Impedance analysis of perovskite solar cells: a case study

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Figure S1. Morphological, and optical characterization of MAPbI$_3$ and CsPbBr$_3$ films and solar cells: (A) Plane-view scanning electron microscope images (SEM), (B) UV-Vis spectra (C) Tauc plot.
Figure S2. EDX map of MAPbI$_3$ and CsPbBr$_3$ films.

Figure S3. Statistical data of photovoltaic parameters for MAPbI$_3$ and CsPbBr$_3$ solar cell devices.
Figure S4. Impedance Bode plots of MAPI and CsPbBr$_3$ solar cells at OC and NOC conditions

Figure S5. (A) Impedance spectra and (B) frequency plot for MAPbI$_3$ based devices at SC conditions and different temperatures. (C) and (D) resistances and capacitances at SC circuit as a function of temperature. (E) Arrhenius plot of the low and high frequency time constants. An activation energy of 36.9 kJ/mol can be extracted from the low frequency data.
Figure S6. Effect of illumination on the impedance response of MAPbI₃ based devices at NOC conditions. In Panels (A) and (B), the voltage dependence of both the high and low frequency time constants and capacitances is shown. Frequency Bode plots at 0.02, 0.05 and 0.2 suns are shown in panels (C), (D) and (E) respectively. Vertical lines mark the position of the frequency peaks.

Figure S7. High and low frequency time constants as extracted from fittings for MAPbI₃ based devices at OC and NOC conditions.
Figure S8. Correction for voltage drop due to series resistance in the impedance measurements at NOC conditions for MAPbI$_3$ devices.

Figure S9. Resistances at NOC conditions corrected for the optical band gap of the perovskite.
Figure S10. Experimental JV curves (symbols) and reconstruction from the impedance data at NOC conditions using Eq. (8) in the main text (lines).

Figure S11. Charge collection efficiency of MAPbI$_3$ solar cells as predicted by Eq. (9) using impedance data at OC and NOC conditions for several choices of $R_{rec}$. 
Figure S12. Absorptance and integrated photocurrent for MAPbI$_3$ (A) and CsPbBr$_3$ (B). Total integrated photocurrent amounts to 24.9 and 10.8 mA/cm$^2$, respectively.