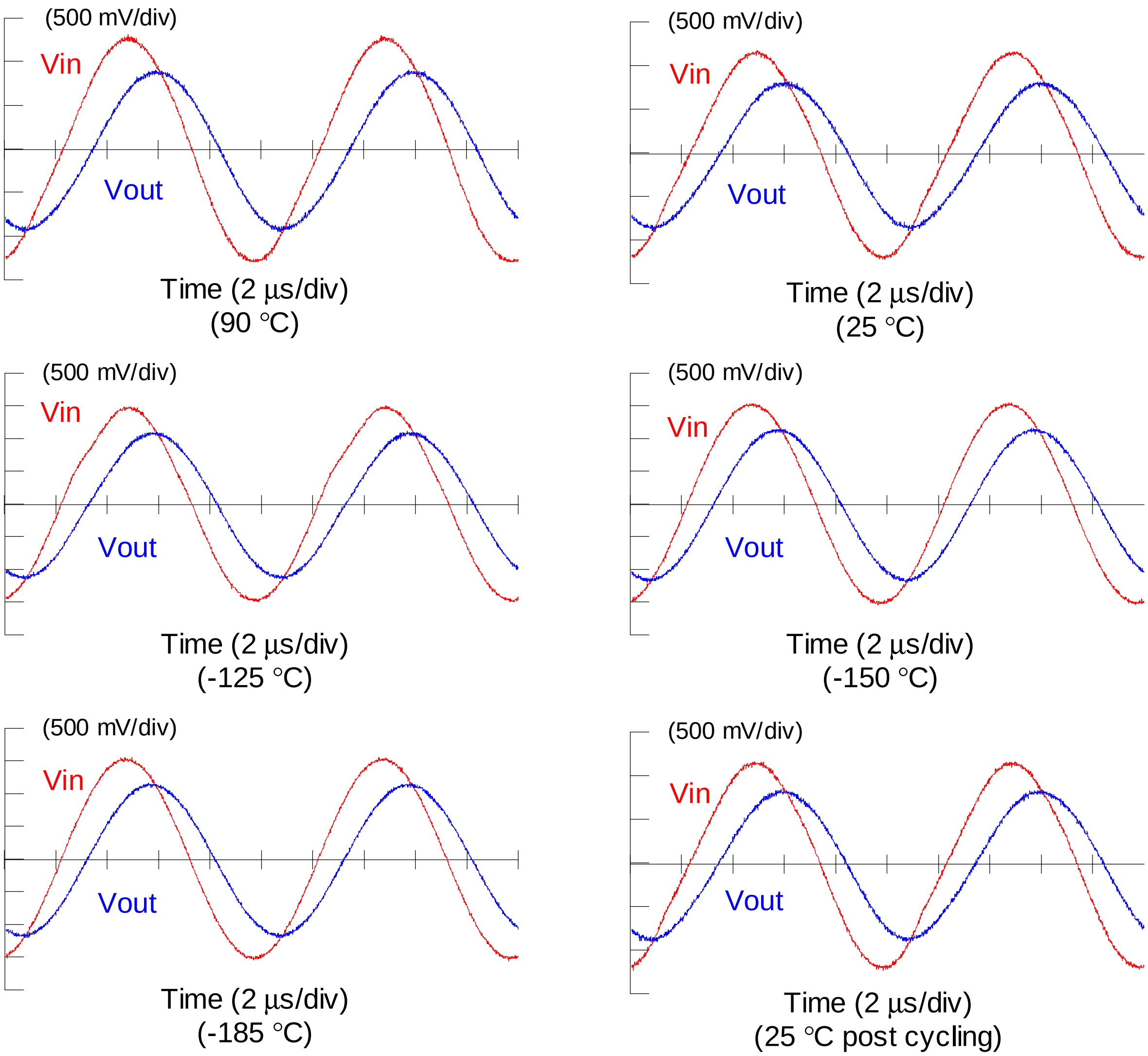

Figure 6. Input and output waveforms at various temperatures at 10 kHz.

