Mahler's theorem for continuous functions on the p-adic integers

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Theorem. *(Mahler) Let f be a continuous function on the p-adic integers taking values in some finite extension K of $\mathbb{Q}_p$, and for each $n \in \mathbb{N}$, put $a_n = \sum_{i=0}^{n}(-1)^{n-i}\binom{n}{i}f(i)$. Then $a_n \to 0$ as $n \to \infty$, the series $\sum_{n=0}^{\infty} a_n\binom{\cdot}{n}$ converges uniformly to f on $\mathbb{Z}_p$, and $\|f\|_\infty = \sup_{n\geq 0}|a_n|_p$, where $\|\cdot\|_\infty$ denotes the sup norm.*