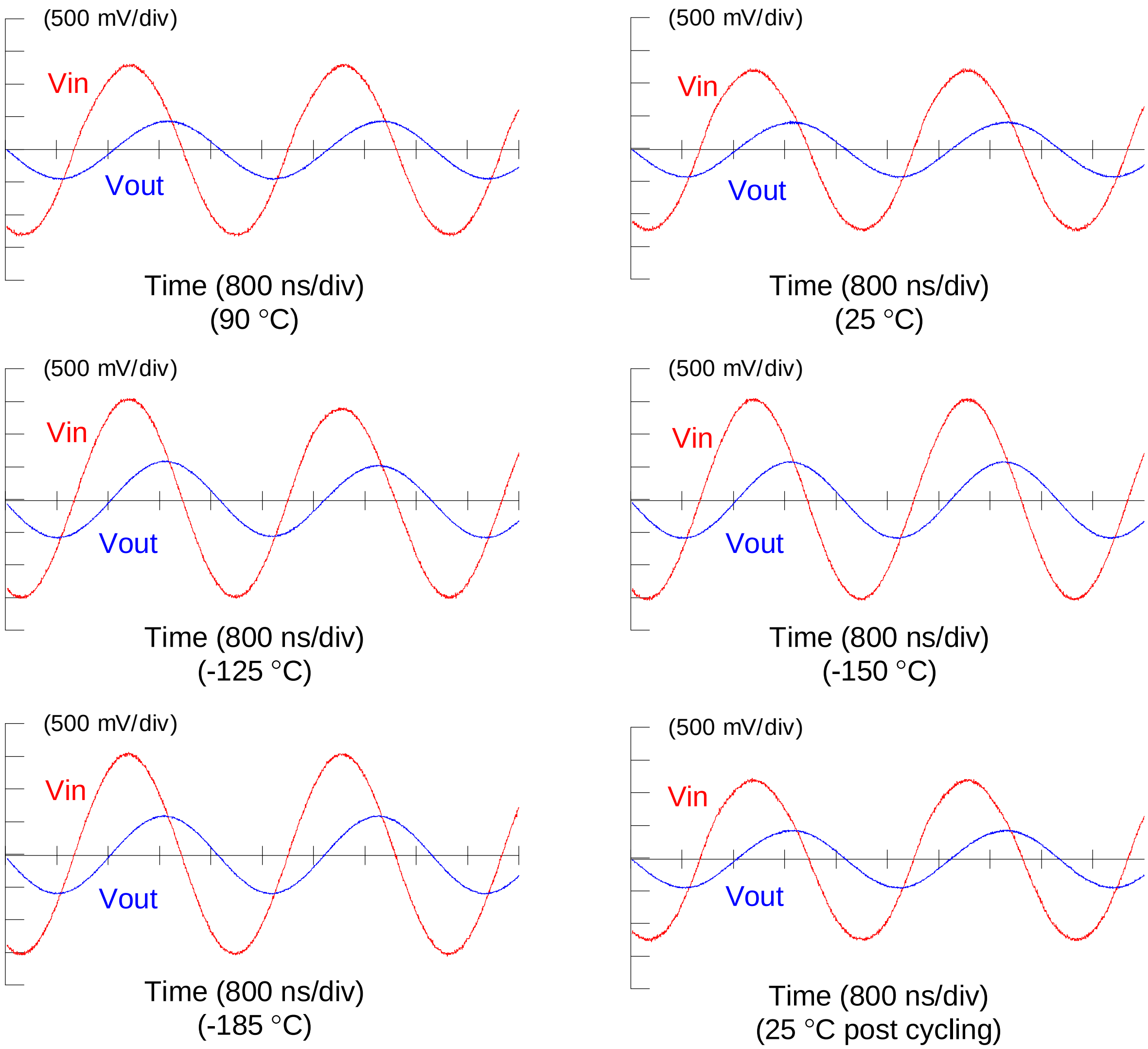

Figure 7. Input and output waveforms at various temperatures at 300 kHz.

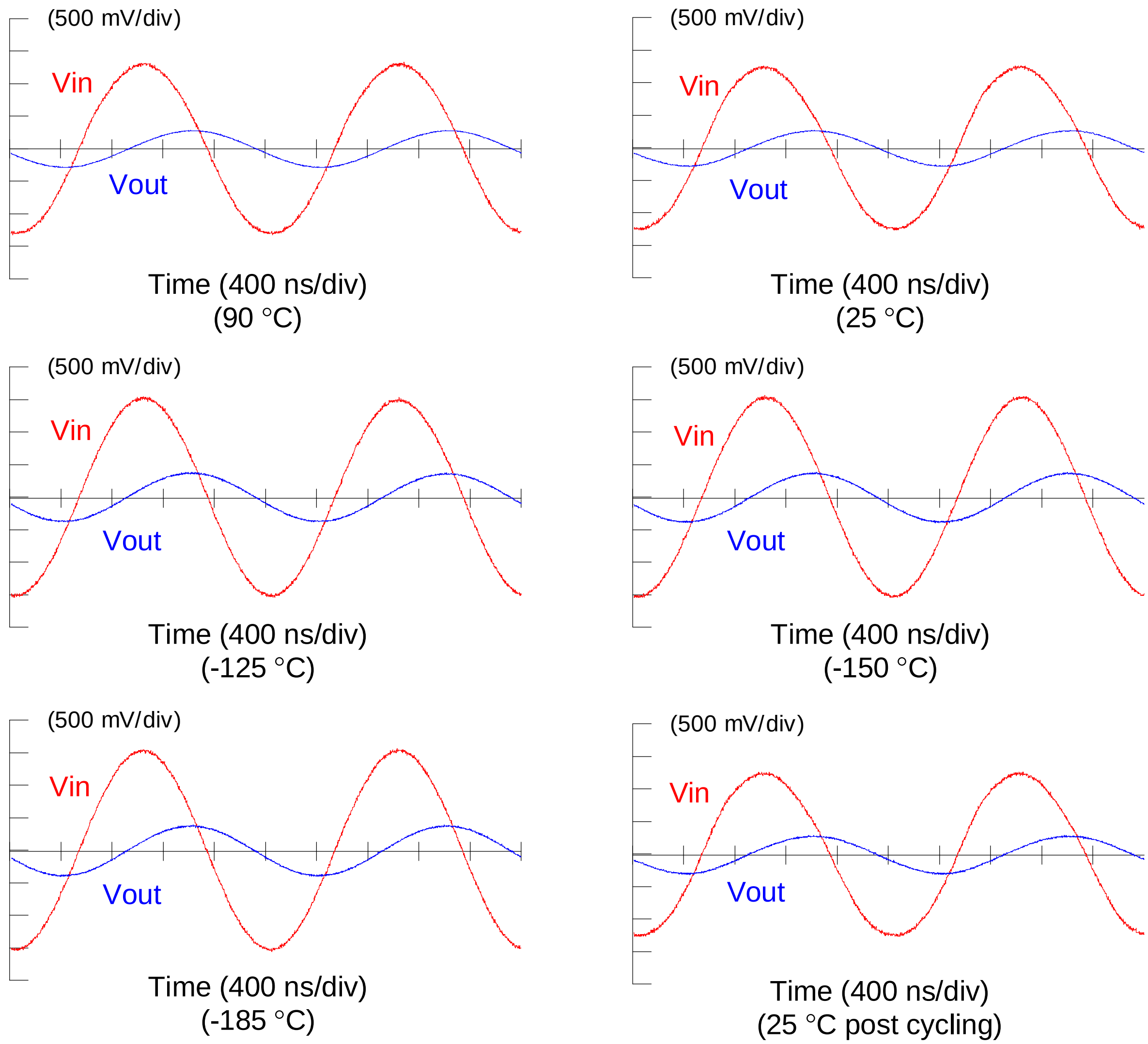

Figure 8. Input and output waveforms at various temperatures at 500 kHz.